BIS Working Papers

No 1127

The impact of green investors on stock prices

by Gong Cheng, Eric Jondeau, Benoit Mojon and Dimitri Vayanos

Monetary and Economic Department

September 2023

JEL classification: G12, G23, Q54.

Keywords: Asset pricing, green investing, passive investing, portfolio rebalancing.

This publication is available on the BIS website (www.bis.org).

ISSN 1020-0959 (print)
ISSN 1682-7678 (online)

The Impact of Green Investors on Stock Prices*

Gong Cheng[1], Eric Jondeau[2], Benoit Mojon[1], and Dimitri Vayanos[3]

[1]Bank for International Settlements

[2]HEC Lausanne and Swiss Finance Institute

[3]London School of Economics

September 18, 2023

Abstract

We study the impact of green investors on stock prices in a dynamic equilibrium asset-pricing model where investors are green, passive or active. Green investors track an index that excludes progressively the firms with the highest greenhouse gas emissions. Active investors maximize expected returns and can buy stocks of brown firms whereas passive investors hold an index of the entire market. Contrary to the literature, we find a large fall in the stock prices of the high-emitting firms that are excluded and in turn an increase in stock prices of greener firms when the exclusion strategy is announced and during the transition process. The immediate and large effects at the announcement date yield a first-mover advantage to green investors that adopt the decarbonization strategy early. This large price impact comes from the imperfect substitution of stocks among investor populations. A smaller size of active investors relative to green investors amplifies the price impact of green investment.

JEL: G12, G23, Q54

Keywords: Asset pricing, green investing, passive investing, portfolio rebalancing

*We thank the participants in the BIS Research Meeting and the NGFS Expert Network on Research webinar series for their constructive comments. We thank Jingtong Zhang for research assistance. The authors' contact: `gong.cheng@bis.org`, `eric.jondeau@unil.ch`, `benoit.mojon@bis.org`, `d.vayanos@lse.ac.uk`.

1 Introduction

In the fight against climate change, the role of financial asset owners and managers is widely debated. As large institutional investors are investing in financially diversified portfolios, they hold shares of firms with high greenhouse gas (GHG) emissions and thus contribute to global warming by financing polluting activities. There have been an increasing number of corporate initiatives to promote net zero investment in recent years. Central Banks, through their Network for Greening the Financial System (NGFS), have also been reflecting on greening central banks' investment portfolios. Two broad approaches prevail. Investors can either divest from the brownest firms or influence the transition of those firms to greener operations through their votes at annual general meetings.

A key question that drives investors' consideration of these two net zero investment strategies concerns whether exclusion or divestment effectively raises the cost of capital of brown firms versus green firms and thereby influences brown firms' future business development. In particular, shares sold by green investors will be bought by less climate-conscious investors. As a result, the impact of divestment on stock prices will depend on the willingness of these other investors to absorb additional brown stocks. If there are few green investors, then the price impact will be small (Berk and van Binsbergen, 2022). If, however, the community of green investors is growing to sell off brown stocks, then the counterparts of green investors may require a significant price discount to buy these stocks.

The main objective of the paper is to evaluate the impact on stock prices of institutional investors reducing their exposure to firms with the highest GHG emissions. We consider three categories of investors. Passive investors or indexers track the market portfolio and represent the mass of non-green passive institutional investors. Green investors also track a benchmark but this benchmark progressively excludes brown firms. The most polluting firms are excluded first from the green benchmark and every year an additional set of firms, based on their carbon emissions, is excluded. This green benchmark mimics the strategy of a portfolio with a decreasing carbon footprint. Indices excluding brown stocks progressively are referred to as "net zero" or "Paris-consistent" indices, and have been growing over time, so are the funds tracking them.[1] Active investors buy brown stocks from green investors at a discounted price that implies higher expected returns.

Given the investment demands of the three types of investors, we solve the model analytically following an approach similar to the one developed by Jiang, Vayanos and Zheng (2022).[2] For a given calibration of the model and a decarbonization trajectory of the green index, we determine the dynamics of equilibrium prices as well as those of investors' demand. This approach allows us to assess the impact on expected and realized returns of different scenarios regarding the proportion of green investors.

In our baseline calibration, where the population of investors is split between 20% green investors, 70% passive indexers and 10% active investors, we find a substantial fall in stock prices of the high-emitting firms that are excluded and in turn an increase in stock prices of greener firms when the exclusion strategy is announced and during the transition process. After the exclusion phase ends in 10 years, the price of the most polluting firms is reduced by 7.1%, while the price of non-excluded firms is increased by 1%. Overall, the cost of capital of the most polluting firms increases by 27 basis points compared with non-excluded firms. In addition, the immediate and large effects at the announcement date yield a first-mover advantage to green investors that adopt the decarbonization strategy at an early stage. The large price impact that we uncover differs from that in Berk and van Binsbergen (2022) by an order of magnitude. This is because we not only incorporate a larger fraction of green investors than Berk and van Binsbergen (2022), but also drop their unrealistic assumption that all non-green investors are active. We assume instead that a significant fraction of non-

[1] The size of this segment of the stock market has grown from 40 billion at the end of 2020 to 100 billion in the first quarter of 2023.

[2] Jiang et al. (2022) assess how how passive investing affects asset prices. The main mechanism is that flows into passive funds raise disproportionately the stock prices of the economy's largest firms. This effect arises because of the re-pricing of systematic and large firms' idiosyncratic risk.

green investors are passive, which implies that the demand function faced by green investors is significantly more price-inelastic than in Berk and van Binsbergen (2022).

Our paper is related to the literature on green investing. Some papers study the construction of benchmark portfolios designed to implement a decarbonization strategy. One approach, followed by Bolton, Kacperczyk and Samama (2021), implements a decarbonization strategy while minimising the tracking error relative to the standard benchmark. A low tracking error can be achieved at the cost of extensive rebalancing of the portfolio. Another approach keeps weights as close as possible to the benchmark, except for the firms with particularly high or low GHG emissions, which are underweighted or overweighted, respectively (Jondeau, Mojon and Pereira Da Silva, 2021; Cheng, Jondeau and Mojon, 2022). While the first paper by Bolton et al. (2021) adopts a forward-looking perspective, assuming that carbon emissions will remain constant in the future, the latter two papers adopt a backward-looking perspective and build a net-zero benchmark over the period 2011–2022. In both cases, decarbonization can be achieved at a relatively low cost in terms of financial performance and tracking error.

Other papers study how green policies of banks or capital-markets investors affect firms' access to finance and their investment. Green and Vallee (2023) find that in the coal industry, exit policies by banks tend to reduce debt issuance by firms that have lending relationships with those banks. Substitution towards other banks or the equity market is limited. Kacperczyk and Peydro (2022) find likewise that high-emissions firms receive less bank credit after banks they have relationships with become committed to green lending. They also find that the environmental performance of these firms does not improve.

Evidence on how green investing affects stock prices is mixed. van der Beck (2021) finds that the strong performance of ESG investments is driven by price pressure arising from flows towards sustainable funds. Gormsen, Huber and Oh (2023) find that the cost of capital of the greenest firms is 2.6% below the cost of capital of the brownest firms on average since

2016. On the other hand, Berk and van Binsbergen (2022) show in a calibrated model that the change in the cost of capital that results from a divestiture strategy is small. They also do not detect empirically any effect of changes in firms' ESG status on their price or cost of capital. Hartzmark and Shue (2022) find that increases in the cost of capital resulting from a divestiture strategy can induce brown firms to pollute more because they lack financial resources to invest in cleaner production processes.

The rest of this paper is organized as follows. Section 2 presents the model. Section 3 solves for equilibrium prices and positions. Section 4 describes the calibration of the model and the various scenarios. Section 5 presents the results for the different scenarios. Section 6 discusses policy implications of our work and concludes. An appendix provides proofs, technical details and additional results.

2 Model

Time t is continuous and goes from zero to infinity. The riskless rate is exogenous and equal to $r > 0$. There are K groups of N firms each. All firms in the same group have the same (unmodelled) level of GHG emissions, with group K having the highest emissions and being excluded from the index first, group $K-1$ having the second highest emissions and being excluded second, and so on.

The stock of firm $n = 1, .., KN$, referred to as stock n, pays dividend flow D_{nt} per share and is in supply of $\eta_n > 0$ shares. The dividend flow of stock n is

$$D_{nt} = \bar{D}_n + b_n^s D_t^s + b_n^c D_t^c + D_{nt}^i, \tag{2.1}$$

where $\{\bar{D}_n, b_n^s, b_n^c\}_{n=1,..,KN}$ are constants and $\{D_t^s, D_t^c, D_{nt}^i\}_{n=1,..,KN}$ are stochastic processes. We refer to $\bar{D}_n$ as the constant component of the dividend flow, $b_n^s D_t^s$ as the systematic component, $b_n^c D_t^c$ as the climate component and D_{nt}^i as the idiosyncratic component. The systematic component is the product of a factor D_t^s times a factor loading $b_n^s \geq 0$. The factor D_t^s follows the square-root process

$$dD_t^s = \kappa^s \left(\bar{D}^s - D_t^s\right) dt + \sigma^s \sqrt{D_t^s} dB_t^s, \tag{2.2}$$

where $\{\kappa^s, \bar{D}^s, \sigma^s\}$ are positive constants and B_t^s is a Brownian motion. The climate component is the product of a factor D_t^c times a factor loading $b_n^c \geq 0$. The factor D_t^c follows the square-root process

$$dD_t^c = \kappa^c \left(\bar{D}^c - D_t^c\right) dt + \sigma^c \sqrt{D_t^c} dB_t^c, \tag{2.3}$$

where $\{\kappa^c, \bar{D}^c, \sigma^c\}$ are positive constants and B_t^c is a Brownian motion. The factors D_t^s and D_t^c are both systematic. We interpret the former as corresponding to business-cycle risk and the latter as corresponding to climate risk, which is described below. The idiosyncratic component follows the square-root process

$$dD_{nt}^i = \kappa_n^i \left(\bar{D}_n^i - D_{nt}^i\right) dt + \sigma_n^i \sqrt{D_{nt}^i} dB_{nt}^i, \tag{2.4}$$

where $\{\kappa_n^i, \bar{D}_n^i, \sigma_n^i\}_{n=1,..,KN}$ are positive constants and $\{B_{nt}^i\}_{n=1,..,KN}$ are Brownian motions. All Brownian motions are independent. By possibly redefining factor loadings, we set the long-run means $\bar{D}^s$ and $\bar{D}^c$ of the systematic factors to one. By possibly redefining the supply η_n, we set the long-run mean $\bar{D}_n + b_n^s + b_n^c + \bar{D}_n^i$ of the dividend flow of stock n to one for all n. With these normalizations, we can write the dividend flow of stock n as

$$D_{nt} = 1 + b_s^n(D_t^s - 1) + b_n^c(D_t^c - 1) + (D_{nt}^i - \bar{D}_n^i). \tag{2.5}$$

The square-root specification (2.2)-(2.4) ensures that dividends and prices are always positive and the volatility of dividends per share increases with the level of dividends per share.[3]

Agents are competitive and form overlapping generations living over infinitesimal time intervals. Each generation includes active investors, indexers and green indexers. Active investors can invest in the riskless asset and in the stocks without constraints. Indexers and green indexers can invest in the riskless asset and in a stock portfolio that tracks an index. The index is a broad index for indexers and a narrower one for green indexers. Indexers and green indexers do not observe the values of the dividend flows (2.2)-(2.4) and make their investment decisions in expectation over these values.

The broad index includes all firms. The green index includes a set $\mathcal{G}_t$ of firms that decreases with time t. At $t = 0$, all firms are included. At $t = T$, firms $n = (K-1)N + 1, .., KN$, i.e., in group K, are dropped. At $t = 2T$, firms $n = (K-2)N+1, .., (K-1)N$, i.e., in group $K-1$, are also dropped. The process continues until $t = K'T$ for $K' < K$, when firms $n = (K-K')N + 1, .., (K-K'+1)N$, i.e., in group K', are the last to be dropped. Times T, $2T$, $\cdots$, $K'T$ correspond to rebalancing times for green indexers.

The broad and the green indices are capitalization-weighted, i.e., they weigh firms according to their market capitalization. Therefore, the number of shares η_{Int} that the broad index includes of any firm n is proportional to the number of shares η_n issued by the firm. By possibly rescaling the broad index, we set $\eta_{Int} = \eta_n$. Likewise, the number of shares η_{Gnt} that the green index includes of any firm $n \in \mathcal{G}_t$ is proportional to η_n. By possibly rescaling the green index, we set $\eta_{Gnt} = \eta_n$ for $n \in \mathcal{G}_t$. Since $\eta_{Gnt} = 0$ for $n \notin \mathcal{G}_t$, we can write η_{Gnt} for all n as $1_{n\in\mathcal{G}_t}\eta_n$.

We denote by W_{At}, W_{It} and W_{Gt} the wealth of an active investor, an indexer and a green indexer, respectively, at time t, by z_{Ant}, z_{Int} and z_{Gnt} the number of shares of firm n that these agents hold, and by μ_{At}, μ_{It} and μ_{Gt} the measure of these agents. An in-

[3] A geometric Brownian motion specification for dividends, which is commonly assumed in asset-pricing models, would also imply these properties. We adopt the square-root specification because it yields closed-form solutions.

dexer holds $z_{Int} = \lambda_{It}\eta_n$ shares of firm n, and a green indexer holds $z_{Gnt} = \lambda_{Gt}\eta_{Gnt}$ shares of the firm, where λ_{It} and λ_{Gt} are proportionality coefficients that the agents choose optimally. The coefficients $(\lambda_{It}, \lambda_{Gt})$ do not depend on the values of the dividend flows, which indexers and green indexers do not observe, but can depend on time. We assume that $(\lambda_{It}, \lambda_{Gt})$ are constant in each of the intervals between rebalancing times $[kT, (k+1)T)$ for $k = 0, .., K' - 1$ and $[K'T, \infty)$. In these intervals, the composition of the green index is held constant, and denote their values by $(\lambda_{Ik}, \lambda_{Gk})$ and $(\lambda_{IK'}, \lambda_{GK'})$, respectively. We likewise assume that $(\mu_{At}, \mu_{It}, \mu_{Gt})$ are constant in each of these intervals, and denote their values by $(\mu_{Ak}, \mu_{Ik}, \mu_{Gk})$ and $(\mu_{AK'}, \mu_{IK'}, \mu_{GK'})$, respectively.

The budget constraint of agent type $i = A, I, G$ is

$$dW_{it} = \left(W_{it} - \sum_{n=1}^{KN} z_{int}S_{nt}\right) rdt + \sum_{n=1}^{KN} z_{int}(D_{nt}dt + dS_{nt}) = W_{it}rdt + \sum_{n=1}^{KN} z_{int}dR^{sh}_{nt}, \tag{2.6}$$

where dW_{it} is the infinitesimal change in wealth and $dR^{sh}_{nt} \equiv D_{nt}dt + dS_{nt} - rS_{nt}dt$ is the share return of stock n in excess of the riskless rate. Agents have mean-variance preferences over dW_{it}. Active investors, who observe $\{D_{nt}\}_{n=1,..,KN}$, maximize the objective function

$$\mathbb{E}_t(dW_{At}) - \frac{\rho}{2}\mathbb{V}\mathrm{ar}_t(dW_{At}) \tag{2.7}$$

over conditional mean and variance at time t. Indexers and green indexers, who do not observe $\{D_{nt}\}_{n=1,..,KN}$, maximize the objective function, for $i = I, G$

$$\mathbb{E}^u_t(dW_{it}) - \frac{\rho}{2}\mathbb{V}\mathrm{ar}^u_t(dW_{it}) \tag{2.8}$$

over unconditional mean and variance at time t. The objective functions (2.7) and (2.8) can be derived from any VNM utility u, as shown in Buffa, Vayanos and Woolley (2022).

3 Equilibrium

We look for an equilibrium where the price S_{nt} of stock n is

$$S_{nt} = \bar{S}_{nt} + b_n^s S_t^s(D_t^s) + b_n^c S_t^c(D_t^c) + S_{nt}^i(D_{nt}^i), \tag{3.1}$$

where $\bar{S}_{nt}$ is a deterministic function of t, $S_t^s(D_t^s)$ is a deterministic function of t and D_t^s, $S_t^c(D_t^c)$ is a deterministic function of t and D_t^c, and $S_{nt}^i(D_{nt}^i)$ is a deterministic function of t and D_{nt}^i. The function $\bar{S}_{nt}$ represents the present value of the constant component of dividends. The functions $b_n^s S_t^s(D_t^s)$, $b_n^c S_t^c(D_t^c)$, and $S_{nt}^i(D_{nt}^i)$ represent the present value of the systematic, climate and idiosyncratic components of dividends, respectively. Assuming that $S_t^s(D_t^s)$, $S_t^c(D_t^c)$, and $S_{nt}^i(D_{nt}^i)$ are twice continuously differentiable, we can write the share return dR_{nt}^{sh} of stock n as

$$\begin{aligned}
dR_{nt}^{sh} &= (\bar{D}_n + b_n^s D_t^s + b_c D_t^c + D_{nt}^i)dt + (d\bar{S}_{nt} + b_n^s dS_t^s(D_t^s) + b_n^c dS_t^c(D_t^c) + dS_{nt}^i(D_{nt}^i)) \\
&\quad - r\left(\bar{S}_{nt} + b_n^s S_t^s(D_t^s) + b_n^c S_t^c(D_t^c) + S_{nt}^i(D_{nt}^i)\right) dt \\
&= \mu_{nt} dt + \sum_{j=s,c} b_n^j \sigma^j \sqrt{D_t^j} \frac{\partial S_t^j(D_t^j)}{\partial D_t^j} dB_t^j + \sigma_n^i \sqrt{D_{nt}^i} \frac{\partial S_{nt}^i(D_{nt}^i)}{\partial D_{nt}^i} dB_{nt}^i,
\end{aligned} \tag{3.2}$$

where

$$\begin{aligned}
\mu_{nt} \equiv \frac{\mathbb{E}_t(dR_{nt}^{sh})}{dt} &= \bar{D}_n + \frac{d\bar{S}_{nt}}{dt} - r\bar{S}_{nt} \\
&+ \sum_{j=s,c} b_n^j \left[D_t^j + \kappa^j(1 - D_t^j)\frac{\partial S_t^j(D_t^j)}{\partial D_t^j} + \frac{1}{2}(\sigma^j)^2 D_t^j \frac{\partial^2 S_t^j(D_t^j)}{\partial (D_t^j)^2} + \frac{\partial S_t^j(D_t^j)}{\partial t} - r S_t^j(D_t^j) \right] \\
&+ D_{nt}^i + \kappa_n^i(\bar{D}_n^i - D_{nt}^i)\frac{\partial S_{nt}^i(D_{nt}^i)}{\partial D_{nt}^i} + \frac{1}{2}(\sigma_n^i)^2 D_{nt}^i \frac{\partial^2 S_{nt}^i(D_{nt}^i)}{\partial (D_{nt}^i)^2} + \frac{\partial S_{nt}^i(D_{nt}^i)}{\partial t} - r S_{nt}^i(D_{nt}^i)
\end{aligned} \tag{3.3}$$

is the instantaneous expected share return of stock n, and the second step in (3.2) follows from (2.2)-(2.4) and Ito's lemma.

Using (2.6) and (3.2), we can write the objective function (2.7) of active investors as

$$\sum_{n=1}^{KN} z_{Ant}\mu_{nt} - \frac{\rho}{2}\left[\sum_{j=s,c}\left(\sum_{n=1}^{KN} z_{Ant}b_n^j\right)^2 (\sigma^j)^2 D_t^j \left[\frac{\partial S_t^j(D_t^j)}{\partial D_t^j}\right]^2 + \sum_{n=1}^{KN} z_{Ant}^2 (\sigma_n^i)^2 D_{nt}^i \left[\frac{\partial S_{nt}^i(D_{nt}^i)}{\partial D_{nt}^i}\right]^2\right]. \tag{3.4}$$

Active investors maximize (3.4) over positions $\{z_{Ant}\}_{n=1,..,KN}$. Their first-order condition is

$$\mu_{nt} = \rho\left[\sum_{j=s,c} b_n^j \left(\sum_{m=1}^{KN} z_{Amt}b_m^j\right)(\sigma^j)^2 D_t^j \left[\frac{\partial S_t^j(D_t^j)}{\partial D_t^j}\right]^2 + z_{Ant}(\sigma_n^i)^2 D_{nt}^i \left[\frac{\partial S_{nt}^i(D_{nt}^i)}{\partial D_{nt}^i}\right]^2\right] \tag{3.5}$$

and equates the instantaneous expected share return μ_{nt} of stock n to the stock's contribution to instantaneous portfolio return variance times the risk-aversion coefficient ρ.

Market clearing requires that the aggregate demand of active investors, indexers and green indexers equals the supply coming from the issuing firm:

$$\mu_{At}z_{Ant} + \mu_{It}\lambda_{It}\eta_n + \mu_{Gt}\lambda_{Gt}1_{n\in\mathcal{G}_t}\eta_n = \eta_n \Rightarrow z_{Ant} = \frac{1-\mu_{It}\lambda_{It}-\mu_{Gt}\lambda_{Gt}1_{n\in\mathcal{G}_t}}{\mu_{At}}\eta_n. \tag{3.6}$$

Substituting z_{Ant} from (3.6) into (3.5) and conjecturing that the functions $S_t^s(D_t^s)$, $S_t^c(D_t^c)$ and $S_{nt}^i(D_{nt}^i)$ are affine increasing in D_t^s, D_t^c and D_{nt}^i, respectively, i.e.,

$$S_t^s(D_t^s) = a_{0t}^s + a_{1t}^s D_t^s, \tag{3.7}$$

$$S_t^c(D_t^c) = a_{0t}^c + a_{1t}^c D_t^c, \tag{3.8}$$

$$S_{nt}^i(D_{nt}^i) = a_{n0t}^i + a_{n1t}^i D_{nt}^i, \tag{3.9}$$

for $(a_{0t}^s, a_{1t}^s, \{a_{n0t}^i, a_{n1t}^i\}_{n=1,..,KN})$ positive functions of t, we find

$$\bar{D}_n + \frac{d\bar{S}_{nt}}{dt} - r\bar{S}_{nt} + \sum_{j=s,c} b_n^j\left[D_t^j + \kappa^j a_{1t}^j(1-D_t^j) + \frac{da_{0t}^j}{dt} + \frac{da_{1t}^j}{dt}D_t^j - r(a_{0t}^j + a_{1t}^j D_t^j)\right]$$

$$
\begin{aligned}
&+ D^i_{nt} + \kappa^i_n a^i_{n1t}(\bar{D}^i_n - D^i_{nt}) + \frac{da^i_{n0t}}{dt} + \frac{da^i_{n1t}}{dt} D^i_{nt} - r(a^i_{n0t} + a^i_{n1t} D^i_{nt}) \\
&= \rho \left[\sum_{j=s,c} b^j_n \left(\sum_{m=1}^{KN} \frac{1 - \mu_{It}\lambda_{It} - \mu_{Gt}\lambda_{Gt} 1_{m\in\mathcal{G}_t}}{\mu_{At}} \eta_m b^j_m \right) (\sigma^j a^j_{1t})^2 D^j_t \right. \\
&\left. + \frac{1 - \mu_{It}\lambda_{It} - \mu_{Gt}\lambda_{Gt} 1_{n\in\mathcal{G}_t}}{\mu_{At}} \eta_n (\sigma^i_n a^i_{n1t})^2 D^i_{nt} \right]. \qquad (3.10)
\end{aligned}
$$

Equation (3.10) is affine in (D^s_t, D^c_t, D^i_{nt}). Identifying linear terms in D^j_t for $j = s, c$ and recalling that $(\lambda_{It}, \lambda_{Gt}, \mu_{At}, \mu_{It}, \mu_{Gt})$ are constant in each of the intervals $[kT, (k+1)T)$ for $k = 0, .., K' - 1$ and $[K'T, \infty)$ yields a Ricatti ordinary differential equation (ODE) in a^j_{1t} in each of these intervals. The solution in the interval $[K'T, \infty)$ is constant. The solution in each interval $[kT, (k+1)T)$ for $k = 0, .., K' - 1$ is time-varying. Identifying linear terms in D^i_{nt} yields an ODE of the same type in a^i_{1nt}. Identifying constant terms yields a linear ODE in each interval.

Proposition 3.1. *The equilibrium price function has the form (3.1) with $S^s_t(D^s_t)$, $S^c_t(D^c_t)$ and $S^i_{nt}(D^i_{nt})$ given by (3.7), (3.8) and (3.9), respectively. The function a^j_{1t} for $j = s, c$ is given by $a^j_{1t} = \bar{a}^j_{1K'}$ for $t \in [K'T, \infty)$ and*

$$
a^j_{1t} = \frac{\bar{a}^j_{1k} \left(g^j_k a^j_{1,(k+1)T} + \frac{1}{\bar{a}^j_{1k}} \right) e^{\left(g^j_k \bar{a}^j_{1k} + \frac{1}{\bar{a}^j_{1k}} \right)[(k+1)T - t]} - \frac{1}{\bar{a}^j_{1k}} \left(\bar{a}^j_{1k} - a^j_{1,(k+1)T} \right)}{\left(g^j_k a^j_{1,(k+1)T} + \frac{1}{\bar{a}^j_{1k}} \right) e^{\left(g^j_k \bar{a}^j_{1k} + \frac{1}{\bar{a}^j_{1k}} \right)[(k+1)T - t]} + g^j_k \left(\bar{a}^j_{1k} - a^j_{1,(k+1)T} \right)} \qquad (3.11)
$$

for $[kT, (k+1)T)$ and $k = 0, .., K' - 1$, where

$$
\begin{aligned}
\bar{a}^j_{1k} &\equiv \frac{2}{r + \kappa^j + \sqrt{(r + \kappa^j)^2 + 4 g^j_k}}, \\
g^j_k &\equiv \rho \left(\sum_{m=1}^{KN} \frac{1 - \mu_{Ik}\lambda_{Ik} - \mu_{Gk}\lambda_{Gk} 1_{\{m \le (K-k)N\}}}{\mu_{Ak}} \eta_m b^j_m \right) (\sigma^j)^2.
\end{aligned}
$$

The function a^i_{1nt} is given by $a^i_{n1t} = \bar{a}^i_{n1K'}$ for $t \in [K'T, \infty)$ and

$$a^i_{n1t} = \frac{\bar{a}^i_{n1k}\left(g^i_{nk}a^i_{n1,(k+1)T} + \frac{1}{\bar{a}^i_{n1k}}\right)e^{\left(g^i_{nk}\bar{a}^i_{n1k}+\frac{1}{\bar{a}^i_{n1k}}\right)[(k+1)T-t]} - \frac{1}{\bar{a}^i_{n1k}}\left(\bar{a}^i_{n1k} - a^i_{n1,(k+1)T}\right)}{\left(g^i_{nk}a^i_{n1,(k+1)T} + \frac{1}{\bar{a}^i_{n1k}}\right)e^{\left(g^i_{nk}\bar{a}^i_{n1k}+\frac{1}{\bar{a}^i_{n1k}}\right)[(k+1)T-t]} + g^i_{nk}\left(\bar{a}^i_{n1k} - a^i_{n1,(k+1)T}\right)}, \quad (3.12)$$

where

$$\bar{a}^i_{n1k} \equiv \frac{2}{r + \kappa^i_n + \sqrt{(r+\kappa^i_n)^2 + 4g^i_{nk}}},$$
$$g^i_{nk} \equiv \rho\frac{1 - \mu_{Ik}\lambda_{Ik} - \mu_{Gk}\lambda_{Gk}1_{\{n\leq(K-k)N\}}}{\mu_{Ak}}\eta_n(\sigma^i_n)^2.$$

The function $\bar{S}_{nt} + \sum_{j=s,c} b^j_n a^j_{0t} + a^i_{n0t}$ is given by

$$\bar{S}_{nt} + \sum_{j=s,c} b^j_n a^j_{0t} + a^i_{n0t} = \frac{\bar{D}_n}{r} + \sum_{j=s,c} b^j_n \kappa^j \int_t^\infty a^j_{1t'}e^{-r(t'-t)}dt' + \kappa^i_n\bar{D}^i_n \int_t^\infty a^i_{n1t'}e^{-r(t'-t)}dt'. \quad (3.13)$$

The values of $(\lambda_{Ik}, \lambda_{Gk})$ for $k = 0, .., K'$ are determined from the first-order conditions of indexers and green indexers in the Appendix A.

Figure 1 summarizes the model set-up by illustrating the portfolio rebalancing between green indexers and active investors. The figure assumes four groups of stocks and the last two groups (most polluting firms) to be excluded by green investors. In time 0, green indexers and active investors hold the same fraction 1/4 of their wealth in the four groups of stocks. In time 1, green indexers sell a fraction of the shares of the most polluting firms (brown bars), which are bought by active investors. The rest of their portfolio is reallocated proportionately. The exclusion goes for a number of periods, as it will be defined in the model; in time t, the most polluting firms are completely excluded from the portfolio of green investors and other groups of stocks are held proportionately.

After all adjustments have been made by green investors, their portfolio consists in the first two groups (least polluting firms). Active investors hold a large fraction of the last two groups (the share initially held by green indexers and their own initial share) and much less of the first two groups (possibly nothing) bought by green investors.

4 Calibration and Scenarios

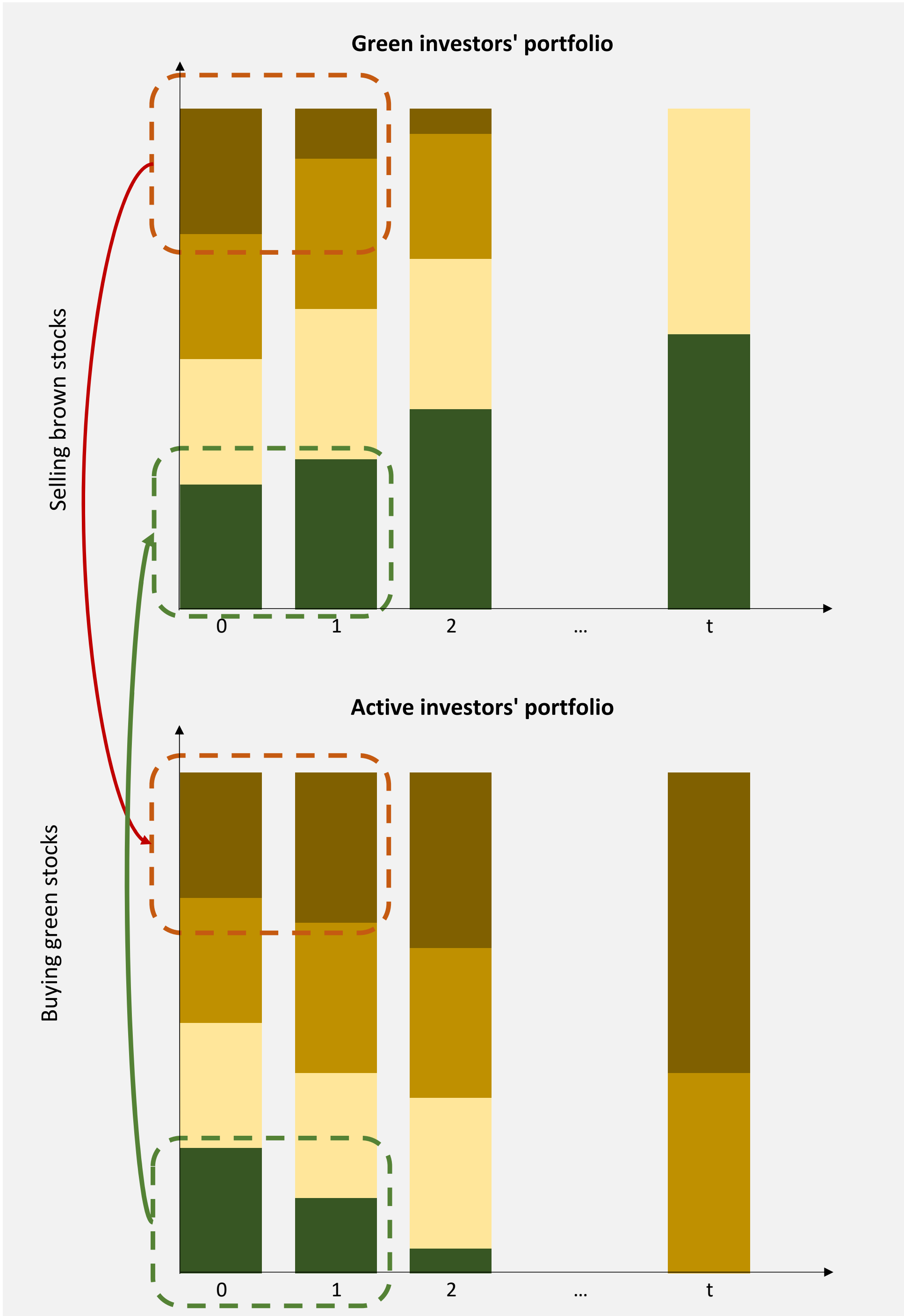
We now describe the simulation experiments that we implement to evaluate the price impact of green investors. We assume that there are $K = 100$ groups of $N = 5$ firms for a total investible space of 500 stocks ($KN = 500$). Groups are based on the GHG emissions of the group members. Firms in Group 1 are the least polluting firms, while firms in Group 100 are the most polluting ones. Otherwise, firms are symmetric, except when climate risk loadings, which affect dividend flows of individual stocks,are introduced.

The decarbonization investment strategy by green investors lasts for 10 years ($K' = 10$). Stocks are dropped from the investible space of green investors by the order of their level of GHG emissions, thus starting with Group 100 and ending with Group 90. Each year, the top first 1% of firms, i.e., the 5 firms with the highest GHG emissions, are excluded from the portfolio until in total 50 firms are excluded from green investors' investible space.

This calibration, especially the pace of exclusion, is consistent with recent empirical findings of the cross-section characteristics of carbon emissions and net zero investment strategies. Carbon emissions behave like a Pareto distribution with an extremely fat right tail. In Jondeau et al. (2021), the exclusion of the most polluting firms representing 1% of the market capitalization results in a reduction by 10% of the portfolio's carbon emissions. Overall, a gradual exclusion of most polluting firms (1% of assets under management) would reduce the emissions of a portfolio by 10% per year or approximately 65% over 10 years.

The choice for a gradual exclusion of most polluting firms is also justified from an operational perspective. Some institutional investors (such as foundations or pension funds) that are willing to reduce the carbon footprint of their portfolios may be reluctant to do

Figure 1: Asset exclusion and exchange between green indexers and other investors



it too quickly given the obligation for them to keep the tracking error of their investment close to a standard benchmark. A gradual approach would help distribute the impact on the tracking error over several years but allow a quick reduction in emissions of the green portfolio. However, as we show with our simulation results, the green investors that adopt the decarbonization strategy early would benefit from a first-mover advantage compared with late comers. This is because, prices of brown stocks will be on a decreasing path. The first movers could sell brown stocks at a higher price relative to later movers. It is worth noting that the design of the strategy adopted by green investors in our model broadly corresponds to the strategy designed for "Paris aligned" or "net zero" indices or funds.[4]

Importantly, in this decarbonization process, green investors would reinvest the proceeds from the exclusion into less polluting firms, as Figure 1 illustrates. More proactive strategies such as reinvesting the proceeds of exclusion in the least polluting firms, would reinforce the price impact documented in the paper. We present an alternative strategy that excludes 2% of stocks each year for 10 years ($K = 50$ and $N = 10$) in Appendix C.

As regards the shares of each of the three types of investors, we present different scenarios in the baseline of the article, as summarized in Table 1. Additional scenarios are presented in the Appendix C.

In Scenario 1, we assume that a relatively modest proportion of green investors ($\mu_G =$ 20%) exclude a moderate fraction of most polluting firms (10% of the value of their portfolio in 10 years). The proportion of active investors is equal to $\mu_A = 10\%$. These active investors are ready to sell green stocks to green investors and buy brown stocks from them, provided the expected return of brown stocks is sufficiently high. Important in our parametrization, the proportion of passive investors is equal to $\mu_I = 70\%$. As they hold a constant fraction of the shares of all firms, they are not available to buy brown stocks from green investors, making

[4]MSCI and S&P have launched the MSCI Climate Paris Aligned Indexes family and the Paris-Aligned & Climate Transition indexe family, respectively. Among others, Amundi, Lyxor, and iShares have launched ETFs or funds based on Paris aligned indices.

brown stocks and green stocks imperfectly substitutable from an investment perspective. This calibration of the proportion of passive investors is consistent with recent empirical evidence. Focusing on U.S. equity funds, Bloomberg reports that index mutual funds and ETFs represented 54% of the equity funds AUM by the end of 2020.[5] Chinco and Sammon (2022) find that strict end-of-day indexers represent approximately 37.8% of the U.S. stock market in 2020, based on the impact on trading volumes of index additions and deletions. At the aggregate market level, the proportion of passive investors is probably larger as it also includes fundamentally passive long-term investors, such as pension funds, banks, and investment advisors, which have very inelastic responses to price changes. Koijen, Richmond and Yogo (2020) find the ownership share of passive and long-term investors to be above 50% in 2019. van der Beck and Jaunin (2021) estimate that the share of inelastic investors is close to 26% and the share of purely passive investors is close to 39%. In contrast, Berk and van Binsbergen (2022) assume that there is no passive investors. This assumption is crucial to obtain their negligible effect of green investing on market prices, as brown and green assets are perfectly substitutable and active investors are available to absorb all brown assets sold by green investors.

In Scenario 2, we allow the share of green indexers to grow over time from an initial $\mu_G = 10\%$ in year 1 to reach 50% in year 10. The share of active investors does not change ($\mu_A = 10\%$), whereas the share of indexers diminishes from $\mu_I = 80\%$ in year 1 to 40% in year 10.

In Scenario 3, we introduce the additional effect of climate risk while keeping the rest of the parameters as in Scenario 2. All firms are positively exposed to climate risk ($b_n^c > 0$ for all n) but most polluting firms are more exposed to this source of risk than least polluting firms. The loading b_n^c on the climate risk factor is parametrized to be consistent with the Pareto cross-section distribution of carbon emissions.

[5] See https://www.bloomberg.com/professional/blog/passive-likely-overtakes-active-by-2026-earlier-if-bear-market/.

Table 1: Key parameters for the three baseline scenarios

	Green investors	Active investors	Indexers	Climate risk factor
Scenario 1	μ_G =20%	μ_A = 10%	μ_I = 70%	$b^c_n = 0$
Scenario 2	μ_G =10% → 50%	μ_A = 10%	μ_I = 80% → 40%	$b^c_n = 0$
Scenario 3	μ_G =10% → 50%	μ_A = 10%	μ_I = 80% → 40%	$b^c_n > 0$

Many of the remaining parameters are set following Jiang et al. (2022) and are chosen to match expected excess returns or CAPM R^2. Key parameters are summarized in Table 2.

The riskless rate is equal to $r = 3\%$. The mean-reversion parameters (κ^s, κ^c, and κ^i_n) are calibrated to the same value of 4%. The long-run means $\bar{D}^i_n$ and the diffusion parameters of the idiosyncratic risk σ^i_n are set to their common values $\bar{D}^i$ and σ^i, respectively. The long-run mean of the dividend flow of stock n is equal to $\bar{D}_n + b^s_n + b^c_n + \bar{D}^i_n = 1$. Parameters b^s_n, b^c_n and $\bar{D}^i_n$ are set to match the CAPM R^2, which is approximately equal to 20%.

The value of the diffusion parameter $\sigma^s = 1.4$ is selected to maximise stocks' return variances.

The number of shares ($\eta = 0.1\%$) and the risk aversion parameter ($\rho = 1$) are chosen to generate expected excess returns across groups that lie between 4% and 6%. Returns are computed from share returns by dividing by the share price. The expected excess return of stock n is

$$dR_{nt} \equiv \frac{dR^{sh}_{nt}}{S_{nt}} = \frac{D_{nt}dt + dS_{nt}}{S_{nt}} - rdt. \tag{4.14}$$

Table 2: Calibrated parameters (Scenario 1)

	Volatility	Beta	Mean-reversion	Dividend
Systematic risk	$\sigma^s = 1.4$	$b_n^s = 0.82$	$\kappa^s = 0.04$	$\bar{D}^s = 1$
Climate risk	$\sigma^c = 1.4$	$b_n^c = 0$	$\kappa^c = 0.04$	$\bar{D}^c = 1$
Idiosyncratic risk	$\sigma_n^i = \sigma^s \sqrt{\bar{D}_n^i}$		$\kappa_n^i = 0.04$	$\bar{D}_n^i = 0.18$
Riskless rate	$r = 3\%$			
Number of shares	$\eta = 0.001$			
Risk aversion	$\rho = 1$			
Number of groups	$K = 100$	$K' = 10$	$N = 5$	

5 Simulation Results

5.1 Scenario 1: Modest Share of Green Investors

Our baseline case corresponds to a situation where the proportion of green investors is modest ($\mu_G = 20\%$) and remains constant over the whole time horizon. Green investors reduce their exposure to brown stocks whereas active investors, who represent 10% of total investors, are ready to sell off green stocks and buy brown stocks. Figure 2 illustrates the evolution of prices and expected returns (or cost of capital) of three representative stocks, namely, stocks of the firms that are excluded in year 1 (first period of exclusion), in year 10 (last period of exclusion) and the firms that are not excluded from the green investors' portfolios. Table 3 provides summary statistics of the changes in prices, in the cost of capital as well as a few other characteristics (return volatility, CAPM β and CAPM R^2) of the representative stocks.

First, at the time when green investors' exclusion strategy (the 10-year exclusion horizon and the order of the groups of stocks to be excluded) is made public, prices and expected returns adjust instantaneously to the new equilibrium (Table 3, $t = 0$ lines). Prices of the excluded stocks drop, with those of Group 1 firms being affected the most. The stock price of the firms excluded in Year 1 is reduced by 6.9%, while that of the firms to be excluded in Year 10 drops by 5%. In contrast, the stock price of the firms that will never be excluded during the 10-year exclusion period would benefit from an instantaneous 0.8% price increase. Simultaneously, the expected return of the excluded firms increases to attract active investors. The instantaneous increase is the largest for the most polluting firms or the ones excluded first, by 16 basis points (bp). In contrast, the expected return of non-excluded firms is reduced by 2 bp. After 10 years, at the end of the exclusion period when a new equilibrium is formed, the stock price of the excluded firms would drop by 7.1%, while the price of non-excluded firms would increase by 1%. Over the same period the cost of capital of the most polluting firms would increase by 24 bp, whereas that of non-excluded firms would decrease by 3 bp, reflecting the higher cost of financing of brown firms relative to green firms.

We observe that the effect of green investors' exclusion strategy on the cost of capital is relatively large. In comparison, Berk and van Binsbergen (2022) find no detectable difference, around 0.44 bp, in the cost of capital between the firms that care about environmental and social costs and firms that do not. In our study, the difference reaches 27 bp, approximately 60 times bigger than what Berk and van Binsbergen (2022) find. Two main factors explain this difference. First, in Berk and van Binsbergen's baseline calibration, green investors only represent 2% of total wealth, whereas they represent 20% of wealth in our model. Even with a much higher fraction of green investors (33%), Berk and van Binsbergen (2022) find a small effect on the cost of capital, equal to 10.6 bp. In fact, to obtain a 27 bp effect in their framework, the fraction of green investors should exceed 50% of total wealth. Second and more importantly, Berk and van Binsbergen (2022) assume that the remaining 98% of the market is composed of active investors, who can thus take over all brown assets that green investors sell, thus making polluting and less polluting assets close to perfect substitutes. In contrast, we assume a much smaller share of active investors in the market (10%) and the remaining 70% of investors are passive indexers who cannot change the composition of their portfolio frequently, and must follow the development of market capitalization. This set-up makes polluting and less polluting assets imperfectly substitutable. With the robustness results in Annex C, we show that the price impact is halved if the share of active investors increases to 20% from 10% in the baseline, other things being equal.

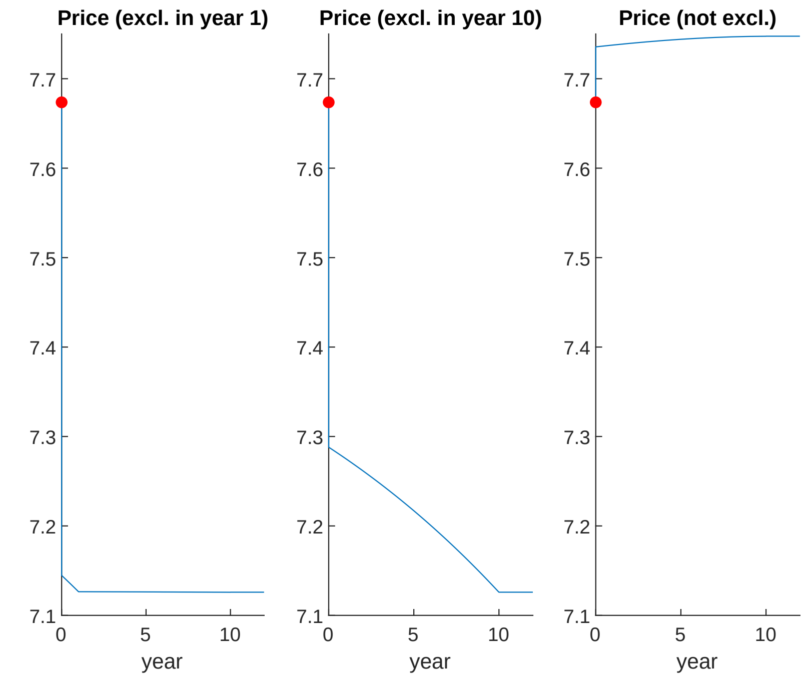
Moreover, we want to highlight an interesting “first-mover advantage” of green investing. Our simulation results show that price and expected returns change at the announcement and over the 10-year transition period, between the first set and the last set of firms that are excluded. For the firms excluded in Year 1, the stock price instantaneously drop by 6.9% at the announcement of the exclusion strategy, very close to the final steady state price at the end of the 10-year transition period, i.e., 7.1%. In comparison, the initial price change in Year 1 for the firms to be excluded in the last round, i.e., in Year 10, is only about 5%, with the gap between the initial price and the final steady state price phased in gradually during the 10-year transition period (Table 3). Similarly, the expected returns show similar patterns: the initial increase in expected returns reaches 16 bp for the first set of firms excluded in Year 1, against 14 bp for the last set of firms to be excluded. At the end of the transition, the expected returns will increase by 24 bp for both groups. Therefore, given the perfect foresight of our model, green investment shows a ”first-mover advantage”, as all brown assets that are expected to be excluded from the green investible space will take a price haircut at the very first moment when the green investing strategy is announced.

5.2 Scenario 2: Growing Proportion of Green Investors

To capture the impact of the size of green investors in driving our results, we now present Scenario 2, in which we allow the population of green investors to grow from 10% of the market ($\mu_G = 10\%$) in Year 1 to half of the market ($\mu_G = 50\%$) in Year 10. We keep the proportion of active investors constant at 10% ($\mu_A = 10\%$), suggesting that active investors will be progressively less effective at compensating the reluctance of green investors to invest in brown firms. The population of passive indexers will reduce to cater for the increase in

Figure 2: Scenario 1

Panel A: Effect of exclusion on stock prices



Panel B: Effect of exclusion on expected returns

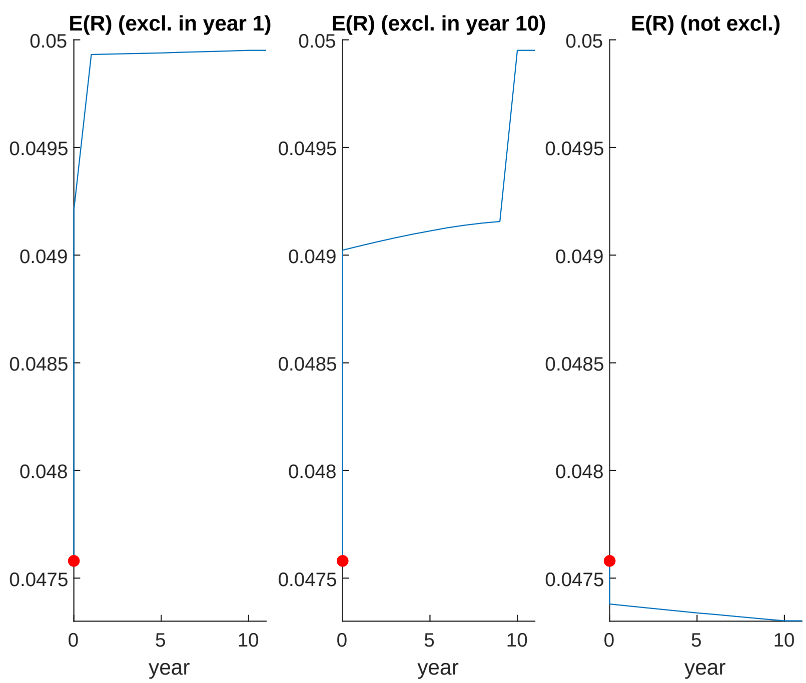


Table 3: Results - Scenario 1

	Firms excluded in Year 1	Firms excluded in Year 10	Non-excluded firms
Δ Price at $t = 0$	-6.9%	-5%	0.8%
Δ Price at $t = 10$	-7.1%	-7.1%	1%
Δ Cost of capital at $t = 0$	0.16%	0.14%	-0.02%
Δ Cost of capital at $t = 10$	0.24%	0.24%	-0.03%
Return volatility at $t = 0$	20.13%	20.13%	20.13%
Return volatility at $t = 10$	20.1%	20.1%	20.14%
CAPM β at $t = 0$	1.15	1.15	1.15
CAPM β at $t = 10$	1.2	1.2	1.14
CAPM R^2 at $t = 0$	21.3%	21.3%	21.3%
CAPM R^2 at $t = 10$	23.19%	23.19%	21.04%

that of green investors.

Figure 3 shows our simulation of stock prices and expected returns and Table 4 gives more detailed return moments. The impact of exclusion on prices and expected returns approximately doubles compared with Scenario 1, as the proportion of green investors increases while that of active investors remains constant, making brown and green assets strongly imperfect substitutes. First, the stock price of the excluded firms is massively reduced at the very moment of announcement, from 12.4% for the firms excluded in Year 1 to 10.1% for the firms to be excluded in Year 10. Not-excluded firms would benefit from a 2% instantaneous increase in their stock prices. During the 10-year transition, prices continue to decrease for the firms listed for exclusion and to increase for the other firms.

As a consequence, differences in expected returns are exacerbated. For the firms excluded in Year 1, the expected return increases immediately by 33 bp at the time of announcement and by 51 bp after 10 years. The reduction in expected returns or the cost of capital for non-excluded firms remains moderate (5 bp in Year 1, 7 bp in Year 10), as they represent approximately 90% of the market portfolio.

In terms of volatilities, return volatilities do not change whereas CAPM β and CAPM R^2 increase more strongly at the end of the exclusion exercise compared with Scenario 1.

Table 4: Results - Scenario 2

	Firms excluded in Year 1	Firms excluded in Year 10	Non-excluded firms
Δ Price at $t = 0$	-12.4%	-10.1%	2%
Δ Price at $t = 10$	-14.3%	-14.3%	2.5%
Δ Cost of capital at $t = 0$	0.33%	0.3%	-0.05%
Δ Cost of capital at $t = 10$	0.51%	0.51%	-0.07%
Return volat. at $t = 0$	20.13%	20.13%	20.13%
Return volat. at $t = 10$	20.06%	20.06%	20.15%
CAPM β at $t = 0$	1.15	1.15	1.15
CAPM β at $t = 10$	1.26	1.26	1.14
CAPM R^2 $t = 0$	21.3%	21.3%	21.3%
CAPM R^2 $t = 10$	25.33%	25.33%	20.58%

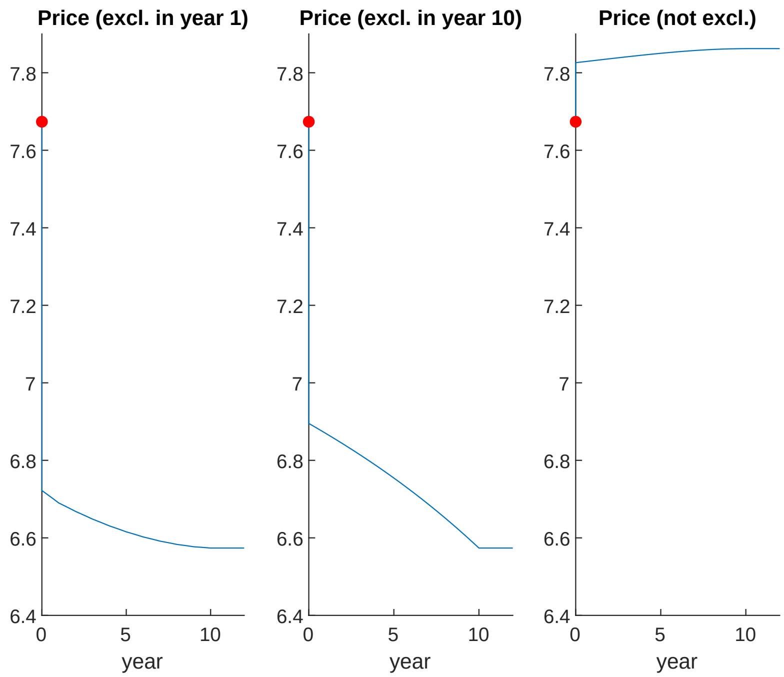
5.3 Scenario 3: Climate Risk and Growing Proportion of Green Investors

Finally, in Scenario 3, we introduce the climate risk factor on top of the growing share of green investors as in Scenario 2. The climate risk factor affects firm n's per-share dividend flow according to Equation (2.1). Loadings on climate factor are calibrated to follow a power law across groups. Namely, 1% of most polluting stocks account for 15% of aggregate loading; 10% of most polluting stocks account for 40% of aggregate loading. These values are chosen based on the empirical findings of Jondeau et al. (2021).

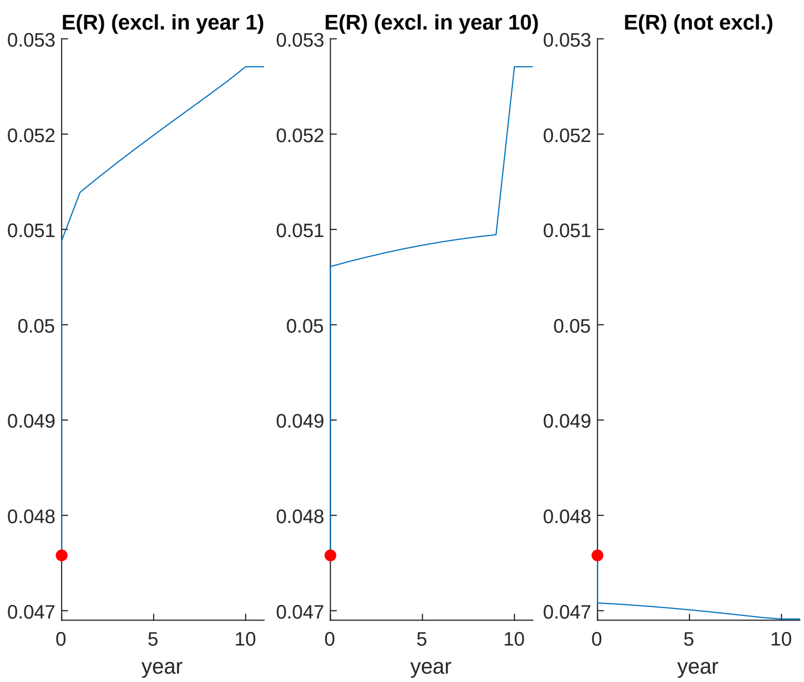
In this scenario, climate risk is calibrated based on the differential between the cost of capital of brown stocks and that of green stocks in the absence of green investors. As Table 5

Figure 3: Scenario 2

Panel A: Effect of exclusion on stock prices



Panel B: Effect of exclusion on expected returns



shows, the effects on stock prices and cost of capital are larger than in Scenario 2 for the stocks excluded in Year 1 and smaller for stocks excluded in later years or the non-excluded ones. At the announcement, firms in Group 100, namely to be excluded first, suffer from a 13.3% cut in stock prices, while the initial decrease for firms in Group 90, namely to be excluded last, is only about 8.7%. At the same time, stock prices of the non-excluded firms would benefit from a 1.6% increase. After 10 years, the price drop is still strongest for firms in Group 100, reaching 15.7%, whereas prices would fall by 12.2% for firms in Group 90.

The cost of capital is also dramatically affected by the decarbonization strategy. The cost of capital increases by 32 bp for the firms excluded first and only by 20 bp for firms to be excluded last at the announcement. Over time, at the end of the 10 years, the impact on cost of capital will double. The cost of funding for the not-excluded firms will drop marginally by 3 to 4 bp at the announcement date or at the end of the transition.

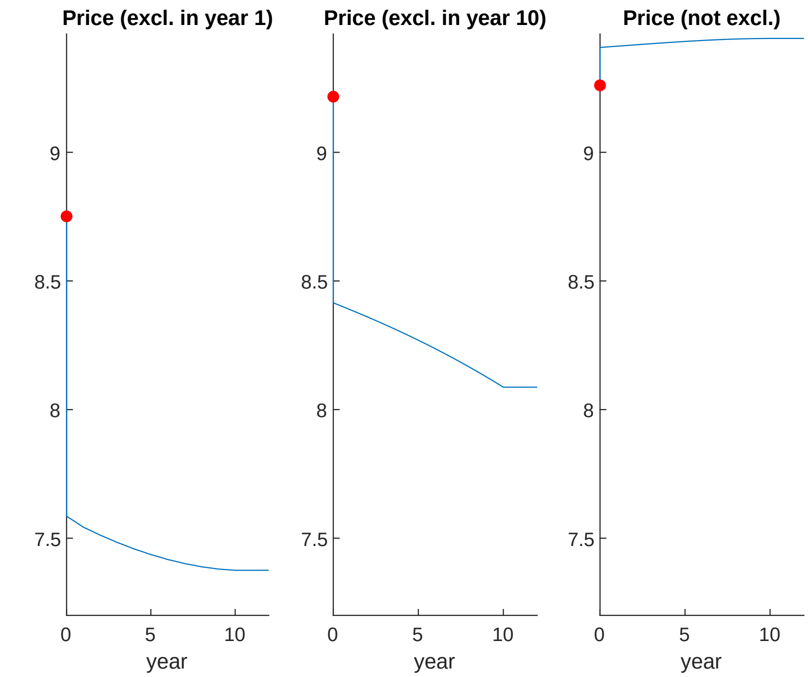
CAPM β and CAPM R^2 increase strongly between the point where exclusion is announced and the end of the exclusion exercise.

Table 5: Results - scenario 3

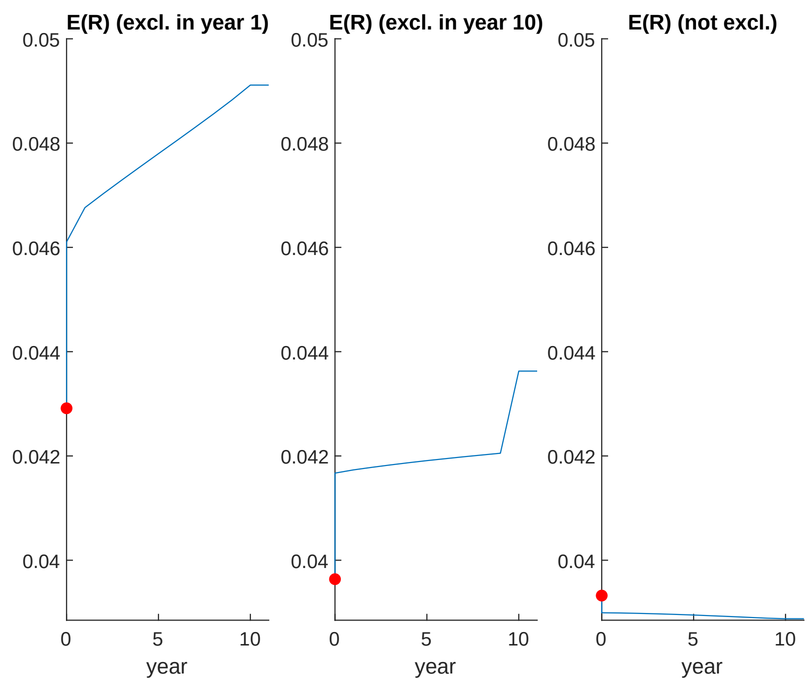
	Firms excluded in Year 1	Firms excluded in Year 10	Non-excluded firms
Δ Price at $t = 0$	-13.3%	-8.7%	1.6%
Δ Price at $t = 10$	-15.7%	-12.2%	2%
Δ Cost of capital at $t = 0$	0.32%	0.2%	-0.03%
Δ Cost of capital at $t = 10$	0.62%	0.4%	-0.04%
Return volat. at $t = 0$	19.2%	16.96%	16.85%
Return volat. at $t = 10$	19.17%	16.52%	16.94%
CAPM β at $t = 0$	1.24	1.11	1.1
CAPM β at $t = 10$	1.35	1.19	1.09
CAPM R^2 $t = 0$	19.99%	20.65%	20.44%
CAPM R^2 $t = 10$	23.59%	24.75%	19.73%

Figure 4: Scenario 3

Panel A: Effect of exclusion on stock prices



Panel B: Effect of exclusion on expected returns



6 Conclusion

We study the impact of green investors on stock prices in a dynamic equilibrium asset-pricing model where three types of investors – green, passive or active – jointly determine stock prices and returns. Green investors' investment consists of reducing their exposure to firms with the highest greenhouse gas emissions. Active investors maximize expected returns and can buy stocks of brown firms whereas passive investors stick to an index of the entire market.

The decarbonization strategy of green investors that we simulate in the model reflects what the academic literature and market practitioners would refer to as "Paris agreement" or "net zero" benchmark indices. The trajectory that we assume (the 1% most polluting firms are excluded every year in a cumulative way) would correspond to an annual carbon emission reduction rate of about 10% for the green portfolio, given the very skewed distribution of carbon emissions.[6] This is the necessary GFG reduction rate that green portfolios need to generate to stay roughly on a net zero trajectory.

We find a large fall in stock prices of the high-emitting firms that are excluded and in turn an increase in stock prices of greener firms when the exclusion strategy is announced and during the transition process. In the baseline scenario where we keep 20% green investors, 10% active investors and 70% passive indexers over time, the stock price of the firms excluded in Year 1 would drop by 6.9%, while that of the firms to be excluded in Year 10 would be lowered by 5%, immediately after the announcement of the exclusion strategy. In contrast, the stock price of the firms that will never be excluded during the 10-year exclusion period would benefit from an instantaneous 0.8% price increase. The changes in stock prices will also be translated into variation in expected returns of the firms to be excluded and those that remain in the investible space. Over a 10-year transition period, prices of the brown firms that are excluded would drop by 7.1% and the cost of capital of the most polluting firms

[6] According to a widely cited report by the Climate Disclosure Project or CDP published in 2017, 70.6% of global GHG emissions since 1988 are due to 100 companies. See https://www.cdp.net/en/articles/media/new-report-shows-just-100-companies-are-source-of-over-70-of-emissions

would increase by 24 bp at the end of the transition period, whereas that of non-excluded firms would decrease by 3 bp, reflecting the higher cost of financing of brown firms relative to green firms.

The large price effect we find complements the findings of earlier papers which generally see unnoticeable price impact especially when the community of green investors is small. The significantly large effect on stock prices and expected returns of green investing stems from the imperfect substitution of different stocks. The assumption that a significant fraction of non-green investors are passive implies that green investors' demand function is significantly more price-inelastic. Moreover, the relative size of green, active and passive investors matter for the magnitude of the price impact of green investing. The bigger the share of green investors and passive indexers, the smaller the share of active investors, and the larger the price impact.

In addition, we assume perfect foresight regarding the green investing strategy, namely as regards the timing and the list of firms to be excluded. This assumption also contributes to the large impact on prices and expected returns. In practice, the process may not be perfectly predictable and this may attenuate the effect on impact. It is likely that the ultimate effect (on Year 10) would remain similar. It should be noted that the large initial impact could trigger a rush if investors want to hedge against the large fall in the price of brown stocks. As a consequence, we would expect a first-mover advantage for green investors to enter the decarbonization strategy at an early stage.

It is important to note that, quantitatively, assumptions behind these figures are far from extreme. Only a small fraction of firms would be excluded in the process, some of them only after 10 years. Capital from green investors would flow from most polluting firms to least polluting firms, helping the development of green technologies, including in the energy and electricity production industries (no sector is a priori excluded).

Finally, our analysis focuses on the impact of green investors on stock prices and does not account for linkages between stock prices and corporate investment. Exclusion of brown firms from indices could induce them to cut down on investment because of their lower stock prices, and the reduced investment could feed back into lower prices. Due to the reduced investment, the lower valuations of brown firms could mainly reflect worsened fundamentals rather than high expected returns. Extending the analysis of green investing to incorporate feedback effects between stock prices and corporate investment is a promising direction of future research.

References

van der Beck, P., 2021. Flow-driven ESG returns. Swiss Finance Institute Research Paper No. 21-71.

van der Beck, P., Jaunin, C., 2021. The equity market implications of the retail investment boom. Swiss Finance Institute Research Paper No. 21-12.

Berk, J.B., van Binsbergen, J.H., 2022. The impact of impact investing. Stanford University Graduate School of Business Research Paper.

Bolton, P., Kacperczyk, M., Samama, F., 2021. Net-zero carbon portfolio alignment. Working Paper, available at SSRN: https://ssrn.com/abstract=3922686.

Buffa, A.M., Vayanos, D., Woolley, P., 2022. Asset Management Contracts and Equilibrium Prices. Journal of Political Economy 130, 3146–3201. URL: https://ideas.repec.org/a/ucp/jpolec/doi10.1086-720515.html.

Cheng, G., Jondeau, E., Mojon, B., 2022. Building portfolios of sovereign securities with decreasing carbon footprints. BIS Working Papers 1038. Bank for International Settlements. URL: https://ideas.repec.org/p/bis/biswps/1038.html.

Chinco, A., Sammon, M., 2022. The passive-ownership share is double what you think it is. Working Paper, Available at SSRN: https://ssrn.com/abstract=4188052.

Gormsen, N.J., Huber, K., Oh, S., 2023. Climate capitalists. Working Paper, Available at https://ssrn.com/abstract=4366445.

Green, D., Vallee, B., 2023. Can finance save the world? measurement and effects of bank coal exit policies. Working Paper, Available at https://ssrn.com/abstract=4090974.

Hartzmark, S.M., Shue, K., 2022. Counterproductive sustainable investing: The impact elasticity of brown and green firms. Working Paper, Available at SSRN: https://ssrn.com/abstract=4359282.

Jiang, H., Vayanos, D., Zheng, L., 2022. Passive investing and the rise of mega-firms. Available at SSRN: https://ssrn.com/abstract=3749534.

Jondeau, E., Mojon, B., Pereira Da Silva, L.A., 2021. Building benchmark portfolios with decreasing carbon footprints. Bank for International Settlements Working Paper, Available at SSRN: https://ssrn.com/abstract=3987186.

Kacperczyk, M.T., Peydro, J.L., 2022. Carbon emissions and the bank-lending channel. Working Paper, Available at https://ssrn.com/abstract=3915486.

Koijen, R.S.J., Richmond, R.J., Yogo, M., 2020. Which Investors Matter for Equity Valuations and Expected Returns? NBER Working Papers 27402. National Bureau of Economic Research, Inc. URL: https://ideas.repec.org/p/nbr/nberwo/27402.html.

Appendix

A Proof of Proposition 3.1

We first derive the first-order conditions of indexers and green indexers. Using (2.6), (3.2) and $z_{Int} = \lambda_I \eta_n$, we can write the objective (2.8) of indexers as

$$\sum_{n=1}^{KN} \lambda_{It}\eta_n\mu_n - \frac{\rho}{2}\lambda_{It}^2 \left[\left(\sum_{n=1}^{KN} \eta_n b_n^s \right)^2 (\sigma^s)^2 \mathbb{E}_t^u \left[D_t^s \left[\frac{\partial S_t^s(D_t^s)}{\partial D_t^s} \right]^2 \right] \right.$$
$$\left. + \left(\sum_{n=1}^{KN} \eta_n b_n^c \right)^2 (\sigma^c)^2 \mathbb{E}_t^u \left[D_t^c \left[\frac{\partial S_t^c(D_t^c)}{\partial D_t^c} \right]^2 \right] + \sum_{n=1}^{KN} \eta_n^2 (\sigma_n^i)^2 \mathbb{E}_t^u \left[D_{nt}^i \left[\frac{\partial S_{nt}^i(D_{nt}^i)}{\partial D_{nt}^i} \right]^2 \right] \right] dt, \tag{A.1}$$

where the expectation is taken over (D_t^s, D_t^c, D_{nt}^i). Noting that λ_{It}^2 is assumed to be constant in each of the intervals $[kT, (k+1)T)$ for $k = 0, .., K'-1$ and $[K'T, \infty)$, and using (3.7)-(3.9), we find the first-order condition

$$\sum_{j=s,c} \left(\sum_{m=1}^{KN} \eta_m b_m^j \right) \left(\sum_{m=1}^{KN} \left[1 - (\mu_{AK'} + \mu_{IK'})\lambda_{IK'} - \mu_{GK'}\lambda_{GK'} 1_{\{m \le (K-K')N\}} \right] \eta_m b_m^j \right) (\sigma^j \bar{a}_{1K'}^j)^2$$
$$+ \sum_{m=1}^{KN} \left[1 - (\mu_{AK'} + \mu_{IK'})\lambda_{IK'} - \mu_{GK'}\lambda_{GK'} 1_{\{m \le (K-K')N\}} \right] \eta_m^2 (\sigma_m^i \bar{a}_{m1K'}^i)^2 \bar{D}_m^i = 0 \tag{A.2}$$

in $[K'T, \infty)$, and

$$\sum_{j=s,c} \left(\sum_{m=1}^{KN} \eta_m b_m^j \right) \left(\sum_{m=1}^{KN} \left[1 - (\mu_{Ak} + \mu_{Ik})\lambda_{Ik} - \mu_{Gk}\lambda_{Gk} 1_{\{m \le (K-k)N\}} \right] \eta_m b_m^j \right) (\sigma^j)^2 \int_{kT}^{(k+1)T} (a_{1t}^j)^2 dt$$
$$+ \sum_{m=1}^{KN} \left[1 - (\mu_{Ak} + \mu_{Ik})\lambda_{Ik} - \mu_{Gk}\lambda_{Gk} 1_{\{m \le (K-k)N\}} \right] \eta_m^2 (\sigma_m^i)^2 \bar{D}_m^i \int_{kT}^{(k+1)T} (a_{m1t}^i)^2 dt = 0 \tag{A.3}$$

in $[kT,(k+1)T)$ for $k=0,..,K'-1$. We can likewise write the objective (2.8) of green indexers as

$$\sum_{n=1}^{KN}\lambda_{It}1_{\{n\in\mathcal{G}_t\}}\eta_n\mu_n-\frac{\rho}{2}\lambda_{It}^2\left[\left(\sum_{n=1}^{KN}1_{\{n\in\mathcal{G}_t\}}\eta_n b_n^s\right)^2(\sigma^s)^2\mathbb{E}_t^u\left[D_t^s\left[\frac{\partial S_t^s(D_t^s)}{\partial D_t^s}\right]^2\right]\right.$$
$$\left.+\left(\sum_{n=1}^{KN}1_{\{n\in\mathcal{G}_t\}}\eta_n b_n^c\right)^2(\sigma^c)^2\mathbb{E}_t^u\left[D_t^c\left[\frac{\partial S_t^c(D_t^c)}{\partial D_t^c}\right]^2\right]+\sum_{n=1}^{KN}1_{\{n\in\mathcal{G}_t\}}\eta_n^2(\sigma_n^i)^2\mathbb{E}_t^u\left[D_{nt}^i\left[\frac{\partial S_{nt}^i(D_{nt}^i)}{\partial D_{nt}^i}\right]^2\right]\right]dt, \tag{A.4}$$

where the expectation is taken over (D_t^s,D_t^c,D_{nt}^i). The first-order condition is

$$\sum_{j=s,c}\left[\left(\sum_{m=1}^{KN}1_{\{m\le(K-K')N\}}\eta_m b_m^j\right)\right. \tag{A.5}$$
$$\left.\times\left(\sum_{m=1}^{KN}\left[1-\mu_{IK'}\lambda_{IK'}-(\mu_{AK'}+\mu_{GK'})\lambda_{GK'}1_{\{m\le(K-K')N\}}\right]\eta_m b_m^j\right)(\sigma^j\bar{a}_{1K'}^j)^2\right]$$
$$+\sum_{m=1}^{KN}\left[1-\mu_{IK'}\lambda_{IK'}-(\mu_{AK'}+\mu_{GK'})\lambda_{GK'}1_{\{m\le(K-K')N\}}\right]\eta_m^2 1_{\{m\le(K-K')N\}}(\sigma_m^i\bar{a}_{m1K'}^i)^2\bar{D}_m^i=0 \tag{A.6}$$

in $[K'T,\infty)$, and

$$\sum_{j=s,c}\left[\left(\sum_{m=1}^{KN}1_{\{m\le(K-k)N\}}\eta_m b_m^j\right)\right. \tag{A.7}$$
$$\left.\times\left(\sum_{m=1}^{KN}\left[1-\mu_{Ik}\lambda_{Ik}-(\mu_{Ak}+\mu_{Gk})\lambda_{Gk}1_{\{m\le(K-k)N\}}\right]\eta_m b_m^j\right)(\sigma^j)^2\int_{kT}^{(k+1)T}(a_{1t}^j)^2dt\right]$$
$$+\sum_{m=1}^{KN}\left[1-\mu_{Ik}\lambda_{Ik}-(\mu_{Ak}+\mu_{Gk})\lambda_{Gk}1_{\{m\le(K-k)N\}}\right]\eta_m^2 1_{\{m\le(K-k)N\}}(\sigma_m^i)^2\bar{D}_m^i\int_{kT}^{(k+1)T}(a_{m1t}^i)^2dt=0 \tag{A.8}$$

in $[kT,(k+1)T)$ for $k=0,..,K'-1$.

We next determine a^j_{1t} for $j = s, c$. Identifying terms in D^j_t in (3.10) yields the ODE

$$1 - (r + \kappa^j)a^j_{1t} - g^j_k(a^j_{1t})^2 + \frac{da^j_{1t}}{dt} = 0. \tag{A.9}$$

When $k = 0, .., K' - 1$, (A.9) is defined over $t \in [kT, (k+1)T)$, and when $k = K'$, (A.9) is defined over $t \in [K'T, \infty)$. When $k = K'$, we look for a constant solution of (A.9), corresponding to the steady state. Such a solution $\bar{a}^j_{1K'}$ must satisfy the quadratic equation

$$1 - (r + \kappa^j)\bar{a}^j_{1K'} - g^j_{K'}(\bar{a}^j_{1K'})^2 = 0. \tag{A.10}$$

Equation (A.10) has two solutions if

$$(r + \kappa^j)^2 + 4g^j_{K'} > 0,$$

which we assume. We focus on the smaller solution, which is the continuous extension of the unique solution when $g^j_{K'} = 0$, and is as in the proposition. When $k = 0, .., K' - 1$, we solve (A.9) recursively with terminal condition $\lim_{t\to(k+1)T} a^j_{1t} = a^j_{1,(k+1)T}$. We find

$$\begin{aligned}
&\frac{da^j_{1t}}{dt} = g^j_k(a^j_{1t})^2 + (r + \kappa^j)a^j_{1t} - 1 \\
&\Rightarrow \frac{da^j_{1t}}{dt} = (a^j_{1t} - \bar{a}^j_{1k})(g^j_k a^j_{1t} + \frac{1}{\bar{a}^j_{1k}}) \\
&\Rightarrow \frac{da^j_{1t}}{(a^j_{1t} - \bar{a}^j_{1k})(g^j_k a^j_{1t} + \frac{1}{\bar{a}^j_{1k}})} = dt \\
&\Rightarrow \frac{da^j_{1t}}{g^j_k \bar{a}^j_{1k} + \frac{1}{\bar{a}^j_{1k}}}\left(\frac{1}{a^j_{1t} - \bar{a}^j_{1k}} - \frac{g^j_k}{g^j_k a^j_{1t} + \frac{1}{\bar{a}^j_{1k}}}\right) = dt \\
&\Rightarrow \log\left(\frac{a^j_{1,(k+1)T} - \bar{a}^j_{1k}}{g^j_k a^j_{1,(k+1)T} + \frac{1}{\bar{a}^j_{1k}}}\right) - \log\left(\frac{a^j_{1t} - \bar{a}^j_{1k}}{g^j_k a^j_{1t} + \frac{1}{\bar{a}^j_{1k}}}\right) = \left(g^j_k \bar{a}^j_{1k} + \frac{1}{\bar{a}^j_{1k}}\right)[(k+1)T - t] \\
&\Rightarrow \frac{g^j_k a^j_{1t} + \frac{1}{\bar{a}^j_{1k}}}{a^j_{1t} - \bar{a}^j_{1k}} = \frac{g^j_k a^j_{1,(k+1)T} + \frac{1}{\bar{a}^j_{1k}}}{a^j_{1,(k+1)T} - \bar{a}^j_{1k}} e^{\left(g^j_k \bar{a}^j_{1k} + \frac{1}{\bar{a}^j_{1k}}\right)[(k+1)T-t]},
\end{aligned}$$

which yields (3.11).

We next determine a^n_{1t}. Identifying terms in D^i_{nt} in (3.10) yields the ODE

$$1-(r+\kappa^i_n)a^i_{n1t}-g^i_{nk}(a^i_{n1t})^2+\frac{da^i_{n1t}}{dt}=0. \tag{A.11}$$

When $k=0,..,K'-1$, (A.11) is defined over $t\in[kT,(k+1)T)$, and when $k=K'$, (A.11) is defined over $t\in[K'T,\infty)$. When $k=K'$, we look for a constant solution of (A.11). Proceeding as for a^j_{1t}, we find $\bar{a}^i_{n1K'}$ in the proposition. When $k=0,..,K'-1$, we solve (A.11) recursively with terminal condition $\lim_{t\to(k+1)T}a^i_{n1t}=a^i_{n1,(k+1)T}$. Proceeding as for a^j_{1t}, we find (3.12).

Identifying the remaining terms yields the ODE

$$\bar{D}_n+\frac{d\bar{S}_{nt}}{dt}-r\bar{S}_{nt}+\sum_{j=s,c}b^j_n\left(\kappa^j a^j_{1t}+\frac{da^j_{0t}}{dt}-ra^j_{0t}\right)+\kappa^i_n a^i_{n1t}\bar{D}^i_n+\frac{da^i_{n0t}}{dt}-ra^i_{n0t}=0 \tag{A.12}$$

in the function $\bar{S}_{nt}+\sum_{j=s,c}b^j_n a^j_{0t}+a^i_{n0t}$. Its solution is

$$\begin{aligned}\bar{S}_{nt}+\sum_{j=s,c}b^j_n a^j_{0t}+a^i_{n0t}&=\int_t^\infty\left(\bar{D}_n+\sum_{j=s,c}b^j_n\kappa^j a^j_{1t'}+\kappa^i_n a^i_{n1t'}\bar{D}^i_n\right)e^{-r(t'-t)}dt'\\&=\frac{\bar{D}_n}{r}+\sum_{j=s,c}b^j_n\kappa^j\int_t^\infty a^j_{1t'}e^{-r(t'-t)}dt'+\kappa^i_n\bar{D}^i_n\int_t^\infty a^i_{n1t'}e^{-r(t'-t)}dt'.\end{aligned} \tag{A.13}$$

For $t\in[K'T,\infty)$, the solution is constant and equal to

$$\bar{S}_n+\sum_{j=s,c}b^j_n a^j_0+a^i_{n0}=\frac{\bar{D}_n+\sum_{j=s,c}b^j_n\kappa^j\bar{a}^j_{1K'}+\kappa^i_n\bar{D}^i_n\bar{a}^i_{n1K'}}{r}.$$

B Case with a Constant Proportion of Green Investors with Climate Risk

The third case corresponds to a small proportion of green investors ($\mu_G = 20\%$), which remains constant over time, with climate risk. Exposure to climate risk follows a power law, which is consistent with the extreme asymmetry observed in carbon emissions: we assume that the firms in the first group are 10 times more polluting than firms in the second group, and so on. The proportion of active investors is equal to $\mu_A = 10\%$. The decarbonization process lasts for 10 years. As firms are exposed to an additional source of risk, equilibrium prices and expected returns are different across firms. Firms with high exposures to climate risk (most polluting firms) have lower prices than firms with low exposures.

Comparing with case 1, the impact of decarbonization on prices and expected returns is similar but starting from different levels. On impact, the price decreases by 7.5% for most polluting firms (Group 1) to 4.3% for firms in Group 10, while not-excluded firms benefit from a 1.6% increase in prices. Regarding expected, we now obtain a combination of two mechanisms that cumulate: First, most polluting firms are more exposed to climate risk and therefore must deliver a higher expected return (4.2% vs. 3.93% for least polluting firms) before announcement. Second, on impact, the expected return of most polluting firms increases as in case 1.

Eventually, the cost of capital at the end of year 10 is equal to 4.55% for firms in Group 1, 4.13% for firms in Group 10 and 3.87% for not-excluded firms. The difference in terms of expected return between Group 1 firms and not-excluded firms is almost tripled compared to case 1.

Risk exposures are also affected by the introduction of climate risk. The volatility of firms in Group 1 is dramatically increased because of their high exposure to climate risk. Their CAPM beta and CAPM R^2 are also largely increased. In contrast, not-excluded firms have essentially the same volatility as in case 1.

C Robustness checks

In this section, we present the results of robustness checks. We follow the same three-scenario structure as described in Section 4 of the main text but change some key parameters, such as the share of active investors in the market, and the pace at which green investors exclude polluting firms or stocks, and the size of climate risk loadings.

C1 With 20% active investors

We present below the simulation results when the share of active investors is increased to 20% from 10% while keeping other parameters unchanged. The key parameters of the three scenarios are summarized in Table A.1

Table A.1: Key parameters for the three baseline scenarios

	Green investors	Active investors	Indexers	Climate risk factor
Scenario 1	μ_G =20%	μ_A = 20%	μ_I = 60%	$b_n^c = 0$
Scenario 2	μ_G =10% $\rightarrow$ 50%	μ_A = 20%	μ_I = 70% $\rightarrow$ 30%	$b_n^c = 0$
Scenario 3	μ_G =10% $\rightarrow$ 50%	μ_A = 20%	μ_I = 70% $\rightarrow$ 30%	$b_n^c > 0$

C2 With 2% annual exclusion

Here, the key parameters of the three scenarios remain exactly the same as in the main text in Table 1. What changes is the pace at which green investors exclude polluting firms or stocks. Instead of removing 1% of firms per year for 10 years, green investors will exclude 2% of firms a year. For this, we change the total number of groups to 50 ($K = 50$) and the number of firms per group to 10 ($N = 10$).

Table A.2: With 20% active investors - Scenario 1

	Firms excluded in Year 1	Firms excluded in Year 10	Non-excluded firms
Δ Price at $t = 0$	-3.8%	-2.8%	0.4%
Δ Price at $t = 10$	-3.9%	-3.9%	0.5%
Δ Cost of capital at $t = 0$	0.09%	0.08%	-0.01%
Δ Cost of capital at $t = 10$	0.13%	0.13%	-0.01%
Return volat. at $t = 0$	20.13%	20.13%	20.13%
Return volat. at $t = 10$	20.11%	20.11%	20.14%
CAPM β at $t = 0$	1.15	1.15	1.15
CAPM β at $t = 10$	1.17	1.17	1.14
CAPM R^2 at $t = 0$	21.3%	21.3%	21.3%
CAPM R^2 at $t = 10$	22.31%	22.31%	21.17%

Table A.3: With 20% active investors - scenario 2

	Firms excluded in Year 1	Firms excluded in Year 10	Non-excluded firms
Δ Price at $t = 0$	-7.4%	-6.1%	1%
Δ Price at $t = 10$	-8.6%	-8.6%	1.2%
Δ Cost of capital at $t = 0$	0.17%	0.18%	-0.05%
Δ Cost of capital at $t = 10$	0.27%	0.29%	-0.06%
Return volat. at $t = 0$	20.13%	20.13%	20.13%
Return volat. at $t = 10$	20.09%	20.09%	20.14%
CAPM β at $t = 0$	1.15	1.15	1.15
CAPM β at $t = 10$	1.21	1.21	1.14
CAPM R^2 at $t = 0$	21.3%	21.3%	21.3%
CAPM R^2 at $t = 10$	23.59%	23.59%	20.95%

Table A.4: With 20% active investors - scenario 3

	Firms excluded in Year 1	Firms excluded in Year 10	Non-excluded firms
Δ Price at $t = 0$	-8%	-5.2%	0.8%
Δ Price at $t = 10$	-9.5%	-7.3%	0.9%
Δ Cost of capital at $t = 0$	0.18%	0.12%	-0.02%
Δ Cost of capital at $t = 10$	0.35%	0.23%	-0.02%
Return volat. at $t = 0$	19.2%	16.96%	16.85%
Return volat. at $t = 10$	19.18%	16.71%	16.89%
CAPM β at $t = 0$	1.24	1.11	1.1
CAPM β at $t = 10$	1.3	1.16	1.1
CAPM R^2 at $t = 0$	19.99%	20.65%	20.44%
CAPM R^2 at $t = 10$	22.02%	22.95%	20.1%

Table A.5: With 2% annual exclusion - Scenario 1

	Firms excluded in Year 1	Firms excluded in Year 10	Non-excluded firms
Δ Price at $t = 0$	-6.9%	-4.9%	1.9%
Δ Price at $t = 10$	-7.1%	-7.1%	2.2%
Δ Cost of capital at $t = 0$	0.16%	0.14%	-0.05%
Δ Cost of capital at $t = 10$	0.24%	0.24%	-0.06%
Return volat. at $t = 0$	20.13%	20.13%	20.13%
Return volat. at $t = 10$	20.1%	20.1%	20.14%
CAPM β at $t = 0$	1.15	1.15	1.15
CAPM β at $t = 10$	1.2	1.2	1.14
CAPM R^2 at $t = 0$	21.3%	21.3%	21.3%
CAPM R^2 at $t = 10$	23.15%	23.15%	20.69%

Table A.6: With 2% annual exclusion - scenario 2

	Firms excluded in Year 1	Firms excluded in Year 10	Non-excluded firms
Δ Price at $t = 0$	-12.4%	-10%	4.8%
Δ Price at $t = 10$	-14.4%	-14.4%	6%
Δ Cost of capital at $t = 0$	0.33%	0.3%	-0.12%
Δ Cost of capital at $t = 10$	0.53%	0.53%	-0.16%
Return volat. at $t = 0$	20.13%	20.13%	20.13%
Return volat. at $t = 10$	20.07%	20.07%	20.16%
CAPM β at $t = 0$	1.15	1.15	1.15
CAPM β at $t = 10$	1.26	1.26	1.12
CAPM R^2 at $t = 0$	21.3%	21.3%	21.3%
CAPM R^2 at $t = 10$	25.13%	25.13%	19.59%

Table A.7: With 2% annual exclusion - scenario 3

	Firms excluded in Year 1	Firms excluded in Year 10	Non-excluded firms
Δ Price at $t = 0$	-13.8%	-8.6%	3.9%
Δ Price at $t = 10$	-16.4%	-12.4%	4.9%
Δ Cost of capital at $t = 0$	0.33%	0.2%	-0.08%
Δ Cost of capital at $t = 10$	0.69%	0.42%	-0.11%
Return volat. at $t = 0$	19.24%	16.97%	16.87%
Return volat. at $t = 10$	19.25%	16.54%	17.07%
CAPM β at $t = 0$	1.26	1.11	1.1
CAPM β at $t = 10$	1.37	1.19	1.08
CAPM R^2 at $t = 0$	20.68%	20.67%	20.44%
CAPM R^2 at $t = 10$	24.01%	24.55%	18.75%

Previous volumes in this series

1126 September 2023	CBDC and the operational framework of monetary policy	Jorge Abad, Galo Nuño and Carlos Thomas
1125 September 2023	Banks' credit loss forecasts: lessons from supervisory data	Martin Birn, Renzo Corrias, Christian Schmieder and Nikola Tarashev
1124 September 2023	The effect of monetary policy on inflation heterogeneity along the income distribution	Miguel Ampudia, Michael Ehrmann and Georg Strasser
1123 September 2023	Global supply chain interdependence and shock amplification – evidence from Covid lockdowns	Sally Chen, Eric Tsang and Leanne (Si Ying) Zhang
1122 September 2023	gingado: a machine learning library focused on economics and finance	Douglas K G Araujo
1121 September 2023	Margins, debt capacity, and systemic risk	Sirio Aramonte, Andreas Schrimpf and Hyun Song Shin
1120 September 2023	Energy Shocks as Keynesian Supply shocks: Implications for Fiscal Policy	Enisse Kharroubi and Frank Smets
1119 September 2023	Keep calm and bank on: panic-driven bank runs and the role of public communication	Olivier Coibion, Yuriy Gorodnichenko, Francesco Grigoli and Damiano Sandri
1118 August 2023	The origins of monetary policy disagreement: the role of supply and demand shocks	Carlos Madeira, João Madeira and Paulo Santos Monteiro
1117 August 2023	An impossibility theorem on truth-telling in fully decentralized systems	Rodney Garratt and Cyril Monnet
1116 August 2023	Absolute blockchain strength? Evidence from the ABS market in China	Jing Liu, Ilhyock Shim and Yanfeng Zheng
1115 August 2023	Sharks in the dark: quantifying HFT dark pool latency arbitrage	Matteo Aquilina, Sean Foley, Peter O'Neill and Thomas Ruf
1114 August 2023	The term structure of inflation forecasts disagreement and monetary policy transmission	Alessandro Barbera, Fan Dora Xia and Xingyu Sonya Zhu
1113 August 2023	To Lend or Not to Lend: the Bank of Japan's ETF purchase program and securities lending	Mitsuru Katagiri, Junnosuke Shino and Koji Takahashi

All volumes are available on our website www.bis.org.