Responsible investing: The ESG-efficient frontier

Pedersen, Lasse Heje, Shaun Fitzgibbons and Lukasz Pomorski.

Journal of Financial Economics, 2020.11

解读者：屠雪永

2021.10.10

Outline

- Introduction
- Portfolio choice with ESG: the ESG-efficient frontier
- Equilibrium asset pricing with ESG
- Empirical results
- Conclusion

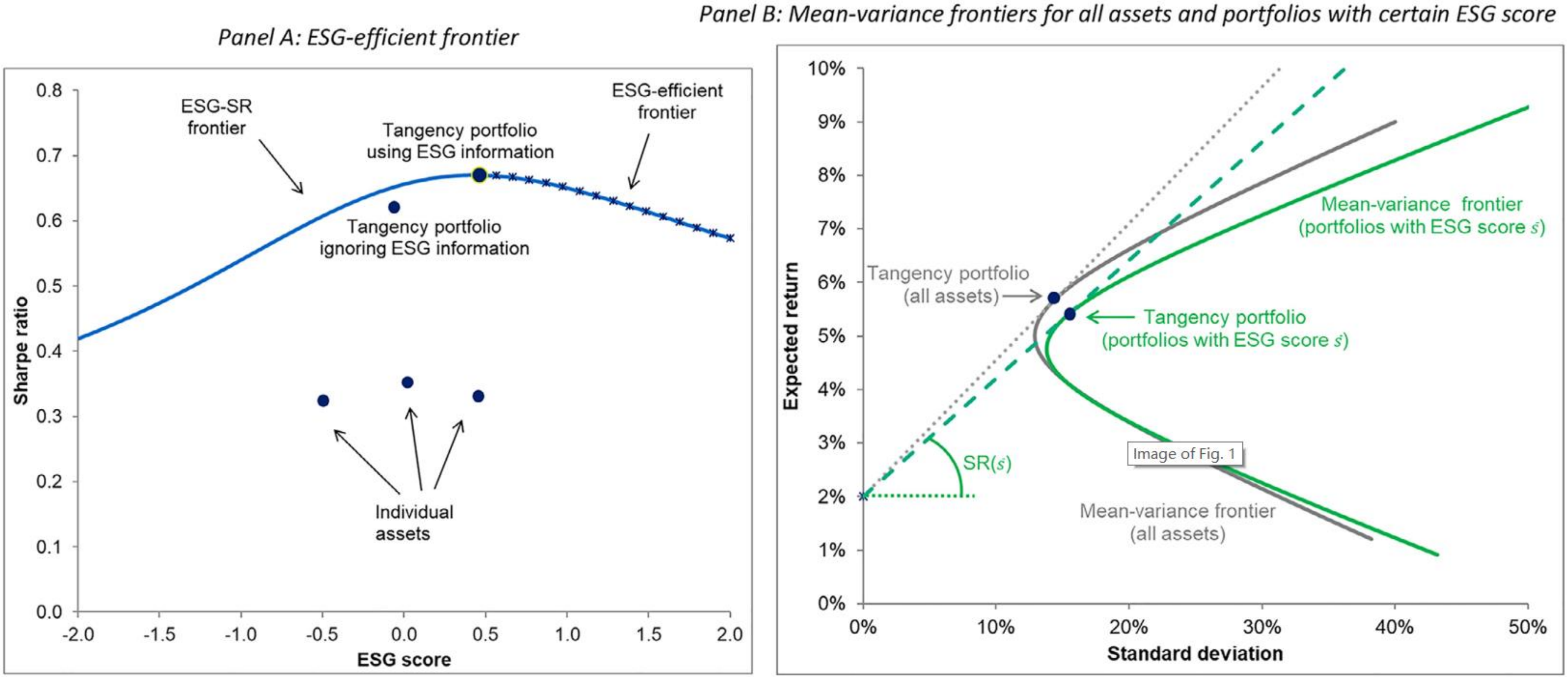
1. Introduction-- Motivation

- Investors have **little guidance** in how to incorporate ESG in portfolio choice
- Opinions **differ** dramatically about whether ESG will help or hurt their performance.
- To **reconcile** these opposing views, we develop a theory that illuminates both the potential costs and benefits of ESG-based investing.

1. Introduction-- Contribution

- We contribute to the literature on ESG both theoretically and empirically.
- Theoretically ,We explicitly model many assets characterized by ESG scores in addition to the standard risk-return characteristics.
- Empirically, our research bridges the gap between papers arguing that ESG hurts performance and those arriving at the opposite conclusion.

1. Introduction-- Content



2. Portfolio choice with ESG: the ESG-efficient frontier

- n risky assets and a risk-free security.
- The risk free return is r^f
- The risky assets have excess returns collected in the vector of random variables denoted by $r = (r^1, ...\ r^n)'$.
- The assets have an ESG scores given by $s\ = (s^1, ...\, s^n)'$.

- Type-U investors: $\mu = E(r)$、$\Sigma =\ var(r)$.
- Type-A investors: $\mu = E(r|s)$、$\Sigma =\ var(r|s)$.
- Type-M investors: $\mu = E(r|s)$、$\Sigma =\ var(r|s)$ and also have **preferences** for high ESG scores

2. Portfolio choice with ESG: the ESG-efficient frontier

- Investor M starts with a wealth W and a portfolio of risky assets $x = (x^1, \dots, x^n)'$

$$\widehat{W} = W\left(1 + r^f + x'r\right).$$

$$U = E\left(\widehat{W}|s\right) - \frac{\bar{\gamma}}{2} Var\left(\widehat{W}|s\right) + W f(\bar{s}). \qquad \bar{s} = \frac{x's}{x'1}$$

$$U = W\left(1 + r^f + x'\mu\right) - \frac{\bar{\gamma}}{2} W^2 x'\Sigma x + W f\left(\frac{x's}{x'1}\right)$$

$$= W\left(1 + r^f + x'\mu - \frac{\gamma}{2} x'\Sigma x + f\left(\frac{x's}{x'1}\right)\right), \qquad \gamma = \bar{\gamma} W$$

$$\max_{x \in X}\left(x'\mu - \frac{\gamma}{2} x'\Sigma x + f\left(\frac{x's}{x'1}\right)\right), \qquad X = \{x \in \mathrm{R}^n | x'1 > 0\},$$

2. Portfolio choice with ESG: the ESG-efficient frontier

➢ **Solution: ESG-SR frontier**

$$SR(\bar{s}) = \max_{\substack{x \in X \\ \text{s.t. } \bar{s} = \frac{x's}{x'1}}} \left(\frac{x'\mu}{\sqrt{x'\Sigma x}} \right) = \max_{\substack{x \\ \text{s.t. } x'1 = 1 \\ \text{and } x's = \bar{s}}} \left(\frac{x'\mu}{\sqrt{x'\Sigma x}} \right)$$

$$\max_{\bar{s}} \left[\max_{\sigma} \left\{ \max_{\substack{x \in X \\ \text{s.t. } \bar{s} = \frac{x's}{x'1} \\ \sigma^2 = x'\Sigma x}} \left(x'\mu - \frac{\gamma}{2} \sigma^2 + f(\bar{s}) \right) \right\} \right]. \quad (6)$$

$$\max_{\bar{s}} \left[\max_{\sigma} \left\{ SR(\bar{s})\sigma - \frac{\gamma}{2} \sigma^2 + f(\bar{s}) \right\} \right]. \quad (7)$$

对公式（7）求一阶导数 $\sigma = SR(\bar{s})/\gamma.$

2. Portfolio choice with ESG: the ESG-efficient frontier

- **Solution: ESG-SR frontier**

Proposition 1 (ESG-SR trade-off). The investor should choose her average ESG score $\bar{s}$ to maximize the following function of the squared Sharpe ratio and the ESG preference function f

$$\max_{\bar{s}} \left[(SR(\bar{s}))^2 + 2\gamma f(\bar{s}) \right]. \tag{8}$$

Proposition 2 (ESG-SR frontier). The maximum Sharpe ratio,SR($\bar{s}$), that can be achieved with an ESG score of $\bar{s}$ is

$$SR(\bar{s}) = \sqrt{c_{\mu\mu} - \frac{\left(c_{s\mu} - \bar{s}c_{1\mu}\right)^2}{c_{ss} - 2\bar{s}c_{1s} + \bar{s}^2 c_{11}}}. \tag{9}$$

$SR(s^*) = \sqrt{c_{\mu\mu}}$, $s^* = c_{s\mu}/c_{1\mu}$. $c_{ab} = a'\Sigma^{-1}b$

2. Portfolio choice with ESG: the ESG-efficient frontier

➢ **Solution: ESG-SR frontier**

Proposition 3 (four-fund separation). Given an average ESG score $\bar{s}$, the optimal portfolio is

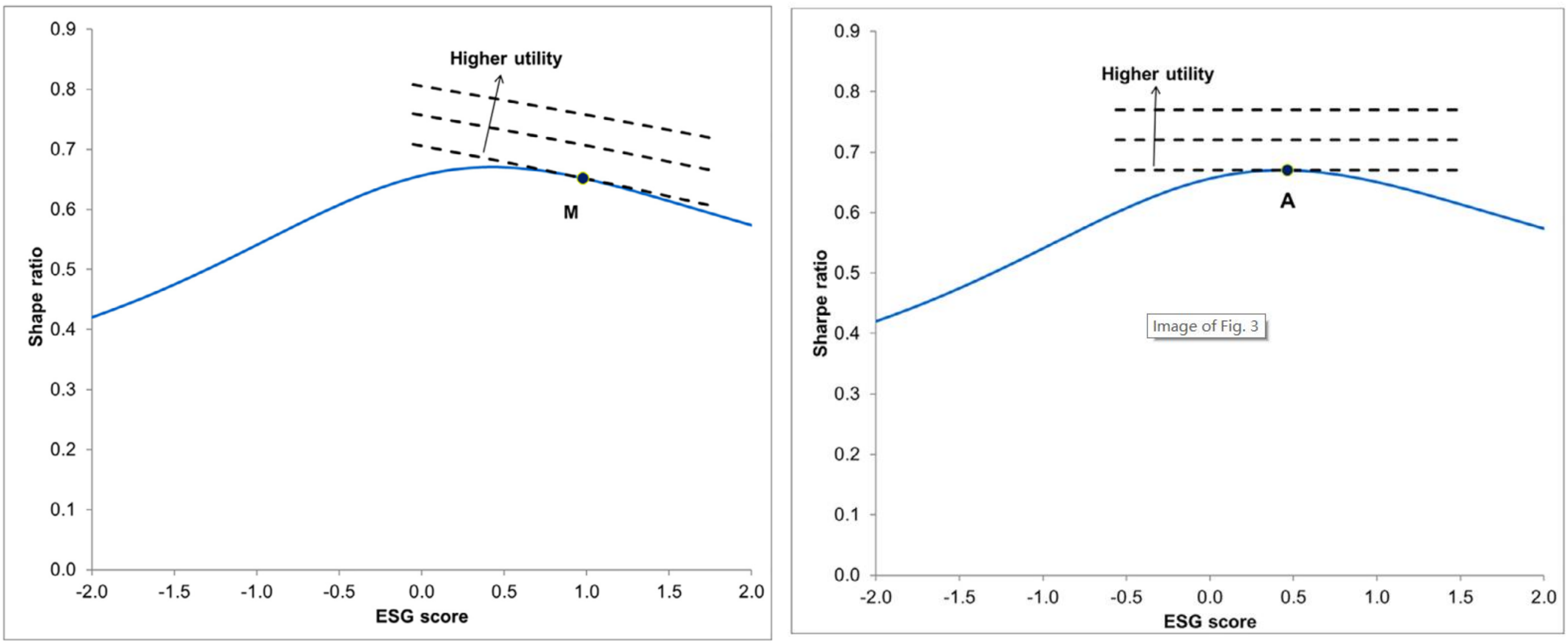
$$x = \frac{1}{\gamma}\Sigma^{-1}(\mu + \pi(s - 1\bar{s})) \qquad (10)$$

The optimal portfolio is therefore a combination of the risk-free asset, the tangency portfolio, $\Sigma^{-1}\mu$,the minimum-variance portfolio, $\Sigma^{-1}1$, and the ESG-tangency portfolio, $\Sigma^{-1}s$.

2. Portfolio choice with ESG: the ESG-efficient frontier

➢ **Example: how investors choose portfolios using the ESG-SR frontier**

Panel A: Indifference curves for an ESG-motivated investor (type-M) *Panel B: Indifference curves for an ESG-aware investor (type-A)*



2. Portfolio choice with ESG: the ESG-efficient frontier

- **Generalized ESG preferences**

Proposition 4 (ESG-SR frontier with screens). The conclusion of Proposition 1 continues to hold for any cone-shaped X.

$$X = \{x \in \mathrm{R}^n | x'1 > 0, \forall i \; x^i = 0 \text{ if } s^i < s^*\}$$

$$X = \{x \in \mathrm{R}^n_+ | \forall i \; x^i = 0 \text{ if } s^i < s^*\}.$$

Proposition 5 (generalized ESG-SR frontier). If the investor has generalized ESG preferences $e(x, s)$, then the investor's problem is

$$\max_{\bar{e}} \left[\frac{(SR(\bar{e}))^2}{2\gamma} + \bar{e} \right], \tag{12}$$

Example: ESG scores: (0.1, 0.8, 0.9) VS (0.6, 0.6, 0.6)

$$e(x, s) = e_1 \frac{x's}{x'1} - e_2 \frac{x' \mathrm{diag}(\frac{1}{s_1}, \; ..., \frac{1}{s_n})x}{(x'1)^2}.$$

3. Equilibrium asset pricing with ESG

➢ ESG-adjusted CAPM

Proposition 6. If all investors are ESG-unaware, i.e., of type-U ($W_A = W_M = 0$), then any security i has steady-state equilibrium price

$$p^i = \frac{\hat{\mu}^i - \frac{\gamma}{W} \operatorname{cov}\left(v^i, v^m\right)}{r^f}.$$

Unconditional expected excess return obeys the standard unconditional CAPM:

$$E\left(r_t^i\right) = \beta^i E\left(r_t^m\right),$$

But conditional expected returns are given by

$$E\left(r_t^i | s\right) = \beta^i E\left(r_t^m\right) + \lambda \frac{s^i - s^m}{p^i}.$$

3. Equilibrium asset pricing with ESG

- **ESG-adjusted CAPM** $$p^i = \frac{\hat{\mu}^i - \frac{\gamma}{W}\ \mathrm{cov}\left(v^i, v^m\right)}{r^f}.$$

Proposition 7 (ESG-CAPM). If all investors are ESG-motivated of type-M ($W_U = W_A = 0$), then any security i has equilibrium price

$$p^i = \frac{\hat{\mu}^i + \lambda\left(s^i - s^m\right) - \frac{\gamma}{W}\ \mathrm{cov}(v^i, v^m | s)}{r^f - \pi\left(s^i - s^m\right)}, \qquad (20)$$

The equilibrium conditional expected excess return is given by

$$E(r_t^i | s) = \bar{\beta}^i E(r_t^m | s) - \pi\left(s^i - s^m\right). \qquad (21)$$

If all investors are ESG-aware of type-A ($W_U = W_M = 0$), the same conclusions hold with $\pi = 0$.

2. Portfolio choice with ESG: the ESG-efficient frontier

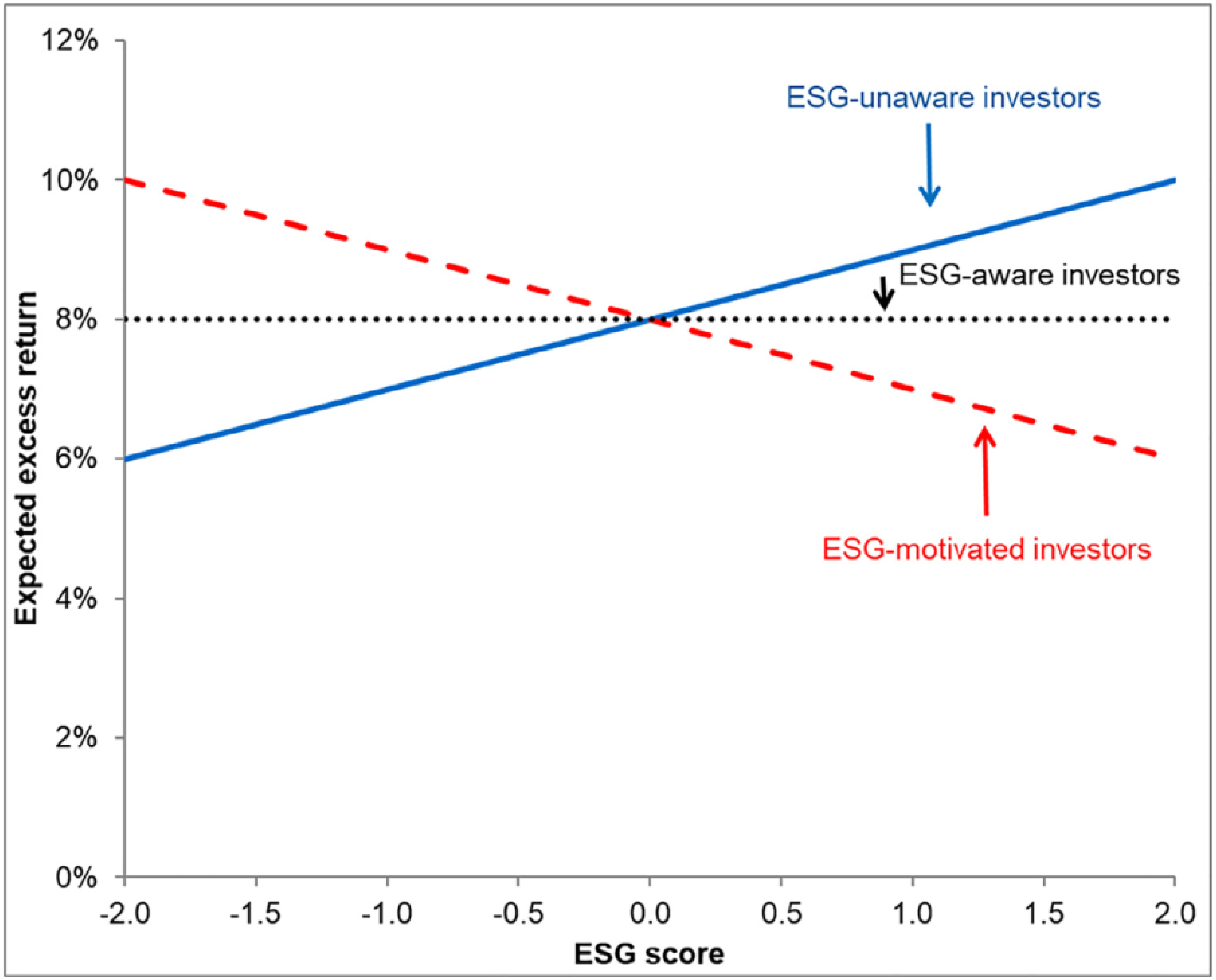


Fig. 2. Environmental, social, and governance–adjusted capital asset pricing model (ESG-CAPM).

4. Empirical results

- **Data**

- **Stocks in the Standard & Poor’s (S&P) 500 index**
- **E**: low carbon intensity, 2009.01~ 2019.03

  (Busch et al., 2018)
- **S**: non–sin stock indicator. zero for sin stocks and the value of one otherwise, 1963.01~2019.03 (Hong and Kacperczyk,2009)
- **G**: low accruals. 1963.01~2019.03 (Sloan,1996))
- overall **ESG**: MSCI ESG scores(0~10), 2007.01~ 2019.03
- XpressFeed database : stock returns and market values
- Compustat database : firm fundamentals,

4. Empirical results

➢ Empirical ESG-SR frontier

- To compute the annualized expected return of any stock i in any month t, U investors use

$$E_t^{\mathrm{U}}(r_{i,t+1}) = \overline{MKT}_t + bm_{i,t}\ \overline{BM}_t, \tag{23}$$

- A and M investors

$$E_t^{\mathrm{A}}(r_{i,t+1}) = \overline{MKT}_t + bm_{i,t}\ \overline{BM}_t + s_{i,t}\ \overline{ESG}_t, \tag{24}$$

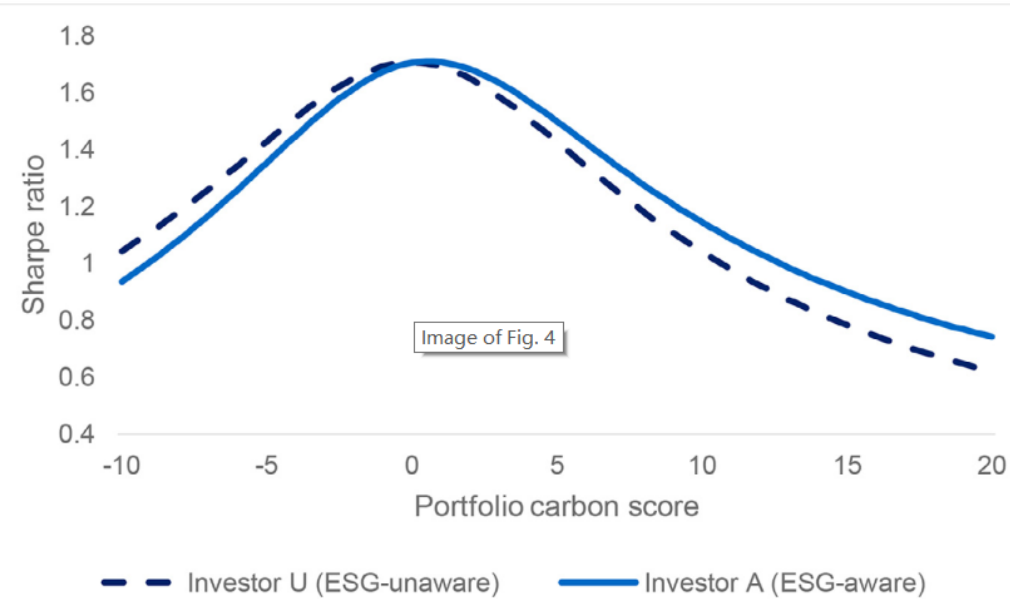
- $\overline{ESG_t}$ is the return premium of the ESG factor, the ESG score $s_{i,t}$ is computed as the cross-sectional z-score of the raw ESG metric.

- To compute risk, Barra's US Equity risk model (Barra USE3L model)

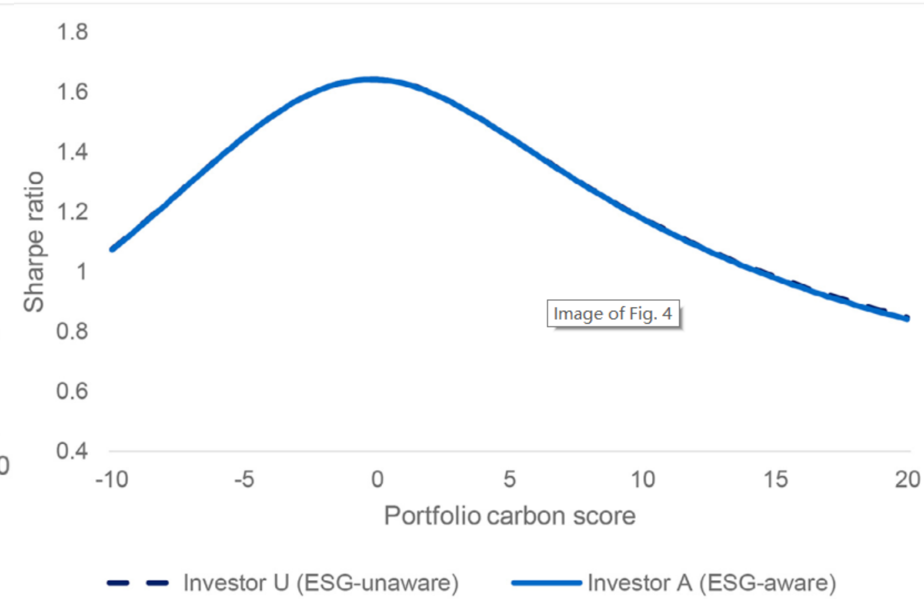
4. Empirical results

➢ **Empirical ESG-SR frontier**

Panel A: Ex ante perceived ESG–Sharpe ratio frontiers



Panel B: Realized ESG–Sharpe ratio frontiers

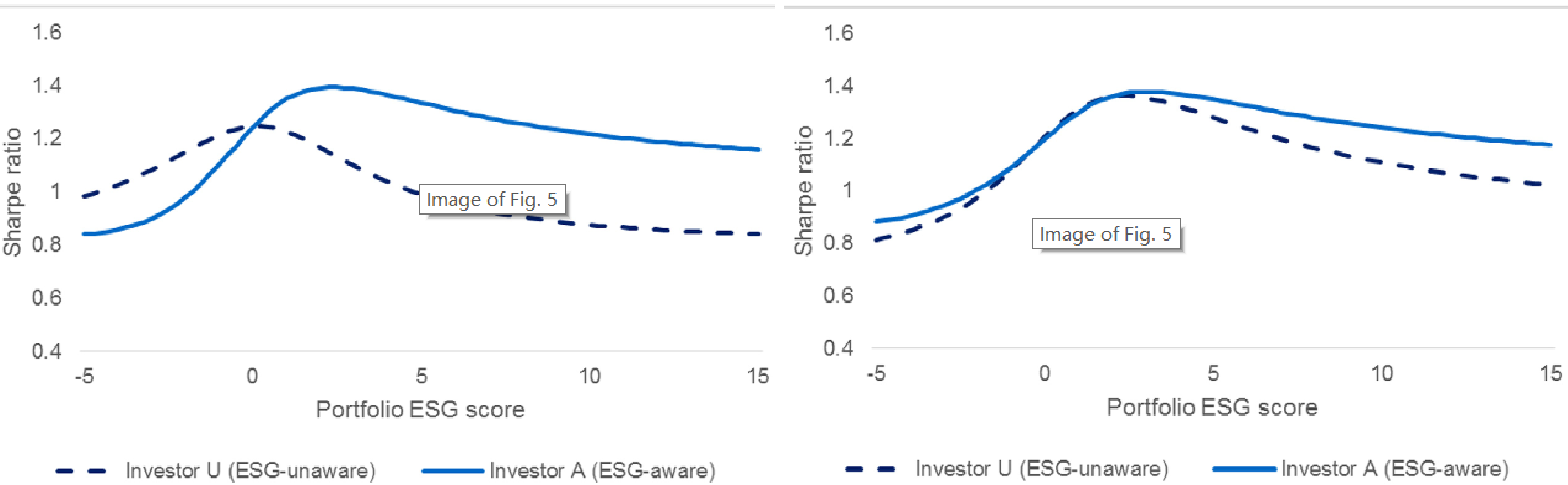


- The environmental proxy we use here is **not very helpful** in explaining average returns.

4. Empirical results

➢ Empirical ESG-SR frontier

Panel A: Ex ante perceived ESG–Sharpe ratio frontiers *Panel B: Realized ESG–Sharpe ratio frontiers*

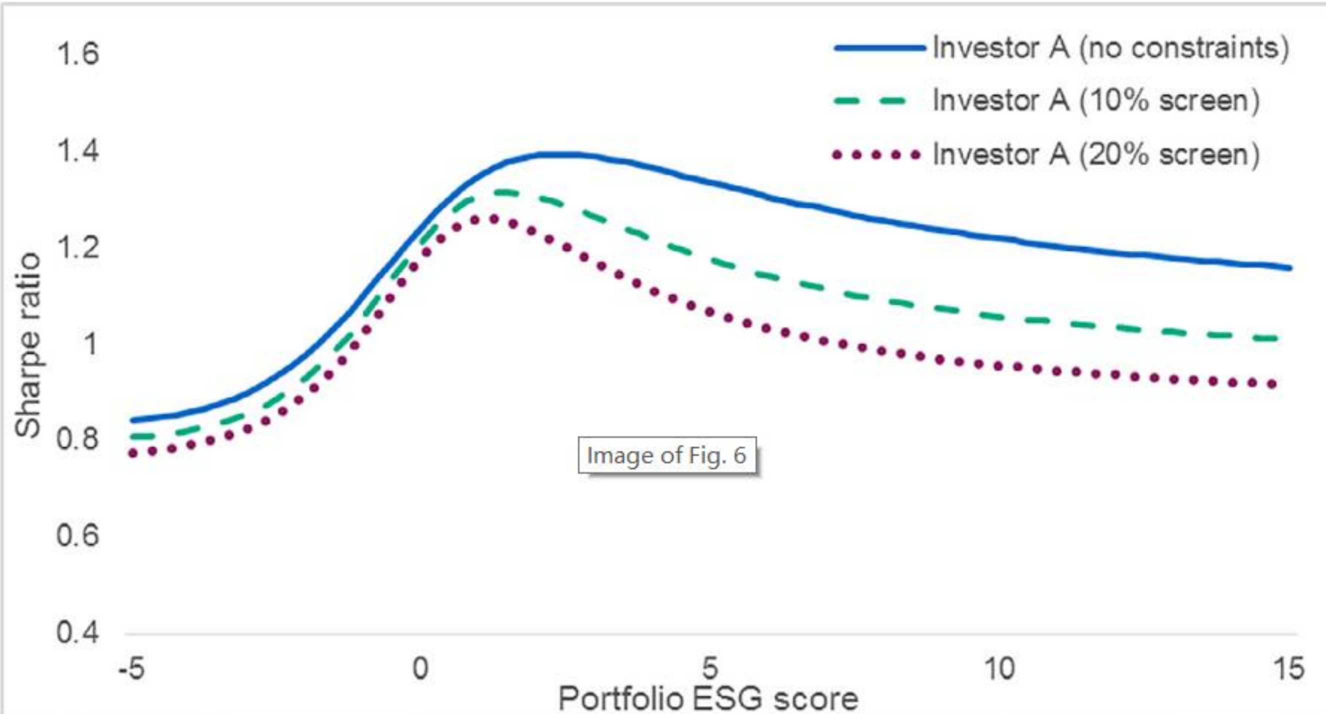


- Empirical ESG–efficient frontier using accruals as a proxy for G.

- The benefit of using G information is 11% higher than the realized SR of the ESG-unaware investor

4. Empirical results

➢ **Impact of restrictions: screening out the worst ESG stocks**



- Empirical ESG–efficient frontier using accruals as a proxy for G.
- Constraints reduce a portfolio’s expected performance.

4. Empirical results

- RNOA : return on net operating assets
- Gross profit over assets

➢ Does ESG predict future fundamentals?

Panel A: Predicting RNOA

Dependent variable	*RNOA* (*t* + 12)							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
E (low CO2)	0.006***	0.006***						
	(4.91)	(7.34)						
S (non-sin)			−0.008*	−0.006***				
			(−1.94)	(−2.88)				
G (low accruals)					0.208***	0.193***		
					(23.26)	(28.64)		
ESG (MSCI)							0.0001	0.0001
							(0.15)	(0.24)
Beta	−0.068***	−0.068***	−0.064***	−0.067***	−0.060***	−0.062***	−0.052***	−0.040***
	(−17.90)	(−10.24)	(−33.77)	(−20.69)	(−31.79)	(−19.43)	(−11.62)	(−4.40)
Ln market cap	0.011***	0.011***	0.015***	0.015***	0.014***	0.014***	0.008***	0.006***
	(12.45)	(23.91)	(32.71)	(26.55)	(30.14)	(26.85)	(6.54)	(4.89)
Ln(P/B)	0.014***	0.015***	0.027***	0.028***	0.028***	0.028***	0.026***	0.038***
	(6.72)	(6.98)	(22.59)	(22.01)	(23.73)	(22.11)	(9.27)	(11.94)
RNOA(t)	0.763***	0.765***	0.710***	0.707***	0.725***	0.720***	0.756***	0.734***
	(88.59)	(97.48)	(167.53)	(118.95)	(169.65)	(128.80)	(63.53)	(61.25)
Constant	0.020***	0.021**	−0.005	0.003	−0.019***	−0.009	0.002	0.001
	(2.78)	(2.32)	(−0.95)	(0.47)	(−6.59)	(−1.56)	(0.19)	(0.06)
Number of observations	239,440	239,440	1374,620	1374,620	1354,499	1354,499	116,130	116,130
R-squared	0.708	0.712	0.631	0.631	0.636	0.635	0.723	0.727
Estimation method	Pooled	FM	Pooled	FM	Pooled	FM	Pooled	FM

- There is strong evidence that accruals correlate with future profitability

4. Empirical results

- institutional ownership,
- trading activity: logarithm of the number of trades
- signed order flow :dollar buy volume over total dollar volume

➢ Does ESG predict investor demand?

Panel A: Predicting institutional ownership

Dependent variable	*Institutional holdings (t + 3)*							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
E (low CO2)	2.206***	2.284***						
	(3.37)	(14.65)						
S (non-sin)			6.128**	7.037***				
			(2.43)	(11.50)				
G (low accruals)					1.060	3.208***		
					(0.74)	(2.98)		
ESG (MSCI)							0.343**	0.420***
							(2.55)	(6.98)
Beta	5.774***	5.912***	5.698***	6.905***	1.610***	3.038***	6.371***	5.512***
	(8.50)	(21.96)	(14.13)	(20.76)	(3.37)	(11.91)	(7.05)	(11.27)
Ln market cap	10.079***	10.057***	9.662***	9.691***	9.599***	9.650***	0.846***	−1.265***
	(50.48)	(108.99)	(62.30)	(64.95)	(53.67)	(85.18)	(3.32)	(−2.67)
Ln(P/B)	−0.321	−0.354***	−1.759***	−1.264***	−2.282***	−1.931***	1.136***	1.642***
	(−1.20)	(−5.08)	(−11.05)	(−8.39)	(−13.90)	(−13.83)	(3.86)	(9.22)
Constant	−10.649***	−10.400***	−17.176***	−19.342***	−3.402***	−5.076***	62.372***	82.049***
	(−6.77)	(−17.28)	(−6.40)	(−18.11)	(−3.00)	(−9.55)	(24.56)	(18.45)
Number of observations	378,623	378,623	962,867	962,867	737,865	737,865	180,326	180,326
R-squared	0.454	0.450	0.470	0.424	0.475	0.422	0.033	0.083
Estimation method	Pooled	FM	Pooled	FM	Pooled	FM	Pooled	FM

- The results are perhaps most intuitive for accruals, where both the number of trades and the fraction of buys increase when this ESG proxy improves

4. Empirical results

- Firm's valuation ratio: the logarithm of price-to-book

➢ **Does ESG predict valuation and future returns?**

Dependent variable	*Ln(P/B)*			
	(1)	(2)	(3)	(4)
E (low CO2)	0.086***			
	(7.25)			
S (non-sin)		0.020		
		(0.30)		
G (low accruals)			−0.470***	
			(−11.59)	
ESG (MSCI)				0.058***
				(8.25)
Beta	−0.449***	0.402***	0.338***	−0.348***
	(−16.39)	(28.48)	(21.13)	(−8.56)
Constant	1.391***	0.366***	0.514***	1.245***
	(38.32)	(5.48)	(27.37)	(21.81)
Number of observations	427,857	2120,679	1708,222	203,502
R-squared	0.050	0.073	0.077	0.046
Estimation method	Pooled	Pooled	Pooled	Pooled

- Shows how the ESG proxies correlate with the logarithm of the price-to-book ratio.

4. Empirical results

➢ **Does ESG predict valuation and future returns?**

	E (*low* CO_2)	*S* (*non-sin*)	*G* (*low accruals*)	*ESG* (*MSCI*)
Panel A: Equal-weighted returns				
Average excess return	5.15%	0.50%	7.84%***	0.38%
	(1.59)	(0.35)	(4.41)	(0.28)
CAPM alpha	7.02%**	−0.42%	7.87%***	1.29%
	(2.09)	(−0.30)	(4.39)	(1.00)
Three-factor (FF) alpha	5.03%	0.06%	7.30%***	0.74%
	(1.63)	(0.05)	(4.03)	(0.60)
Five-factor (FF) alpha	5.98%*	1.28%	8.85%***	0.28%
	(1.92)	(0.94)	(4.91)	(0.22)
Six-factor (FF + Mom) alpha	5.12%*	1.03%	8.71%***	0.27%
	(1.73)	(0.74)	(4.76)	(0.22)

- The portfolio based on G has highly significant returns.

6. Conclusion

- We show that an investor optimally chooses a portfolio on the ESG efficient frontier both theoretically and empirically.

- We test the theory's equilibrium predictions using four ESG proxies, providing a rationale for **why certain ESG measures predict returns differently**.

Reflection

- The model can be used to invest in assets with specific themes, such as scientific and technological innovation capability.