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The Impact of Green Investors on Stock Prices

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Abstract

We study how green investors impact firms' stock prices and cost of capital in a model where they track an index that progressively excludes the brownest firms and trade with passive investors tracking a broad index and with active investors. Because stock demand elasticity is low with passive investors, the impact of green investors is significantly larger than in previous calibrations. That impact is further amplified when the brownest firms load heavily on climate transition risk. Although an announcement of future exclusion is reflected into brown firms' current prices, the future price decline until exclusion is significant.

JEL: G12, G23, Q54

Keywords: Green investment, Asset pricing, Institutional investors, Climate change

1 Introduction

In the fight against climate change, the role of large institutional investors is widely debated. As these investors hold diversified portfolios, they own shares of firms with high greenhouse gas (GHG) emissions and thus contribute to global warming by financing polluting activities. A number of private-sector initiatives have sought to promote net zero investment in recent years.[1] Central banks, through the Network for Greening the Financial System (NGFS), have also been reflecting on greening their investment portfolios. Two broad approaches promoting green investment prevail. Investors can divest from brown firms, or can influence the transition of brown firms to greener operations by using their financial stakes to engage with firms' management.

A key question that drives investors' consideration of divestment versus engagement is whether divestment raises the cost of capital of brown firms and thereby influences their future business development. The impact of divestment on firms' cost of capital is the subject of a growing theoretical literature, starting with Heinkel, Kraus, and Zechner (2001). Papers in that literature assume that green investors underweight brown firms, or exclude them from their portfolios altogether, and overweight green firms. Taking the other side of green investors' positions are investors with purely financial objectives. The impact of divestment on stock prices depends on the relative size of the two types of investors and on the aggregate size and return characteristics of brown firms. A calibration by Berk and Van Binsbergen (2025) suggests that the effects of divestment on the cost of capital are tiny, less than one basis point.

In this paper we study the impact of divestment on firms' cost of capital in a model that departs from previous literature in three important respects. First, we assume that not all non-green investors trade actively against green investors. This is because a significant

[1] These initiatives include the Net Zero Asset Managers (NZAM) Initiative, the Net Zero Asset Owner (NZAO) Alliance, the Glasgow Financial Alliance for Net Zero (GFANZ), the Climate Action 100+, the Paris Aligned Asset Owners (PAAO), the Institutional Investors Group on Climate Change (IIGCC).

fraction of non-green investors are passive funds, who track broad market indexes and hence do not buy the brown stocks that green investors sell. Because of the passive investors, stock demand is significantly less price-elastic than when all non-green investors are active, and the impact of green investors on firms' cost of capital is larger than in Berk and Van Binsbergen (2025) by an order of magnitude. Second, we assume that exclusion is not one-off but occurs dynamically over time. This is because green investors in our model follow net zero strategies whereby they exclude the firms with the highest GHG emissions (or other decarbonization metric) first, the firms with the second-highest emissions next, and so on, until a fixed fraction of the the market is excluded. Exclusion is dynamic also because the fraction of green investors can grow over time. We show that while more than half of the price decline due to future exclusion is reflected into the current price of brown firms, the future price decline until exclusion is significant. Third, we allow for a heavy right tail in firms' emissions, which we identify with firms' loadings on a climate transition risk factor. Because of that right tail, the impact of divestment on the cost of capital differs across brown firms and is particularly large for the brownest ones.

Our model, presented in Section 2, assumes continuous time, infinite horizon, a constant riskless rate and multiple stocks. Stocks' dividends load on a business-cycle and a climate transition risk factor, and have additional variation that is idiosyncratic. Stocks are symmetric except possibly on their dividends' loadings on the climate factor. We model the random components of dividends as square-root processes. As in Buffa, Vayanos, and Woolley (2022) and Jiang, Vayanos, and Zheng (2025), the square-root specification allows for a tractable equilibrium where prices are affine functions of dividends while also ensuring that prices and dividends are always positive. There are three types of investors. Active investors can invest in the riskless asset and in the stocks without constraints. Passive investors can invest in the riskless asset and in a capitalization-weighted index that includes all firms. Green investors can invest in the riskless asset and in a capitalization-weighted index that progressively excludes brown firms. The green index replicates the strategy of a portfolio with a decreasing carbon footprint. Indexes excluding brown stocks progressively are referred to as “net zero” or “Paris aligned”, and have been growing in popularity over time.[2] All investors maximize a mean-variance objective over infinitesimal changes in wealth.

The equilibrium, derived in Section 3, consists of a transition phase, during which brown stocks are gradually excluded from the green index, and of a stochastic steady state that follows. During the transition phase, the brown stocks sold by green investors are bought by active investors. Passive investors keep holding the market portfolio throughout and do not add to their holdings of brown stocks.

In Section 4 we calibrate the model without a climate risk factor. We assume that there are 500 stocks and that five stocks are excluded from the green index at the end of each year for the first ten years, resulting in a cumulative exclusion of 50 stocks. This exclusion strategy can yield a large reduction in portfolio emissions because a small fraction of firms generate a large fraction of total emissions (Jondeau, Mojon, and Pereira Da Silva (2021)). We calibrate stocks' supply and the parameters of the dividend processes based on moments of stock returns. We allow the fraction of green investors to range from 5% to 15%, reflecting different estimates of the size of the sustainable fund sector. We allow the fraction of passive investors to range from 50% to 90% of combined active and passive. The lower end of our assumed range, 50%, reflects the current size of passive and active. The upper end, 90%, reflects that many active investors track indexes closely because of explicit or implicit constraints, or trade infrequently even in the absence of such constraints. Estimates of demand elasticity for stocks suggest that the fraction of truly active investors could be even

[2]The rationale for excluding brown firms progressively is operational. Institutional investors aiming to decrease the GHG footprint of their portfolios might be hesitant to implement rapid changes given their obligation to maintain a tracking error relative to a benchmark. A gradual approach spreads the impact on tracking error over multiple years while facilitating a swift reduction in GHG emissions for the overall portfolio through the early exclusion of the brownest firms. MSCI and S&P have launched the MSCI Climate Paris Aligned Indexes family and the Paris Aligned & Climate Transition Indexes family, respectively. Amundi, Lyxor, and iShares, among others, have launched ETFs or funds based on Paris aligned indexes.

less than 10% of combined active and passive, as we point out in Section 6.

When the ratio of green to active investors takes the lowest value implied by the ranges that we assume in our calibration, exclusion from the green index raises the cost of capital of the brownest firms by 1-2 basis points (bps), in line with Berk and Van Binsbergen (2025). When the ratio takes its highest value, the effect rises to 18-24 bps, which is modest but larger than Berk and Van Binsbergen (2025) by an order of magnitude. In the former case, the stock prices of the brownest firms drop by 0.2-0.5%, and in the latter case they drop by 2.8-6.3%. If the fraction of green investors rises to 30%, then their effect on the cost of capital rises to 41-49 bps and stock prices drop by 6.0-12.5%.

Future exclusion is anticipated in prices to a significant extent. The immediate price effect from the anticipation of exclusion in ten years is approximately 70% of the effect in ten years. The remaining 30% reflects a gradual price drop until the tenth year. Excluded stocks' expected returns rise gradually before exclusion and discontinuously upon exclusion. When the measure of green investors rises over time, the gradual drop in prices becomes larger relative to the immediate drop.

In Section 5 we calibrate the model with a climate risk factor. When climate shocks to dividends are assumed to be small relative to business-cycle shocks—approximately 7% for the brownest firms and 0.45% for the average firm—the effects of divestment are somewhat larger than without climate risk: the cost of capital of the brownest firms rises by 22-30 bps and their stock prices drop by 4.5-9.1% in the case where the ratio of green to active investors takes its highest value in our calibration. When climate shocks to dividends are assumed four times larger, the effects of divestment become significantly larger than without climate risk: the cost of capital rises by 93-136 bps and prices drop by 10.8-13.6%. Intuitively, climate risk introduces additional comovement between brown stocks. This raises the variance of the brown portfolio that active investors buy from green investors, and hence the expected returns that they require to hold brown stocks.

In the presence of climate risk, expected returns differ across brown and green stocks not only because of the price impact of green investors but also because brown stocks load more heavily on the climate risk factor. The effect of climate risk on expected returns is comparable in size to the effect of divestment when climate shocks to dividends are small relative to business-cycle shocks. It becomes dominant when climate shocks are larger.

A growing theoretical literature studies how divestment affects firms' stock prices and cost of capital. In Merton (1987), each investor holds only a subset of stocks, and stocks held by few investors earn high expected returns. Investors' incomplete diversification is interpreted as arising from lack of information but could alternatively arise from ethical preferences. In Heinkel, Kraus, and Zechner (2001), green investors do not hold brown stocks, and the ensuing price impact can incentivize brown firms to become greener. In Luo and Balvers (2017), exclusion of brown stocks by green investors depresses the prices of other correlated stocks. In Pastor, Stambaugh, and Taylor (2021), green stocks earn lower expected returns than brown stocks both because green investors derive utility from holding them and because they outperform brown stocks following negative climate news. Moreover, the cross-section of expected returns is described by a market and an ESG factor. In Pedersen, Fitzgibbons, and Pomorski (2021), the cross-section of expected returns is described by a similar two-factor model. Moreover, portfolio optimization by green investors who care about the ESG score of their portfolio in addition to financial returns is described by a generalized portfolio frontier. In Zerbib (2022), the cross-section of expected returns includes separate taste and exclusion premia arising from green investors' taste for green stocks and exclusion of brown stocks. A common theme across all these papers is that divestment drives up the cost of capital. Some of these papers perform a calibration exercise, which is further developed in Berk and Van Binsbergen (2025).

A large empirical literature provides estimates for the effects of divestment. Teoh, Welch, and Wazzan (1999) find that divestment from firms doing business in South Africa, in the context of the apartheid boycott, had weak effects on their stock prices. Hong and Kacperczyk (2009) find instead large effects of exclusion: they estimate an expected return premium from holding sin stocks (alcohol, tobacco and gaming) of 250 bps per year. Bolton and Kacperczyk (2021, 2023) find a similarly large expected return premium from holding brown stocks using the level and growth rate of firms' carbon emissions to measure brownness. Hsu, Li, and Tsou (2023) report similar findings measuring brownness by firms' toxic emissions intensity. Eskildsen, Ibert, Jensen, and Pedersen (2024) estimate instead modest effects by combining information on a large number of ESG measures and countries: annualized expected returns decrease by 30 bps per one standard deviation increase in greenness. Pastor, Stambaugh, and Taylor (2022) find that green stocks outperformed brown stocks by 174% cumulatively from 2012 to 2020 because of inflows into green strategies. In a similar spirit, Van Der Beck (2023) finds that a \$1 flow into ESG stocks raises their aggregate market value by \$0.7, implying a low demand elasticity, and Ardia, Bluteau, Boudt, and Inghelbrecht (2023) find that green stocks outperform brown stocks on days with negative climate news. We map our results to some of these estimates in Section 6.

The closest empirical counterpart to our model is Cenedese, Han, and Kacperczyk (2024), who measure the expected time until a firm's exclusion from a net zero portfolio. They find that annualized expected returns decrease by 150 bps per one standard deviation increase in that measure, which they term Distance-to-Exit. Moreover, exclusion renders net zero portfolios only mildly under-diversified. Jondeau, Mojon, and Pereira Da Silva (2021), Bolton, Kacperczyk, and Samama (2022) and Cheng, Jondeau, and Mojon (2022) develop methodologies to construct net zero portfolios and benchmarks.

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. Firms in group K, with the highest indices $n = (K-1)N+1, .., KN$, have the highest emissions and are excluded from the index first. Firms in group $K-1$, with the second highest indices $n = (K-2)N+1, .., (K-1)N$, have the second highest emissions and are 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. We interpret the factor D_t^s as a standard systematic risk factor corresponding to business-cycle risk. We interpret the factor D_t^c, which is also systematic, as corresponding to climate transition risk. Climate transition risk refers to the uncertainty associated with the transition towards a low-carbon economy. It can arise from policies to mitigate climate change and achieve environmental sustainability goals, and the impact that these policies have on different firms. In Section 5, we equate firms' exposure to climate transition risk to their GHG emissions. The idiosyncratic component follows the square-root process

$$dD^i_{nt} = \kappa^i_n \left(\bar{D}^i_n - D^i_{nt}\right) dt + \sigma^i_n \sqrt{D^i_{nt}} dB^i_{nt}, \tag{2.4}$$

where $\{\kappa^i_n, \bar{D}^i_n, \sigma^i_n\}_{n=1,..,KN}$ are positive constants and $\{B^i_{nt}\}_{n=1,..,KN}$ are Brownian motions. All Brownian motions are independent. By possibly redefining factor loadings and the parameters of the square-root processes (2.2) and (2.3), 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 and the parameters of the square-root process (2.4), we set the long-run mean $\bar{D}_n + b^s_n + b^c_n + \bar{D}^i_n$ of the dividend flow of stock n to one for all n.

Our specification (2.1)-(2.4) for dividends differs from typical specifications in the asset-pricing literature in two main respects. First, dividends are typically assumed to be non-stationary, while our specification yields stationarity because the random components of dividends mean-revert. Second, the volatility of dividends per share is typically assumed proportional to their level, while under our specification volatility is proportional to the square root of the level. Both assumptions are made for tractability and are not essential for our results. The square-root specification ensures that two important properties of typical specifications carry through to our model: dividends are always positive, and the volatility of dividends increases with their level. Jiang, Vayanos, and Zheng (2025) provide further motivation and evidence for the square-root specification.

Denoting by S_{nt} the price of stock n, the stock's return per share in excess of the riskless rate is

$$dR^{sh}_{nt} \equiv D_{nt}dt + dS_{nt} - rS_{nt}dt, \tag{2.5}$$

and the stock's return per dollar in excess of the riskless rate is

$$dR_{nt} \equiv \frac{dR_{nt}^{sh}}{S_{nt}} = \frac{D_{nt}dt + dS_{nt}}{S_{nt}} - rdt. \tag{2.6}$$

We refer to dR_t^{sh} as share return, omitting that it is in excess of the riskless rate. We refer to dR_t as return, omitting that it is per dollar and in excess of the riskless rate. All return moments that we compute in our calibration in Sections 4 and 5 concern dR_t.

Agents are competitive and form overlapping generations living over infinitesimal time intervals. Each generation includes active investors, passive investors and green investors. Active investors can invest in the riskless asset and in the stocks without constraints. Passive investors and green investors can invest in the riskless asset and in a stock portfolio that tracks an index. The index is a broad index for passive investors and a narrower one for green investors.

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 investors.

The broad and the green indexes are capitalization-weighted, i.e., 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, a passive investor and a green investor, 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. A passive investor holds $z_{Int} = \lambda_{It}\eta_n$ shares of firm n, and a green investor 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. We assume for tractability that the coefficients $(\lambda_{It}, \lambda_{Gt})$ are independent of the dividend flows and are constant in each of the intervals between rebalancing times $[kT, (k+1)T)$ for $k = 0, .., K' - 1$ and $[K'T, \infty)$. This assumption can reflect that passive and green investors adjust their portfolios infrequently because they observe less information or face higher transaction costs than active investors. We likewise assume that the measures $(\mu_{At}, \mu_{It}, \mu_{Gt})$ are constant in each of the intervals $[kT, (k+1)T)$ for $k = 0, .., K' - 1$ and $[K'T, \infty)$. Abusing notation, we denote the constant values of $(\lambda_{It}, \lambda_{Gt}, \mu_{At}, \mu_{It}, \mu_{Gt}, \mathcal{G}_t)$ in the intervals $[kT, (k+1)T)$ for $k = 0, .., K' - 1$ and $[K'T, \infty)$ by $(\lambda_{Ik}, \lambda_{Gk}, \mu_{Ak}, \mu_{Ik}, \mu_{Gk}, \mathcal{G}_k)$ for $k = 0, .., K'$.

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

$$dW_{it} = \left(W_{it} - \sum_{n=1}^{KN} z_{int} S_{nt} \right) r dt + \sum_{n=1}^{KN} z_{int}(D_{nt} dt + dS_{nt}) = W_{it} r dt + \sum_{n=1}^{KN} z_{int} dR_{nt}^{sh}, \tag{2.7}$$

where dW_{it} is the infinitesimal change in wealth and $dR_{nt}^{sh} \equiv D_{nt} dt + dS_{nt} - rS_{nt} dt$ is the share return of stock n in excess of the riskless rate. Agents have mean-variance preferences over dW_{it}. Active investors maximise the objective function

$$\mathbb{E}_t(dW_{At}) - \frac{\rho}{2} \mathbb{V}\text{ar}_t(dW_{At}) \tag{2.8}$$

over conditional mean and variance at time t. Passive and green investors maximise the objective function

$$\mathbb{E}_k^u(dW_{it}) - \frac{\rho}{2} \mathbb{V}\text{ar}_k^u(dW_{it}), \tag{2.9}$$

for $i = I, G$, over unconditional mean and variance across dividend flows and times t in the interval $[kT, (k+1)T)$ for $k = 0, .., K' - 1$ and $[K'T, \infty)$ for $k = K'$.

Figure 1 illustrates the portfolio flows between green and active investors. We assume four groups of firms for this figure, which are shown in green, yellow, beige and brown, ranging from the least to the most polluting. The green index progessively excludes the brown and beige firms, from year 0 to year K'. In year 0, active and green investors hold one quarter of their portfolio in each of the four groups of firms. In year 1, green investors sell a fraction of their holdings of brown firms to active investors, and rebalance their portfolio proportionally towards the other three groups. In year 2, green investors sell a further fraction of their brown holdings to active investors. This process continues until green investors hold no brown firms. They then start selling their beige holdings. This process continues until year K' when green investors hold no beige firms either, and their portfolio thus consists only of green and yellow firms.

Alternative exclusion strategies to those assumed in our model and shown in Figure 1 could be envisioned. For example, green investors could direct the proceeds from selling brown firms toward the green firms only instead of rebalancing their portfolio proportionally towards all non-brown groups. Such strategies would strengthen the price impact that we find.

3 Equilibrium

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

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

the sum of the present value $\bar{S}_{nt}$ of dividends from the constant component, the present value $b_n^s S_t^s(D_t^s)$ of dividends from the systematic component, the present value $b_n^c S_t^c(D_t^c)$ of

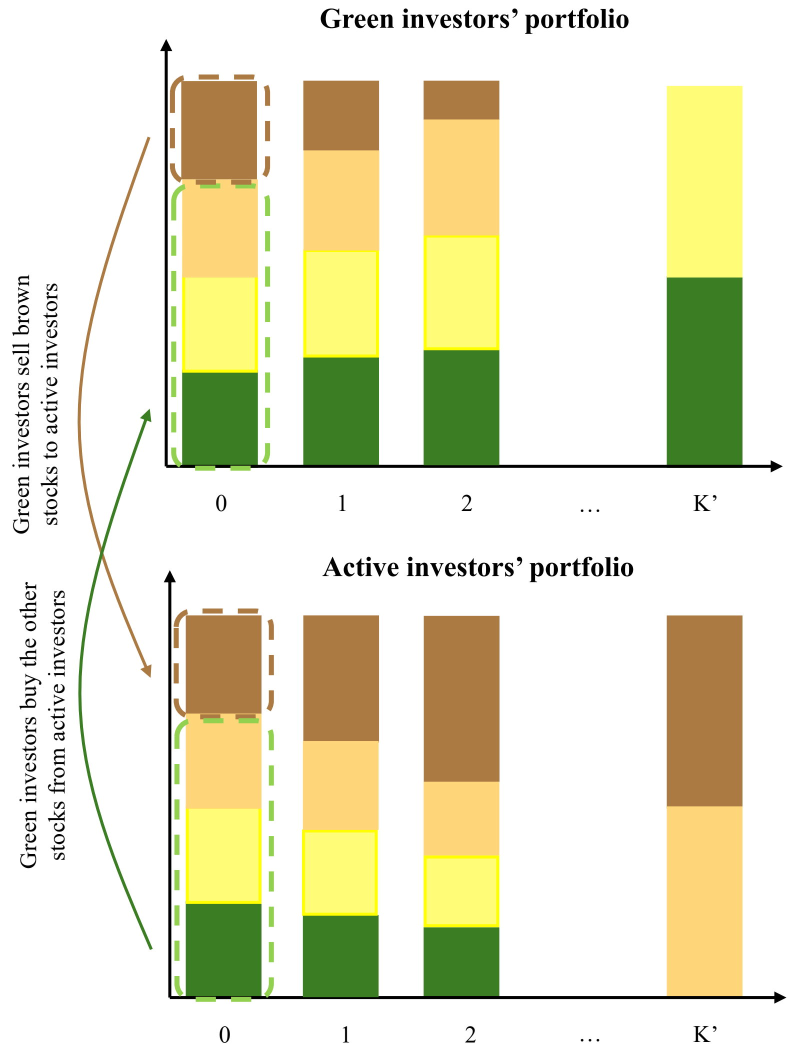


Figure 1: Asset exclusion and exchange between green investors and active investors

dividends from the climate component, and the present value $S^i_{nt}(D^i_{nt})$ of dividends from the idiosyncratic component. Assuming that the functions $(S^s_t(D^s_t), S^c_t(D^c_t), S^i_{nt}(D^i_{nt}))$ are twice continuously differentiable, we can write the share return dR^{sh}_{nt} of stock n as

$$dR^{sh}_{nt} = (\bar{D}_n + b^s_n D^s_t + b_c D^c_t + D^i_{nt})dt + (d\bar{S}_{nt} + b^s_n dS^s_t(D^s_t) + b^c_n dS^c_t(D^c_t) + dS^i_{nt}(D^i_{nt}))$$
$$- r\left(\bar{S}_{nt} + b^s_n S^s_t(D^s_t) + b^c_n S^c_t(D^c_t) + S^i_{nt}(D^i_{nt})\right) dt$$

$$= \mu_{nt} dt + \sum_{j=s,c} b_n^j \sigma^j \sqrt{D_t^j} \frac{\partial S_t^j(D_t^j)}{\partial D_t^j} dB_t^j + \sigma_n^i \sqrt{D_{nt}^i} \frac{\partial S_{nt}^i(D_{nt}^i)}{\partial D_{nt}^i} dB_{nt}^i, \tag{3.2}$$

where

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

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 (2.7) and (3.2), we can write the objective function (2.8) of active investors as

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

Using (2.7), (3.2), $z_{Int} = \lambda_{Ik}\eta_n$ and $z_{Gnt} = \lambda_{Gk}\eta_n$, we can likewise write the objective function (2.9) of passive investors as

$$\begin{aligned}
&\sum_{n=1}^{KN} \lambda_{Ik} \eta_n \mu_{nk}^u - \frac{\rho}{2} \lambda_{Ik}^2 \left[\sum_{j=s,c} \left(\sum_{n=1}^{KN} \eta_n b_n^j \right)^2 (\sigma^j)^2 \mathbb{E}_k^u \left[D_t^j \left[\frac{\partial S_t^j(D_t^j)}{\partial D_t^j} \right]^2 \right] \right. \\
&\left. + \sum_{n=1}^{KN} \eta_n^2 (\sigma_n^i)^2 \mathbb{E}_k^u \left[D_{nt}^i \left[\frac{\partial S_{nt}^i(D_{nt}^i)}{\partial D_{nt}^i} \right]^2 \right] \right],
\end{aligned} \tag{3.5}$$

and the objective function (2.9) of green investors as

$$\sum_{n=1}^{KN}\lambda_{Gk}1_{\{n\in\mathcal{G}_k\}}\eta_n\mu^u_{nk}-\frac{\rho}{2}\lambda^2_{Gk}\left[\sum_{j=s,c}\left(\sum_{n=1}^{KN}1_{\{n\in\mathcal{G}_k\}}\eta_n b^j_n\right)^2(\sigma^j)^2\mathbb{E}^u_k\left[D^j_t\left[\frac{\partial S^j_t(D^j_t)}{\partial D^j_t}\right]^2\right]\right.$$
$$\left.+\sum_{n=1}^{KN}1_{\{n\in\mathcal{G}_k\}}\eta^2_n(\sigma^i_n)^2\mathbb{E}^u_k\left[D^i_{nt}\left[\frac{\partial S^i_{nt}(D^i_{nt})}{\partial D^i_{nt}}\right]^2\right]\right], \tag{3.6}$$

where $\mu^u_{nk}\equiv\frac{\mathbb{E}^u_k(dR^{sh}_{nt})}{dt}=\mathbb{E}^u_k(\mu_{nt})$. Active investors maximise (3.4) over positions $\{z_{Ant}\}_{n=1,..,KN}$. Passive investors maximize (3.5) over λ_{Ik} and green investors maximize (3.6) over λ_{Gk}. Taking the first-order condition in (3.4) and substituting $\{z_{Ant}\}_{n=1,..,KN}$ from the market clearing equation

$$\mu_{At}z_{Ant}+\mu_{It}\lambda_{It}\eta_n+\mu_{Gt}\lambda_{Gt}1_{n\in\mathcal{G}_t}\eta_n=\eta_n, \tag{3.7}$$

which requires that the demand of active investors, passive investors and green investors equals the supply coming from the issuing firm, we find

$$\mu_{nt}=\rho\left[\sum_{j=s,c}b^j_n\left(\sum_{m=1}^{KN}\frac{1-\mu_{It}\lambda_{It}-\mu_{Gt}\lambda_{Gt}1_{m\in\mathcal{G}_t}}{\mu_{At}}\eta_m b^j_m\right)(\sigma^j)^2D^j_t\left[\frac{\partial S^j_t(D^j_t)}{\partial D^j_t}\right]^2\right.$$
$$\left.+\frac{1-\mu_{It}\lambda_{It}-\mu_{Gt}\lambda_{Gt}1_{m\in\mathcal{G}_t}}{\mu_{At}}\eta_n(\sigma^i_n)^2D^i_{nt}\left[\frac{\partial S^i_{nt}(D^i_{nt})}{\partial D^i_{nt}}\right]^2\right]. \tag{3.8}$$

We look for functions $S^s_t(D^s_t)$, $S^c_t(D^c_t)$ and $S^i_{nt}(D^i_{nt})$ that are affine in their arguments

$$S^s_t(D^s_t)=a^s_{0t}+a^s_{1t}D^s_t, \tag{3.9}$$

$$S^c_t(D^c_t)=a^c_{0t}+a^c_{1t}D^c_t, \tag{3.10}$$

$$S^i_{nt}(D^i_{nt})=a^i_{n0t}+a^i_{n1t}D^i_{nt}, \tag{3.11}$$

for $(a^s_{0t},a^s_{1t},a^c_{0t},a^c_{1t},\{a^i_{n0t},a^i_{n1t}\}_{n=1,..,KN})$ positive functions of t. Substituting (3.3) and (3.9)-

(3.11) into (3.8), we find

$$\begin{aligned}
&\bar{D}_n + \frac{d\bar{S}_{nt}}{dt} - r\bar{S}_{nt} + \sum_{j=s,c} b_n^j \left[D_t^j + \kappa^j a_{1t}^j (1 - D_t^j) + \frac{da_{0t}^j}{dt} + \frac{da_{1t}^j}{dt} D_t^j - r(a_{0t}^j + a_{1t}^j D_t^j) \right] \\
&+ D_{nt}^i + \kappa_n^i a_{n1t}^i (\bar{D}_n^i - D_{nt}^i) + \frac{da_{n0t}^i}{dt} + \frac{da_{n1t}^i}{dt} D_{nt}^i - r(a_{n0t}^i + a_{n1t}^i D_{nt}^i) \\
&= \rho \left[\sum_{j=s,c} b_n^j \left(\sum_{m=1}^{KN} \frac{1 - \mu_{It}\lambda_{It} - \mu_{Gt}\lambda_{Gt} 1_{m\in\mathcal{G}_t}}{\mu_{At}} \eta_m b_m^j \right) (\sigma^j a_{1t}^j)^2 D_t^j \right. \\
&\left. + \frac{1 - \mu_{It}\lambda_{It} - \mu_{Gt}\lambda_{Gt} 1_{n\in\mathcal{G}_t}}{\mu_{At}} \eta_n (\sigma_n^i a_{n1t}^i)^2 D_{nt}^i \right]. \qquad (3.12)
\end{aligned}$$

Equation (3.12) is affine in (D_t^s, D_t^c, D_{nt}^i). Identifying linear terms in D_t^j 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_{1t}^j 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_{nt}^i yields an ODE of the same type in a_{1nt}^i. Identifying constant terms yields a linear ODE in each interval. Substituting $(a_{1t}^s, a_{1t}^c, \{a_{n1t}^i\}_{n=1,..,N})$ into the first-order conditions of passive investors and green investors yields equations for $(\lambda_{Ik}, \lambda_{Gk})$ for $k = 0, .., K'$. We solve the resulting system recursively, starting from the interval $[K'T, \infty)$ and rolling back. Proposition 3.1 characterizes the equilibrium. The proposition does not establish that the equilibrium is unique, although our numerical analysis does not indicate existence of multiple equilibria. The proposition's proof is in Appendix A.

Proposition 3.1. *The equilibrium price function has the form (3.1) with $S_t^s(D_t^s)$, $S_t^c(D_t^c)$ and $S_{nt}^i(D_{nt}^i)$ given by (3.9), (3.10) and (3.11), respectively. The function a_{1t}^j for $j = s, c$ is* *given by* $a^j_{1t} = \bar{a}^j_{1K'}$ *for* $t \in [K'T, \infty)$ *and*

$$a^j_{1t} = \frac{\bar{a}^j_{1k}\left(g^j_k a^j_{1,(k+1)T} + \frac{1}{\bar{a}^j_{1k}}\right) e^{\left(g^j_k \bar{a}^j_{1k} + \frac{1}{\bar{a}^j_{1k}}\right)[(k+1)T-t]} - \frac{1}{\bar{a}^j_{1k}}\left(\bar{a}^j_{1k} - a^j_{1,(k+1)T}\right)}{\left(g^j_k a^j_{1,(k+1)T} + \frac{1}{\bar{a}^j_{1k}}\right) e^{\left(g^j_k \bar{a}^j_{1k} + \frac{1}{\bar{a}^j_{1k}}\right)[(k+1)T-t]} + g^j_k\left(\bar{a}^j_{1k} - a^j_{1,(k+1)T}\right)} \tag{3.13}$$

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

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

for $k = 0, .., K'$. *The function* a^i_{1nt} *is given by* $a^i_{n1t} = \bar{a}^i_{n1K'}$ *for* $t \in [K'T, \infty)$ *and*

$$a^i_{n1t} = \frac{\bar{a}^i_{n1k}\left(g^i_{nk} a^i_{n1,(k+1)T} + \frac{1}{\bar{a}^i_{n1k}}\right) e^{\left(g^i_{nk} \bar{a}^i_{n1k} + \frac{1}{\bar{a}^i_{n1k}}\right)[(k+1)T-t]} - \frac{1}{\bar{a}^i_{n1k}}\left(\bar{a}^i_{n1k} - a^i_{n1,(k+1)T}\right)}{\left(g^i_{nk} a^i_{n1,(k+1)T} + \frac{1}{\bar{a}^i_{n1k}}\right) e^{\left(g^i_{nk} \bar{a}^i_{n1k} + \frac{1}{\bar{a}^i_{n1k}}\right)[(k+1)T-t]} + g^i_{nk}\left(\bar{a}^i_{n1k} - a^i_{n1,(k+1)T}\right)} \tag{3.14}$$

$t \in [kT, (k+1)T)$ *and* $k = 0, .., K'-1$, *where*

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

for $k = 0, .., K'$. *The function* $\bar{S}_{nt} + \sum_{j=s,c} b^j_n a^j_{0t} + a^i_{n0t}$ *is given by*

$$\bar{S}_{nt} + \sum_{j=s,c} b^j_n a^j_{0t} + a^i_{n0t} = \frac{\bar{D}_n}{r} + \sum_{j=s,c} b^j_n \kappa^j \int_t^\infty a^j_{1t'} e^{-r(t'-t)} dt' + \kappa^i_n \bar{D}^i_n \int_t^\infty a^i_{n1t'} e^{-r(t'-t)} dt'. \tag{3.15}$$

The values of $(\lambda_{Ik}, \lambda_{Gk})$ *for* $k = 0, .., K'$ *are determined from the first-order conditions (A.4)-(A.7) of passive and green investors in Appendix A.*

From time $K'T$ onward, the price S_{nt} of stock n is an affine function of (D_t^s, D_t^c, D_{nt}^i) with time-independent coefficients. The affine coefficients depend on investor demand through the terms $(g_{K'}^s, g_{K'}^c, g_{nK'}^i)$. An increase in the measures $(\mu_{IK'}, \mu_{GK'})$ of passive or green investors or in their investment $(\lambda_{IK'}, \lambda_{GK'})$ in their respective indices from time $K'T$ onward lowers $(g_{K'}^s, g_{K'}^c, g_{nK'}^i)$, thus raising $(\bar{a}_{1K'}^s, \bar{a}_{1K'}^c, \bar{a}_{n1K'}^i)$. Therefore, the price of stock n from time $K'T$ onward increases. Likewise, if stock n is excluded from the green index at time $K'T$, then $g_{nK'}^i$ is higher than for a stock n' with otherwise identical characteristics. Therefore, stock n trades at a lower price than stock n' from time $K'T$ onward. These effects are anticipated in the price before time $K'T$ as well, through the recursive formulas (3.13) and (3.14). Indeed, higher values of $(\bar{a}_{1K'}^s, \bar{a}_{1K'}^c, \bar{a}_{n1K'}^i)$ imply higher values of $(a_{1t}^s, a_{1t}^c, a_{n1t}^i)$ for $t \in [(K'-1)T, K'T)$, which imply higher values of $(\bar{a}_{1,K'-1}^s, \bar{a}_{1,K'-1}^c, \bar{a}_{n1,K'-1}^i)$, and so on.

The price S_{nt} of stock n at a time t prior to $K'T$ is an affine function of (D_t^s, D_t^c, D_{nt}^i) with time-dependent coefficients. The coefficients depend on current demand during the interval corresponding to time t, and on anticipated demand during all subsequent intervals (including from time $K'T$ onward). Higher demand during an interval $[kT, (k+1)T)$ lowers (g_k^s, g_k^c, g_{nk}^i), thus raising $(\bar{a}_{1k}^s, \bar{a}_{1k}^c, \bar{a}_{n1k}^i)$ and $(a_{1t}^s, a_{1t}^c, a_{n1t}^i)$ for $t \in [kT, (k+1)T)$. This raises prices during the interval $[kT, (k+1)T)$, as well as prices in all preceding intervals through the recursion.

4 No Climate Risk

In this section we compute the equilibrium numerically when the loadings $\{b_n^c\}_{n=1,..,KN}$ on the climate transition risk factor D_t^c are set to zero. This leaves D_t^s as the only systematic factor.

4.1 Parameter Values

The model parameters are the riskless rate r, the number K of groups of firms, the number N of firms per group, the number K' of groups to be excluded, the time T between consecutive exclusions, the parameters $\{\kappa^s, \sigma^s\}$ and $\{\bar{D}_n, b_n^s, \kappa_n^i, \bar{D}_n^i, \sigma_n^i\}_{n=1,..,KN}$ of the dividend processes, the numbers $\{\eta_n\}_{n=1,..,KN}$ of shares, the measures $\{\mu_{Ak}, \mu_{Ik}, \mu_{Gk}\}_{k=0,..,K'}$ of active, passive and green investors during each of the intervals $[K'T, \infty)$ and $[kT, (k+1)T)$ for $k = 0, .., K'-1$, and the investors' risk-aversion coefficient ρ.

We assume that the total measure $\mu_{Ak} + \mu_{Ik} + \mu_{Gk}$ of active, passive and green investors remains constant over time. Changes to the measure of each investor group can thus only occur because of investors switching groups. We set the total measure of investors to one. This is a normalization because we can redefine the risk-aversion coefficient ρ. We set ρ to one. This is also a normalization because we can redefine the numeraire in the units of which wealth is expressed. Since the dividend flow is normalized by $\bar{D}_n + b_n + \bar{D}_n^i = 1$, redefining the numeraire amounts to rescaling the numbers of shares $\{\eta_n\}_{n=1,..,KN}$. We set the riskless rate r to 3%.

We set the number K of groups to 100 and the number N of firms per group to five. This yields a total of $KN = 500$ firms, allowing us to interpret the broad index as the S&P500. Group 1 of firms is the least polluting and Group 100 is the most polluting. We set the number K' of groups to be excluded to ten and the time T between consecutive exclusions to one. The horizon $K'T$ of the decarbonization strategy is thus ten years. Firms in Group 100 are excluded from the green index first, in year 1. Firms in Group 91 are excluded last, in year 10. All in all, $K'N = 50$ firms are excluded, which amount to 10% of all firms.

The calibration of the number of excluded firms aligns with recent empirical findings on the cross-sectional characteristics of GHG emissions and net zero investment strategies. GHG emissions exhibit a Pareto distribution with a heavy right tail. Jondeau, Mojon, and Pereira Da Silva (2021) estimate that the most polluting firms representing 1% of world market capitalization account for 15% of total carbon emissions. Moreover, a policy that reduces carbon emissions by 10% per year over ten years—a cumulative reduction of 65% ($= 1 - (1-10\%)^{10}$)—requires excluding in total the most polluting firms representing approximately 10% of market capitalization. Therefore, our scheme of excluding 1% of the most polluting firms every year for ten years can yield a cumulative 65% reduction of portfolio emissions.[3]

We assume that firms have identical characteristics $\{\bar{D}_n, b^s_n, \kappa^i_n, \bar{D}^i_n, \sigma^i_n, \eta_n\}_{n=1,..,KN}$, which we denote by $\{\bar{D}, b^s, \kappa^i, \bar{D}^i, \sigma^i, \eta\}$. They only differ in their level of GHG emissions, which are not modelled in this section and are identified with loadings on the climate transition risk factor in Section 5.[4]

We set the mean-reversion parameters κ^i and κ^s to a common value κ, which we take to be 0.04. Our analysis is not sensitive to the value of κ in the sense that the effects of changing κ on our numerical results are similar to those of changing the other parameters. We set $\frac{\sigma^i}{\sqrt{\bar{D}^i}} = \frac{\sigma^s}{\sqrt{\bar{D}^s}} = \sigma^s$. This assumption together with $\kappa^s = \kappa^i$ ensure that the distributions of D^s_t and $\{D^i_{nt}\}_{n=1,..,KN}$ are the same when scaled by their long-run means: $\frac{D^i_{nt}}{\bar{D}^i}$ has the same distribution as $\frac{D^s_t}{\bar{D}^s} = D^s_t$. We set $\bar{D}$ to zero. Minimizing $\bar{D}$ maximizes return variances, bringing them closer to their empirical counterparts as we explain below. Our normalization $\bar{D}_n + b^s_n + b^c_n + \bar{D}^i_n = 1$ implies $\bar{D}^i = 1 - b^s$.

We calibrate b^s and η based on stocks' expected returns and CAPM R-squareds. We use the unconditional versions of these moments, taking expectations with respect to the stationary distribution of the stochastic processes D^s_t and $\{D^i_{nt}\}_{n=1,..,KN}$. We use as calibration targets the values of the moments when there are no green investors. Without green investors, the moments are the same for all stocks.

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

[4]By taking the parameters $\{\bar{D}_n, b^s_n, \kappa^i_n, \bar{D}^i_n, \sigma^i_n, \eta_n\}_{n=1,..,KN}$ to be the same across firms, we are assuming that firms have the same long-run average market capitalization. The results of Jiang, Vayanos, and Zheng (2025) suggest that if firms differ in size, then the effects of green investors would be stronger for larger firms: stronger positive for larger green firms and stronger negative for larger brown firms.

The supply η affects mainly stocks' expected return: with higher η, investors bear more risk and require higher expected return. We target expected return (in excess of the riskless rate) to be 6%. To assess the sensitivity of our results to that target, we also report results for an alternative target of 4%.

The loading b^s on the systematic factor (which is related to the long-run mean of the idiosyncratic component of dividends through $\bar{D}^i = 1 - b^s$) affects mainly stocks' CAPM R-squared: with higher b^s, systematic dividends are more important relative to idiosyncratic dividends, and CAPM R-squared is higher. We target CAPM R-squared to be 25%, which approximates the average CAPM R-squared of the stocks in the S&P500. We also report results for an alternative target of 20%.

We calibrate the volatility parameter σ^s of systematic dividends (which is related to the volatility parameter σ^i of idiosyncratic dividends through $\frac{\sigma^i}{\sqrt{\bar{D}^i}} = \frac{\sigma^s}{\sqrt{\bar{D}^s}} = \sigma^s$) based on stocks' unconditional return volatility. Raising σ^s has two countervailing effects on return volatility. For given values of D_t^s and $\{D_{nt}^i\}_{n=1,..,KN}$, return volatility rises. At the same time, the stationary distributions of D_t^s and $\{D_{nt}^i\}_{n=1,..,KN}$ shift weight towards very small or very large values, for which return volatility is low under the square-root specification.[5] The maximum return volatility that our model generates remains bounded when σ^s goes to infinity because of the low volatility at the extremes. The bound is approximately 25%. One approach is to set σ^s to a value that yields a return volatility of approximately 20%, typical for S&P500 firms (Vuolteenaho (2002)). That value, however, yields prices that are overly low relative to the calibrated unconditional expected return because of the time variation of the conditional expected return.[6] Another approach is to use a lower value for σ^s and obtain

[5] For small values of D_t^s and $\{D_{nt}^i\}_{n=1,..,KN}$, return volatility per share is small but share price does not converge to zero because of the mean-reversion of D_t^s and $\{D_{nt}^i\}_{n=1,..,KN}$. (The price converges to $\bar{S}_{nt} + b_n^s a_{0t}^s + a_{n0t}^i$, as shown in Proposition 3.1.) Therefore, return volatility converges to zero. For large values of D_t^s and $\{D_{nt}^i\}_{n=1,..,KN}$, return volatility converges to zero because return volatility per share is proportional to the square root of D_t^s and $\{D_{nt}^i\}_{n=1,..,KN}$ but share price is affine in these variables.

[6] The expected return is close to zero for small values of D_t^s and $\{D_{nt}^i\}_{n=1,..,KN}$ because return volatility converges to zero. It increases significantly away from zero, and the unconditional average of the price is primarily determined by the expected return away from zero. For $\sigma^s = 1.5$, target expected return 6%

prices more in line with expected returns. We report results under both approaches, to assess the sensitivity of our results to return volatility. Under the first approach, we set $\sigma^s = 1.5$. The values of (b^s, η) are $(0.87, 0.00132)$ for a target expected return of 6% and R-squared 25%. They become $(0.825, 0.000643)$ when the target expected return is changed to 4% (and R-squared remains at 25%), and $(0.8475, 0.00157)$ when the target R-squared is changed to 20% (and expected return remains at 6%). Return volatility ranges between 20.43% and 20.51% across these cases. Under the second approach, we set $\sigma^s = 0.5$. The values of (b^s, η) are $(0.799, 0.0028)$ for a target expected return of 6% and R-squared 25%. They become $(0.74, 0.00144)$ when the target expected return is changed to 4%, and $(0.78, 0.00339)$ when the target R-squared is changed to 20%. Return volatility ranges between 12.63% and 12.77% across these cases.

We consider multiple values for the measures $(\mu_{Ak}, \mu_{Ik}, \mu_{Gk})$ of active, passive and green investors. A simplifying property of our calibration is that holding constant the ratio of active to green investors, the measure of passive investors has a negligible effect on prices. For example, prices are almost the same when one-half of investors are passive, one-quarter are active and one-quarter are green, as they are when one-half of investors are active, one-half are green and there are no passive. Intuitively, active investors are the ones absorbing the flows that green investors generate, as illustrated in Figure 1. Therefore, the price impact of green flows depends only on the relative measures of green and active investors. The irrelevance of the measure of passive investors is not an exact result because when exclusion from the green index takes place, the expected return on the broad index changes and passive investors change their position λ_{Ik} in that index. However, because exclusion is limited to a small set of firms in our calibration (10% of firms), its effect on the expected return of the broad index is small. Therefore, passive investors hold approximately the per-capita supply

and target R-squared 25%, the unconditional average of the price of each stock is 5.76. In comparison, discounting average dividends of one at the sum of the riskless rate of 3% plus the unconditional expected return (in excess of the riskless rate) of 6% yields $\frac{1}{9\%} = 11.11$. The discrepancy between expected return and average price becomes smaller for $\sigma^s = 0.5$, as the average price rises to 9.82.

of each stock before, during and after the exclusion phase.[7]

We calibrate the measure μ_{Gk} of green investors based on the percentage of assets under management (AUM) of sustainable funds relative to total AUM. Morgan Stanley (2025) estimate that AUM of all sustainable funds were \$3.56 trillion at the end of 2024 and constituted 6.8% of total global AUM. Morningstar estimate that at the end of 2024 there were 7510 sustainable funds with combined AUM of \$3.19 trillion. US SIF (2024) estimate instead AUM of sustainable funds at \$6.5 trillion. Based on these estimates, we consider values of μ_{Gk} ranging from 5% to 15%. We also consider the value 30% for μ_{Gk}, which is twice the upper end of our assumed range, so that we evaluate a scenario in which μ_{Gk} rises gradually over time to that value.

A caveat to our calibration of μ_{Gk} is that it is based on AUM of all sustainable funds and not specifically of net-zero funds, which are the green investors in our model. AUM of net-zero funds are significantly smaller than of all sustainable funds. Phenix Capital (2023) estimate that in February 2023 there were 729 net-zero aligned funds with combined AUM of \$289 billion. A richer model could account for the distinction between net-zero funds and other sustainable funds by allowing for two types of green investors: net-zero green investors who exclude polluting firms gradually over time, from $t = T$ to $t = K'T$, and conventional green investors who exclude all polluting firms at the same time $t = T$. Our calibration results are informative about the price impact of green investing in the alternative model as well. Indeed, the effects of green investors at the end of the exclusion phase would be identical across the two models. Moreover, the anticipation of future exclusion would affect current prices in the alternative model as well, especially if the measure of conventional green investors is expected to grow over time.

Calibrating the measure μ_{Ik} of passive investors (and deducing that of active investors

[7] Formally, the position λ_{Ik} of passive investors remains close to one for all k. Moreover, when $\lambda_{Ik} \approx 1$, the values of $\{g_k^j\}_{j=s,c}$ and g_{nk}^i for $k = 0, .., K'$, defined in Proposition 3.1, are approximately the same for $(\mu_{Ak}, \mu_{Ik}, \mu_{Gk})$ and $\left(\frac{\mu_{Ak}}{1-\mu_{Ik}}, 0, \frac{\mu_{Gk}}{1-\mu_{Ik}}\right)$, as can be seen by dividing the numerator and denominator by $1 - \mu_{Ik}$. Therefore, the price is approximately independent of μ_{Ik} and equal to its value for $\mu_{Ik} = 0$.

by $\mu_{Ak} = 1 - \mu_{Ik} - \mu_{Gk}$) is challenging because of three reasons. First, many active investors face explicit or implicit constraints limiting their deviations from indexes. These tracking constraints make them closer to passive investors than to the unconstrained active investors assumed in our model. Second, while some active investors can deviate significantly from indexes, they may trade infrequently and act as buy-and-hold investors. Third, some passive investors track green indexes so they should be classified as green.

According to the Investment Company Institute (2022), AUM of passive funds in the US equity market at the end of 2021 were 53% of the combined AUM of active and passive funds, and 16% of the US equity market. Assuming that the same ratio applies to active and passive green funds, the ratio $\frac{\mu_{Ik}}{\mu_{Ak}+\mu_{Ik}}$ of the measure of passive investors to the total measure of active and passive investors can be set to 53%. This should be viewed, however, as a lower bound because of tracking constraints and buy-and-hold behavior. An estimate of the effect of tracking constraints comes from Chinco and Sammon (2024), who examine abnormal trading volumes around index additions and deletions. The implied share of passive investors, derived as the fraction of investors who adjust their positions to track the index, is approximately twice the share of passive funds: it is 33.5% of the US equity market at the end of 2021. To account for the effects of tracking constraints and buy-and-hold behavior, we consider values of $\frac{\mu_{Ik}}{\mu_{Ak}+\mu_{Ik}}$ ranging from 50% to 90%.

4.2 Price Impact of Green Investors

We first examine the impact of green investors when the measures of the three types of investors are constant over time. Figure 2 plots price and expected return information for the stocks in group 100, which are excluded from the green index in year 1, the stocks in group 91, which are excluded in year 10, and the stocks in groups 1 to 90, which are never excluded. The top panel shows the percentage change in the price in year 0, compared to the case without green investors. The bottom panel shows the change in the expected return averaged across years 1 and 12 and expressed in percentage points (100 bps), compared to the case without green investors. Both variables are plotted as a function of the ratio $\frac{\mu_{Gk}}{\mu_{Ak}+\mu_{Gk}}$ of the measure of green investors to the total measure of active and green investors. Since the measures of the three types of investors are assumed constant over time, the ratio $\frac{\mu_{Gk}}{\mu_{Ak}+\mu_{Gk}}$ is independent of k. The percentage price change concerns the average price, computed by setting D_t^s and $\{D_{nt}^i\}_{n=1,..,KN}$ to their unconditional expectations. The brown lines correspond to the stocks in group 100, the beige lines to the stocks in group 91, and the green lines to the stocks in groups 1 to 90. In each case, the solid lines are drawn for $\sigma^s = 1.5$, target expected return 6% and target R-squared 25%, and the dotted lines are drawn for $\sigma^s = 0.5$ instead of $\sigma^s = 1.5$. We set the measure μ_{Ik} of passive investors to 50%, but as noted in Section 4.1, the lines are almost independent of μ_{Ik}. We consider other values for μ_{Ik} in our analysis below.

The impact (in absolute value) of green investors on stock prices and expected returns is an increasing and convex function of $\frac{\mu_{Gk}}{\mu_{Ak}+\mu_{Gk}}$. Thus, the impact is increasing the more green investors there are relative to active investors, and the increase occurs at an increasing rate. The impact is largest for the stocks in group 100, which are excluded from the green index first. The price of these stocks drops the most, and their expected return rises the most. The impact is lower for the stocks in group 91, which are excluded last, and is lowest for the stocks in groups 1 to 90. The prices of the stocks in groups 1 to 90 rise and their expected returns drop because green investors flow into these stocks. All of the above effects are larger when return volatility is high ($\sigma^s = 1.5$) than when it is low ($\sigma^s = 0.5$).

To assess the effects quantitatively, we consider the lowest and highest values of $\frac{\mu_{Gk}}{\mu_{Ak}+\mu_{Gk}}$ implied by the ranges that we assume in our calibration. The lowest value of $\frac{\mu_{Gk}}{\mu_{Ak}+\mu_{Gk}}$ is 9.52%, achieved for green investors being 5% of the market ($\mu_{Gk} = 5\%$) and active investors being 50% of combined active and passive, which is 47.5% of the market ($\mu_{At} = 50\% \times (1 - 5\%) = 47.5\%$). Under that value of $\frac{\mu_{Gk}}{\mu_{Ak}+\mu_{Gk}}$, the price impact of green investors for the stocks

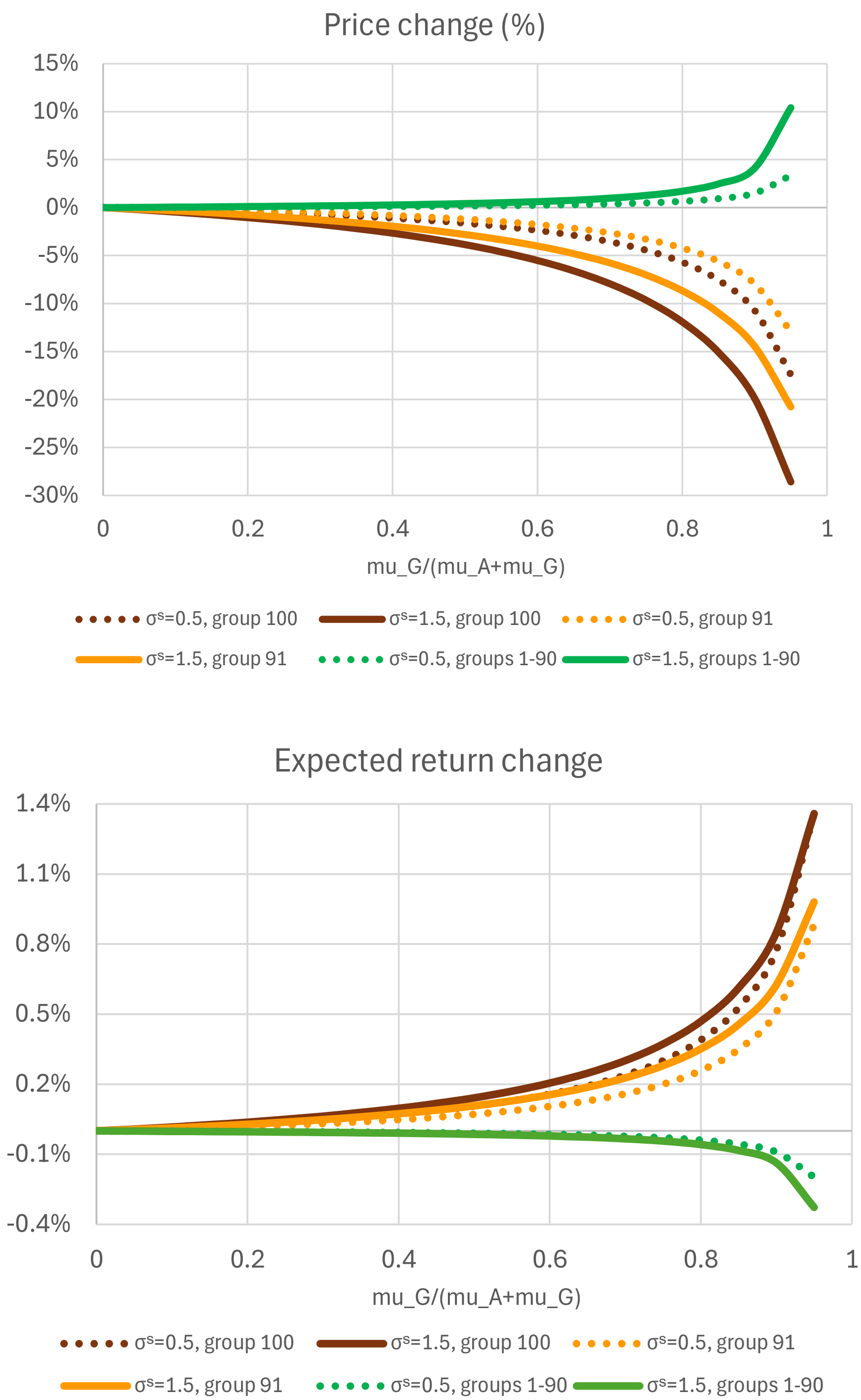


Figure 2: Price and expected return change for the stocks in group 100, which are excluded from the green index in year 1, the stocks in group 91, which are excluded in year 10, and the stocks in groups 1 to 90, which are never excluded, as a function of ratio $\frac{\mu_{Gk}}{\mu_{Ak}+\mu_{Gk}}$ of the measure of green investors to the total measure of active and green investors.

in group 100 ranges from 0.18% when $\sigma^s = 0.5$ to 0.5% when $\sigma^s = 1.5$, and their impact on expected return ranges from 1 to 2 basis points (bps). The highest value of $\frac{\mu_{Gk}}{\mu_{Ak}+\mu_{Gk}}$ is 63.83%, achieved for green investors being 15% of the market and active investors being 10% of combined active and passive, which is 8.5% of the market. Under that value, the price impact of green investors for the stocks in group 100 ranges from 2.75% when $\sigma^s = 0.5$ to 6.31% when $\sigma^s = 1.5$, and their effect on the expected return ranges from 18 to 24 bps. If the measure of green investors rises further to 30% and the ratio of passive to active remains 9:1, so that the measure of active investors drops to 7%, then $\frac{\mu_{Gk}}{\mu_{Ak}+\mu_{Gk}}$ rises to 81.08%. The price impact of green investors for the stocks in group 100 then rises to 6.01% when $\sigma^s = 0.5$ and to 12.49% when $\sigma^s = 1.5$, and their effect on the expected return rises to 41-49 bps. The impact on price and expected return for the stocks in group 91 is approximately 70% of that for the stocks in group 100. The same impact for the stocks in groups 1 to 90 is approximately 10% of that for the stocks in group 100 for values of $\frac{\mu_{Gk}}{\mu_{Ak}+\mu_{Gk}}$ up to 80%, and rises to up to 40% for higher values. Lowering the target expected return from 6% to 4% lowers the above effects by approximately 30%. Lowering the R-squared from 25% to 20% raises them by approximately 30%.

The main takeaways from the above analysis are as follows. When the ratio $\frac{\mu_{Gk}}{\mu_{Ak}+\mu_{Gk}}$ of the measure of green investors to the total measure of active and green investors takes its lowest value in our calibration, the impact of green investors on stock prices and expected returns is negligible. This result is in line with Berk and Van Binsbergen (2025), who take the fraction of green investors to be 2% and assume no passive investors. When $\frac{\mu_{Gk}}{\mu_{Ak}+\mu_{Gk}}$ takes its highest value in our calibration, the impact of green investors is modest, while also larger than Berk and Van Binsbergen (2025) by an order of magnitude. The impact becomes large when green investors become a significantly larger fraction of the market than they currently are, e.g., twice the upper end of our assumed range.

We next assess the extent to which future exclusion is reflected in current prices. We do so for stocks in group 91, which are excluded from the green index last. The thick lines in Figure 3 show the percentage change in the average price of those stocks in year 0, compared to the case where there are no green investors. This reflects the anticipation of future exclusion. The thin lines show the percentage change in the stocks' average price in year 10, compared to the case without green investors. This reflects the exclusion. In each case, the solid lines are drawn for $\sigma^s = 1.5$, target expected return 6% and target R-squared 25%, and the dotted lines are drawn for $\sigma^s = 0.5$ instead of $\sigma^s = 1.5$. All variables are plotted as a function of the ratio $\frac{\mu_{Gk}}{\mu_{Ak}+\mu_{Gk}}$ of the measure of green investors to the total measure of active and green investors. That ratio is assumed independent of k. Figure 3 shows that the price effect arising in year 0 from the anticipation of exclusion in year 10 is approximately 70% of the effect in year 10.

Figure 4 shows the full dynamic evolution of the prices and expected returns of the stocks of all groups. The top panel shows the average price of the stocks in each group as a function of time. The bottom panel shows the expected return of the stocks in each group as a function of time. Each panel has eleven graphs arranged in three rows. The graph in the top row is for groups 1 to 90, which are never excluded from the green index. The five graphs in the middle row are for groups 100 to 96, which are excluded in years 1 to 5, respectively. The five graphs in the bottom row are for groups 95 to 91, which are excluded in years 6 to 10, respectively. The units in the x-axis are years. All graphs are drawn for $\sigma^s = 1.5$, target expected return 6%, target R-squared 25% and measures $\mu_{Ak} = 7\%$ of active investors, $\mu_{Ik} = 63\%$ of index investors and $\mu_{Gk} = 30\%$ of green investors. We use $\mu_{Gk} = 30\%$, which is twice the upper end of our assumed range, to facilitate the comparison with the case where the measure of green investors grows gradually over time, studied below. This is because the steady state from year 10 onward is the same across both cases. The red dot in each graph shows the price and expected return in the absence of green investors. These are the same for all stocks.

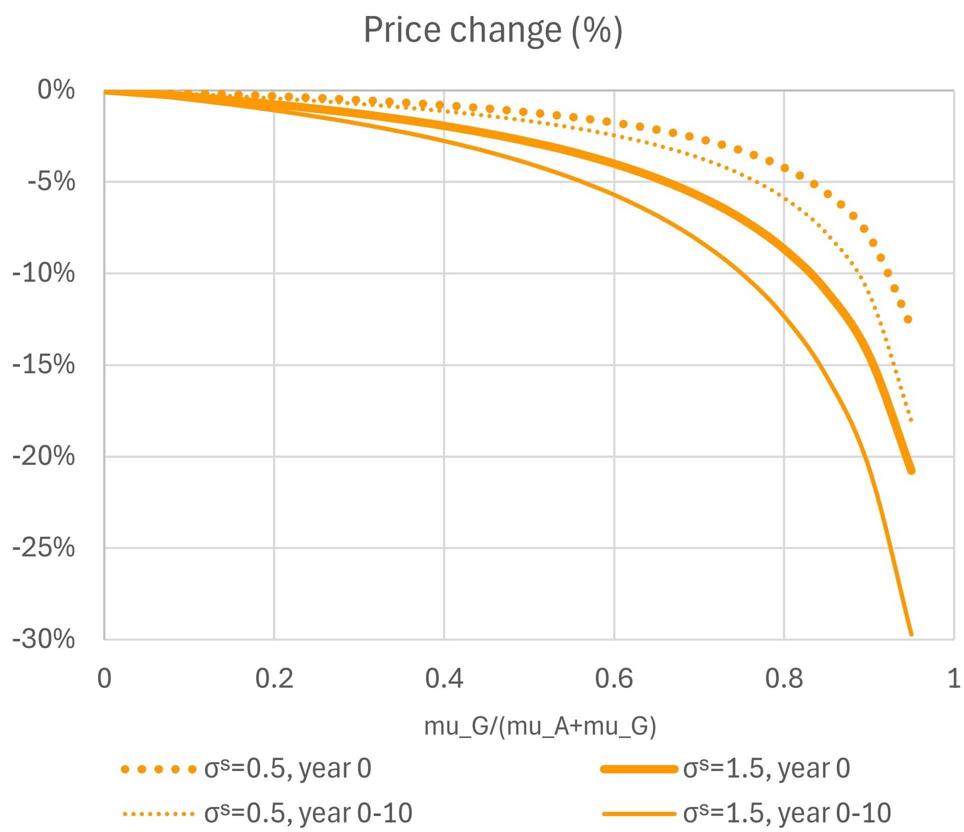
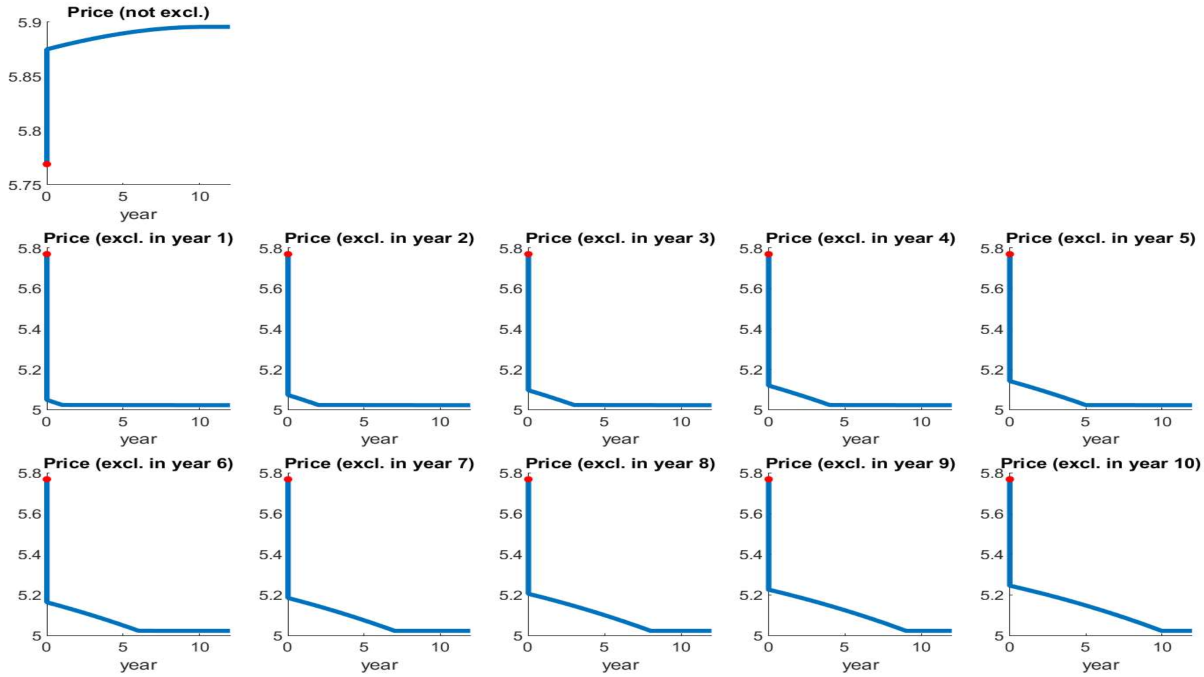


Figure 3: Price change in years 0 and 10 for the stocks in group 91, which are excluded from the green index in year 10, as a function of ratio $\frac{\mu_{Gk}}{\mu_{Ak}+\mu_{Gk}}$ of the measure of green investors to the total measure of active and green investor.

Green investors cause the prices of stocks in groups 91 to 100 to drop and the prices of stocks in groups 1 to 90 to rise. The price drop in year 0 is largest for the stocks in group 100, which are the first to be excluded, second largest for the stocks in group 99, and so on. The prices of the stocks in each group from 91 to 100 drop discontinuously in year 0 because of the anticipated future exclusion, then drop gradually until the exclusion date, and then stabilize. In year 10, prices are the same for all stocks in groups 91 to 100 because all these stocks are excluded by that year. The prices of the stocks in groups 1 to 90 rise discontinuously in year 0 because of the anticipation that green investors will be investing in these stocks as they drop the stocks in groups 91 to 100. They continue rising gradually until year 10, when the exclusion process is completed.

Top panel: Prices



Bottom panel: Expected returns

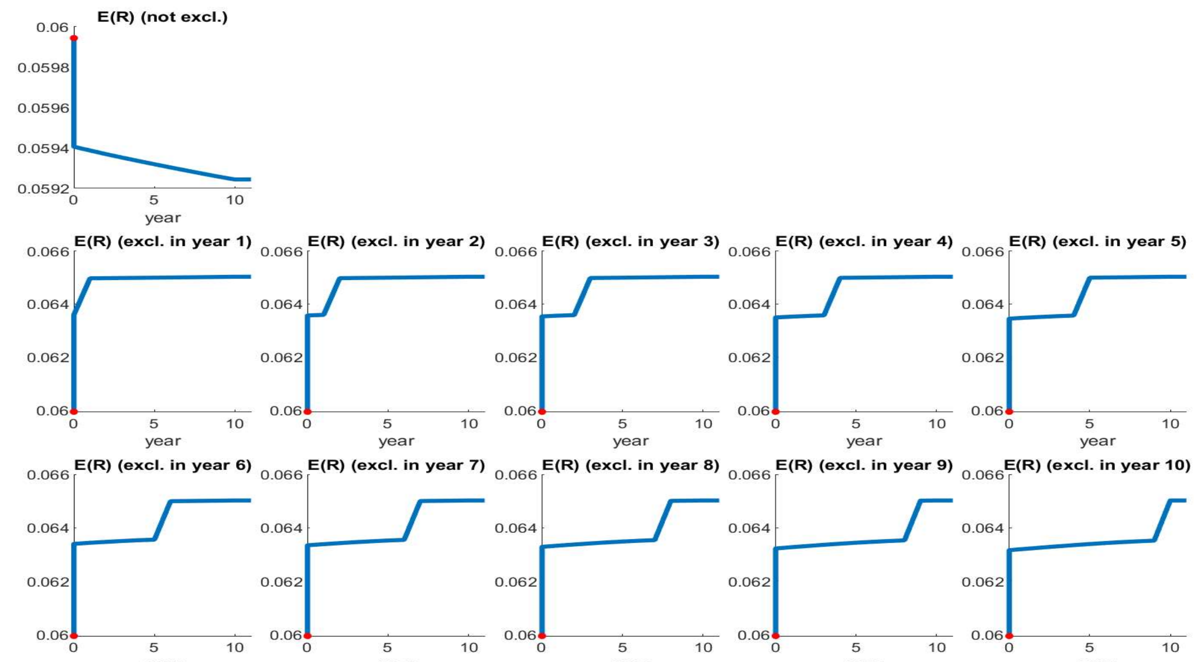


Figure 4: Prices and expected returns for all stock groups, as a function of time, for measures $\mu_{Ak} = 7\%$ of active investors, $\mu_{Ik} = 63\%$ of index investors and $\mu_{Gk} = 30\%$ of green investors.

Expected returns move in the opposite direction to prices. They drop discontinuously in year 0 for stocks in groups 1 to 90, as their prices rise, and keep dropping gradually until year 10, as their prices rise further. They rise discontinuously in year 0 for stocks in each group from 91 to 100, as their prices drop, rise further on the year of exclusion, and then stabilize.

We next examine the impact of green investors when the measures of the three types of investors change over time. When the measure of green investors grows gradually over time to a value $\mu_{GK'}$ in year K', stocks in groups 92 to 100 drop in price less in year 0 and more between years 0 and 10, compared to the case where the measure of green investors is equal to $\mu_{GK'}$ for the entire period. Likewise, the expected returns of these stocks rise less in year 0 and more during years 0 and 10, including after their year of exclusion. We illustrate these properties in Appendix B, in an example where the measure of green investors grows linearly from 10% in year 0 to 30% in year 10, and the ratio $\frac{\mu_{Ik}}{\mu_{Ak}+\mu_{Ik}}$ of the measure of passive investors to the total measure of active and passive investors is kept constant at 90%.

5 Climate Risk

In this section we compute the equilibrium numerically when the loadings $\{b_n^c\}_{n=1,..,KN}$ on the climate transition risk factor D_t^c are positive.

5.1 Parameter Values

We choose values for $(r, K, N, K', T, \kappa^s, \sigma^s, \{\bar{D}_n, b_n^s, \kappa_n^i, \bar{D}_n^i, \sigma_n^i, \eta_n\}_{n=1,..,KN}, \{\mu_{Ak}, \mu_{Ik}, \mu_{Gk}\}_{k=0,..,K'}, \rho)$ as in Section 4.1 with minor modifications described at the end of this section. In the presence of climate risk, we need to choose additionally values for $(\kappa^c, \sigma^c, \{b_n^c\}_{n=1,..,KN})$. We set the mean-reversion and volatility parameters (κ^c, σ^c) of the climate factor equal to their counterparts (κ^s, σ^s) for the business-cycle factor. We set the loadings $\{b_n^c\}_{n=1,..,KN}$ on the climate factor to $\frac{b^c}{\left(100+\alpha-\lceil\frac{n}{K}\rceil\right)^\gamma}$, where (b^c, α, γ) are positive constants. Climate loadings are the same for all firms in the same group because of the term $\lceil\frac{n}{K}\rceil$, which is the group number, and increase as the group number rises from 1 to 100. Climate loadings are thus highest for the firms in group 100, which are the first to be excluded from the green index, second highest for the firms in group 99, and so on. We assume this monotonicity property because we are identifying climate loadings with firms' GHG emissions, which increase as the group number rises from 1 to 100.

Our specification for climate loadings has the additional property that the increase in loadings with group number occurs at an increasing rate. This generates a heavy right tail in the distribution of climate loadings. We assume this convexity property because firms' GHG emissions exhibit a heavy right tail. Indeed, Jondeau, Mojon, and Pereira Da Silva (2021) estimate that the most polluting firms representing 1% of world market capitalization account for 15% of total carbon emissions. Moreover, a policy that reduces emissions by 10% per year over ten years—a cumulative reduction of 65% ($= 1-(1-10\%)^{10}$)—requires excluding in total the most polluting firms representing approximately 10% of market capitalization. We calibrate α and γ based on these percentages, requiring that the sum of climate loadings b_n^c across the firms in Group 100 is 15% of the sum of climate loadings across all firms, and the sum of climate loadings across the firms in Groups 91 to 100 is 65% of the sum of climate loadings across all firms. The values of (α, γ) are $(5.83, 1.87)$.

The parameter b^c determines the size of climate loadings in absolute terms (rather than their relative comparison across firms, which is determined by (α, γ)). We calibrate b^c based on the relative size of shocks to the climate factor and to the business-cycle factor. Empirical estimates on these shocks are not available to the best of our knowledge, but we consider two values that generate a wide enough range. Under the first value, which is 1.5, climate shocks to dividends are small: they are approximately 7% of business-cycle shocks for firms in group 100, 1% for firms in group 90, and 0.03% for firms in group 1. Under the second value, which is 6, climate shocks to dividends are significantly larger: they are approximately 30% of business-cycle shocks for firms in group 100, 5% for firms in group 90, and 0.14% for firms in group 1.

We make two modifications to the parameter values chosen in Section 4.1. First, because climate loadings differ across firms, stock return moments differ across firms even in the absence of green investors. The targets for expected return and R-squared in the absence of green investors cannot thus concern a common value of these moments across firms, as they do in Section 4.1. We assume instead that they concern the average of the moments across firms. Second, because climate loadings are positive, our normalization $\bar{D}_n + b_n^s + b_n^c + \bar{D}_n^i = 1$ no longer implies $b^s = 1 - \bar{D}^i$. We maintain the assumption of Section 4.1 that $\{b_n^s, \bar{D}_n^i\}_{n=1,..,KN}$ are independent of n and denote them without the subscript n. To ensure that $\bar{D}_n + b_n^s + b_n^c + \bar{D}_n^i = 1$ holds for all n when b_n^c differs across firms, we reintroduce the constant component $\bar{D}_n$ and assume that its variation offsets the variation in b_n^c. We minimize $\bar{D}_n$ by setting it to zero for the firms with the highest climate loading, which are in Group 100. As in Section 4.1, minimizing $\bar{D}_n$ maximizes return variances.

We report results for $\sigma^s = 0.5$ and $\sigma^s = 1.5$, for a target expected return of 6% and for a target R-squared of 25%. The values of (b^s, η) are $(0.778, 0.00397)$ for $\sigma^s = 0.5$ and $b^c = 1.5$, $(0.843, 0.00212)$ for $\sigma^s = 1.5$ and $b^c = 1.5$, $(0.71, 0.0211)$ for $\sigma^s = 0.5$ and $b^c = 6$, and $(0.743, 0.0139)$ for $\sigma^s = 1.5$ and $b^c = 6$. The relative size of climate to business-cycle shocks follows from these values. Indeed, since the climate factor follows a square-root process with the same parameters as the business-cycle factor, the relative size of climate to business-cycle shocks for firm n is the ratio of factor loadings, i.e.,

$$\frac{b_n^c}{b_n^s} = \frac{b^c}{b^s \left(100 + \alpha - \lceil \frac{n}{K} \rceil\right)^\gamma}. \tag{5.1}$$

Substituting $(K, b^s, b^c, \alpha, \gamma)$ into (5.1), we find the ratio of factor loadings as function of n.

5.2 Price Impact of Green Investors

We begin with the case $b^c = 1.5$. In the absence of green investors, expected returns differ across stocks because firms load differently on the climate factor. The cross-sectional standard deviation of expected returns ranges from 6 bps when $\sigma^s = 0.5$ to 16 bps when $\sigma^s = 1.5$. The expected return of stocks in group 100 exceeds that of stocks in group 1 by 42 bps when $\sigma^s = 0.5$ and 110 bps when $\sigma^s = 1.5$. The difference across extreme groups is significantly larger than the cross-sectional standard deviation because the heavy right tail of climate loadings generates a heavy right tail of expected returns.

We next add green investors and assume that $\frac{\mu_{Gk}}{\mu_{Ak}+\mu_{Gk}}$ takes the highest value in our calibration: green investors are 15% of the investor population and active investors are 10% of active plus passive. The cross-sectional standard deviation of expected returns rises to 11 bps when $\sigma^s = 0.5$ and to 22 bps when $\sigma^s = 1.5$. The difference between the expected return of stocks in group 100 and of stocks in group 1 rises to 64 bps when $\sigma^s = 0.5$ and to 141 bps when $\sigma^s = 1.5$. Green investors raise the expected return of the most polluting stocks by 22-30 bps. (This is approximately the change in the expected return difference between groups 100 and 1 because the expected return of stocks in group 1 stays approximately constant.) The effect of green investors on expected returns is somewhat larger than the counterpart effect in the absence of climate risk, which is 18-24 bps. The same is true for the effect of green investors on prices: stocks in group 100 drop by 4.53% in year 0 when $\sigma^s = 0.5$ and by 9.14% when $\sigma^s = 1.5$, while they drop by 2.75% and 6.01%, respectively, in the absence of climate risk. The intuition why green investors have larger price impact in the presence of climate risk is that climate risk introduces additional comovement between brown stocks, thus raising the variance of a brown portfolio. As a result, active investors require a higher expected return to buy brown stocks from green investors.

We next turn to the case $b^c = 6$. In the absence of green investors, the cross-sectional standard deviation of expected returns ranges from 96 bps when $\sigma^s = 0.5$ to 141 bps when

$\sigma^s = 1.5$. The expected return of stocks in group 100 exceeds that of stocks in group 1 by 741 bps when $\sigma^s = 0.5$ and 1170 bps when $\sigma^s = 1.5$. These effects are 9-18 times larger than when $b^c = 1.5$. When green investors are 15% of the investor population and active investors are 10% of active plus passive, the cross-sectional standard deviation of expected returns rises to 107 bps when $\sigma^s = 0.5$ and to 155 bps when $\sigma^s = 1.5$. Moreover, the difference between the expected return of stocks in group 100 and stocks in group 1 rises to 835 bps when $\sigma^s = 0.5$ and to 1307 bps when $\sigma^s = 1.5$. Green investors raise the expected return of the most polluting stocks by 93-136 bps. These effects are 7-13 times larger than when $b^c = 1.5$. The effect of green investors on expected returns is likewise significantly larger than in the absence of climate risk. The same is true for the effect of green investors on prices: stocks in group 100 drop by 10.78% in year 0 when $\sigma^s = 0.5$ and by 13.61% when $\sigma^s = 1.5$.

6 Relationship to Empirical Findings

One strand of the empirical literature on divestment estimates the effect of ESG flows on prices. To map our results to the empirical findings, we consider the price changes caused by green investors in the version of our model without climate risk. Van Der Beck (2023) estimates that a \$1 flow into ESG stocks raises their aggregate market value by \$0.7. The aggregate flow into green stocks in our model is approximately equal to green investors' aggregate flow out of brown stocks. Assuming that green investors are 15% of all investors and recalling that they exclude 50 brown stocks by year 10, the aggregate flow into green stocks by year 10 is $15\% \times 50 \times V$, where V is the average market capitalization of each stock (which is the same across stocks in the absence of green investors and climate risk). Since green investors keep 450 green stocks in their portfolio after year 10, the rise in the aggregate market value of these stocks by that year is $\frac{\Delta\mathbb{E}(S_{nt})}{\mathbb{E}(S_{nt})} \times 450 \times V$, where $\frac{\Delta\mathbb{E}(S_{nt})}{\mathbb{E}(S_{nt})}$ is computed as the green line in Figure 2 for year 10 rather than year 0. The ratio of the rise in the aggregate market value of green stocks to the aggregate flow into green stocks thus is $\frac{1}{9\times 15\%}\frac{\Delta\mathbb{E}(S_{nt})}{\mathbb{E}(S_{nt})}$. When passive investors are 50% of combined active and passive, that ratio ranges from 0.039-0.10. When passive investors are 90%, the ratio ranges from 0.20-0.53. Therefore, our results are closer to the 0.7 estimate in Van Der Beck (2023) for the 90% upper bound. The results in Van Der Beck (2023), as well as the evidence surveyed in Gabaix and Koijen (2021) that suggests an inverse elasticity of one for individual stocks (rather than 0.7 as in Van Der Beck (2023)), indicate that truly active investors could be even less than 10% of combined active and passive.

Another strand of the empirical literature on divestment estimates the difference in expected returns between brown and green stocks. As shown in Pastor, Stambaugh, and Taylor (2021), the expected returns of green stocks can be lower than of brown stocks because (i) some investors prefer to hold green stocks and (ii) green stocks outperform brown stocks following negative climate news. The risk effect is present in our model only in its version with a climate risk factor. To map our results to the empirical findings, we use that version and assume that green investors are 15% of all investors and passive investors are 90% of combined active and passive. Our model not only quantifies the difference in expected returns between brown and green stocks as a function of underlying parameters, but also determines the relative size of the price impact and risk effects.

Bolton and Kacperczyk (2021) find an expected return increase of 180 bps per one standard deviation decrease in firms' scope 1 carbon emissions, with the effect rising to 290 bps for scope 2 emissions and to 400 bps for scope 3 emissions. The counterpart quantity in our model is the cross-sectional standard deviation of expected returns. This is because expected returns in our model vary across stocks only because of greenness. Among the two cases analyzed in Section 5, our results are closer to the estimates in Bolton and Kacperczyk (2021) when $b^c = 6$, which is when climate shocks are approximately 30% of business-cycle shocks for firms in group 100 and 0.45% for the average firm. The cross-sectional standard deviation of expected returns in that case ranges from 107-155 bps. Out of that standard deviation, 11-14 bps are caused by the price impact of green investors and the remainder is caused by stocks' different loadings on the climate risk factor.

Eskildsen, Ibert, Jensen, and Pedersen (2024) find an expected return increase of 30 bps per one standard deviation decrease in firms' green score. Among the two cases analyzed in Section 5, our results are closer to the estimate in Eskildsen, Ibert, Jensen, and Pedersen (2024) when $b^c = 1.5$, which is when climate shocks are approximately 7% of business-cycle shocks for firms in group 100 and 0.45% for the average firm. The cross-sectional standard deviation of expected returns in that case ranges from 11-22 bps. Out of that standard deviation, 5-6 bps are caused by the price impact of green investors and the remainder is caused by firms' different loadings on the climate risk factor.

7 Conclusion

We study how green investors impact firms' stock prices and cost of capital in a model where they interact dynamically with active and passive investors. Green investors track a capitalization-weighted index that progressively excludes the brownest firms. Active investors hold a mean-variance efficient portfolio of all firms. Passive investors track a capitalization-weighted index that includes all firms. Passive investors can be interpreted broadly to include investors who are classified as active but track indexes closely because of explicit or implicit constraints or trade infrequently even in the absence of such constraints.

The index tracked by green investors captures within our model the mechanics of "net zero" or "Paris aligned" indexes. We assume that 1% of the most polluting firms are excluded from the green index each year for ten years. This yields an average reduction rate of carbon emissions of 10% per year, given the heavy right tail of the distribution of emissions. Green portfolios need to generate such a reduction rate to stay roughly on a net zero trajectory by 2050. Since exclusion is based on the emissions of individual firms and not on whether they belong to a particular sector (no sector is a priori excluded), green investors could engage in a best-in-class approach and help the development of green technologies, including in the energy and electricity production industries.

The impact of green investors in our calibration is significantly larger than in previous ones. This is because of the passive investors, who cause stock price elasticities to be low and in line with empirical estimates (e.g., Gabaix and Koijen (2021), Van Der Beck (2023)). When the fraction of green investors is 15% and active investors constitute 10% of the remainder, exclusion from the green index raises the cost of capital of the brownest firms by 18-24 bps and lowers their stock prices by 2.8%-6.3%. These effects become larger in the presence of climate risk, under the assumption that firms' loadings on that risk reflect their emissions. When climate shocks are 30% of business-cycle shocks for the brownest firms and 2% for the average firm, exclusion from the green index raises the cost of capital of the brownest firms by 93-136 bps and lowers their stock prices by 10.8-13.6%.

We assume perfect foresight regarding the timing of exclusion and the set of firms to be excluded. Because of this assumption, a significant fraction of the price decline due to future exclusion is anticipated in the current price—70% for the firms to be excluded after ten years. In practice, exclusion might not be perfectly predictable. This would attenuate the immediate effects and strengthen the gradual subsequent effects. The ultimate effects (after ten years) would remain the same. Because the effects of net zero investment on stock prices are gradual, a first-mover advantage could arise among investors who consider greening their portfolio.

Our analysis focuses on the impact of green investors on stock prices and does not account for linkages between stock prices and corporate investment. One linkage relates to incentives: in a similar spirit to Heinkel, Kraus, and Zechner (2001), firms would seek to decarbonize faster to avoid their exclusion from the green index. A meaningful analysis of incentives would require treating the composition of the green index as endogenous. The composition of the green index might still be deterministic in the equilibrium path, so our perfect foresight assumption regarding the timing of exclusion and the set of firms to be excluded might hold.[8] Another linkage is that the drop in the stock prices of the brownest firms when they are excluded from the green index could force them to cut down on investment, further accentuating the drop. This could strengthen incentives, but could also result perversely in brown firms finding it costlier to invest in greening their business model (Hartzmark and Shue (2024)). Extending our analysis to incorporate real investment and its two-way feedback with stock prices is a promising direction of future research.

[8] The following simple example illustrates why perfect foresight might hold in the presence of incentives. There are only two firms, 1 and 2. Firm 2 is the brownest initially. Firms can become greener by making an investment, with firm 1 deciding first and firm 2 deciding second after observing firm 1's decision. The green index excludes the firm that is the brownest after investments are made.

If investments are no possible (as in our model), then firm 2 is excluded from the green index because it is the brownest initially. If investments are possible, then firm 2 is again excluded. Moreover, if firm 2 is not much browner than firm 1 initially, then firm 1 makes the investment. Indeed, firm 1 knows that if it does not make the investment then firm 2 will make it and become greener than firm 1, causing firm 1 to be excluded.

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Appendix – For Online Publication

A Proof of Proposition 3.1

We first derive the first-order conditions of passive and green investors. Taking the first-order condition in (3.5) and using (3.9)-(3.11), we find

$$\sum_{n=1}^{KN} \eta_n \mu_{nk}^u - \rho \lambda_{Ik} \left[\sum_{j=s,c} \left(\sum_{n=1}^{KN} \eta_n b_n^j \right)^2 (\sigma^j)^2 \mathbb{E}_k^u \left[D_t^j (a_{1t}^j)^2 \right] + \sum_{n=1}^{KN} \eta_n^2 (\sigma_n^i)^2 \mathbb{E}_k^u \left[D_{nt}^i (a_{n1t}^i)^2 \right] \right] = 0. \tag{A.2}$$

Using the definition of μ_{nk}^u, the first-order condition (3.8) of active investors and (3.9)-(3.11), we can write (A.2) as

$$\begin{aligned}
&\sum_{n=1}^{KN} \eta_n \left[\sum_{j=s,c} b_n^j \left(\sum_{m=1}^{KN} \frac{1 - \mu_{Ik}\lambda_{Ik} - \mu_{Gk}\lambda_{Gk} 1_{m \in \mathcal{G}_k}}{\mu_{Ak}} \eta_m b_m^j \right) (\sigma^j)^2 \mathbb{E}_k^u \left[D_t^j (a_{1t}^j)^2 \right] \right. \\
&\left. + \frac{1 - \mu_{Ik}\lambda_{Ik} - \mu_{Gk}\lambda_{Gk} 1_{n \in \mathcal{G}_k}}{\mu_{Ak}} \eta_n (\sigma_n^i)^2 \mathbb{E}_k^u \left[D_{nt}^i (a_{n1t}^i)^2 \right] \right] \\
&= \lambda_{Ik} \left[\sum_{j=s,c} \left(\sum_{n=1}^{KN} \eta_n b_n^j \right)^2 (\sigma^j)^2 \mathbb{E}_k^u \left[D_t^j (a_{1t}^j)^2 \right] + \sum_{n=1}^{KN} \eta_n^2 (\sigma_n^i)^2 \mathbb{E}_k^u \left[D_{nt}^i (a_{n1t}^i)^2 \right] \right] = 0.
\end{aligned} \tag{A.3}$$

Rearranging (A.3) and taking $(a_{1t}^s, a_{1t}^c, \{a_{n1t}^i\}_{n=1,..,N})$ to be constant in $[K'T, \infty)$, we find

$$\begin{aligned}
&\sum_{j=s,c} \left(\sum_{m=1}^{KN} \eta_m b_m^j \right) \left(\sum_{m=1}^{KN} \left[1 - (\mu_{AK'} + \mu_{IK'})\lambda_{IK'} - \mu_{GK'}\lambda_{GK'} 1_{\{m \leq (K-K')N\}} \right] \eta_m b_m^j \right) (\sigma^j \bar{a}_{1K'}^j)^2 \\
&+ \sum_{m=1}^{KN} \left[1 - (\mu_{AK'} + \mu_{IK'})\lambda_{IK'} - \mu_{GK'}\lambda_{GK'} 1_{\{m \leq (K-K')N\}} \right] \eta_m^2 (\sigma_m^i \bar{a}_{m1K'}^i)^2 \bar{D}_m^i = 0
\end{aligned} \tag{A.4}$$

for $[K'T, \infty)$. We likewise find

$$\sum_{j=s,c}\left(\sum_{m=1}^{KN}\eta_m b_m^j\right)\left(\sum_{m=1}^{KN}\left[1-(\mu_{Ak}+\mu_{Ik})\lambda_{Ik}-\mu_{Gk}\lambda_{Gk}1_{\{m\leq(K-k)N\}}\right]\eta_m b_m^j\right)(\sigma^j)^2\int_{kT}^{(k+1)T}(a_{1t}^j)^2dt$$
$$+\sum_{m=1}^{KN}\left[1-(\mu_{Ak}+\mu_{Ik})\lambda_{Ik}-\mu_{Gk}\lambda_{Gk}1_{\{m\leq(K-k)N\}}\right]\eta_m^2(\sigma_m^i)^2\bar{D}_m^i\int_{kT}^{(k+1)T}(a_{m1t}^i)^2dt=0 \tag{A.5}$$

for $[kT, (k+1)T)$ and $k = 0, .., K'-1$. Following the same steps, we can write the first-order condition of green investors as

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

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

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

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

We next determine a^j_{1t} for $j = s, c$. Identifying terms in D^j_t in (3.12) yields the ODE

$$1 - (r + \kappa^j)a^j_{1t} - g^j_k (a^j_{1t})^2 + \frac{da^j_{1t}}{dt} = 0. \tag{A.8}$$

When $k = 0, .., K' - 1$, (A.8) is defined over $t \in [kT, (k+1)T)$, and when $k = K'$, (A.8) is defined over $t \in [K'T, \infty)$. When $k = K'$, we look for a constant solution of (A.8), corresponding to the steady state. Such a solution $\bar{a}^j_{1K'}$ must satisfy the quadratic equation

$$1 - (r + \kappa^j)\bar{a}^j_{1K'} - g^j_{K'} (\bar{a}^j_{1K'})^2 = 0. \tag{A.9}$$

Equation (A.9) 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.8) recursively with terminal condition $\lim_{t \to (k+1)T} a^j_{1t} = a^j_{1,(k+1)T}$. We find

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

$$\Rightarrow \frac{g_k^j a_{1t}^j + \frac{1}{\bar{a}_{1k}^j}}{a_{1t}^j - \bar{a}_{1k}^j} = \frac{g_k^j a_{1,(k+1)T}^j + \frac{1}{\bar{a}_{1k}^j}}{a_{1,(k+1)T}^j - \bar{a}_{1k}^j} e^{\left(g_k^j \bar{a}_{1k}^j + \frac{1}{\bar{a}_{1k}^j}\right)[(k+1)T-t]},$$

which yields (3.13).

We next determine a_{n1t}^i. Identifying terms in D_{nt}^i in (3.12) yields the ODE

$$1 - (r + \kappa_n^i) a_{n1t}^i - g_{nk}^i (a_{n1t}^i)^2 + \frac{d a_{n1t}^i}{dt} = 0. \tag{A.10}$$

When $k = 0, .., K' - 1$, (A.10) is defined over $t \in [kT, (k+1)T)$, and when $k = K'$, (A.10) is defined over $t \in [K'T, \infty)$. When $k = K'$, we look for a constant solution of (A.10). Proceeding as for a_{1t}^j, we find $\bar{a}_{n1K'}^i$ in the proposition. When $k = 0, .., K' - 1$, we solve (A.10) recursively with terminal condition $\lim_{t \to (k+1)T} a_{n1t}^i = a_{n1,(k+1)T}^i$. Proceeding as for a_{1t}^j, we find (3.14).

Identifying the remaining terms yields the ODE

$$\bar{D}_n + \frac{d\bar{S}_{nt}}{dt} - r\bar{S}_{nt} + \sum_{j=s,c} b_n^j \left(\kappa^j a_{1t}^j + \frac{d a_{0t}^j}{dt} - r a_{0t}^j \right) + \kappa_n^i a_{n1t}^i \bar{D}_n^i + \frac{d a_{n0t}^i}{dt} - r a_{n0t}^i = 0 \tag{A.11}$$

in the function $\bar{S}_{nt} + \sum_{j=s,c} b_n^j a_{0t}^j + a_{n0t}^i$. Its solution is

$$\begin{aligned} \bar{S}_{nt} + \sum_{j=s,c} b_n^j a_{0t}^j + a_{n0t}^i &= \int_t^\infty \left(\bar{D}_n + \sum_{j=s,c} b_n^j \kappa^j a_{1t'}^j + \kappa_n^i a_{n1t'}^i \bar{D}_n^i \right) e^{-r(t'-t)} dt' \\ &= \frac{\bar{D}_n}{r} + \sum_{j=s,c} b_n^j \kappa^j \int_t^\infty a_{1t'}^j e^{-r(t'-t)} dt' + \kappa_n^i \bar{D}_n^i \int_t^\infty a_{n1t'}^i e^{-r(t'-t)} dt'. \end{aligned} \tag{A.12}$$

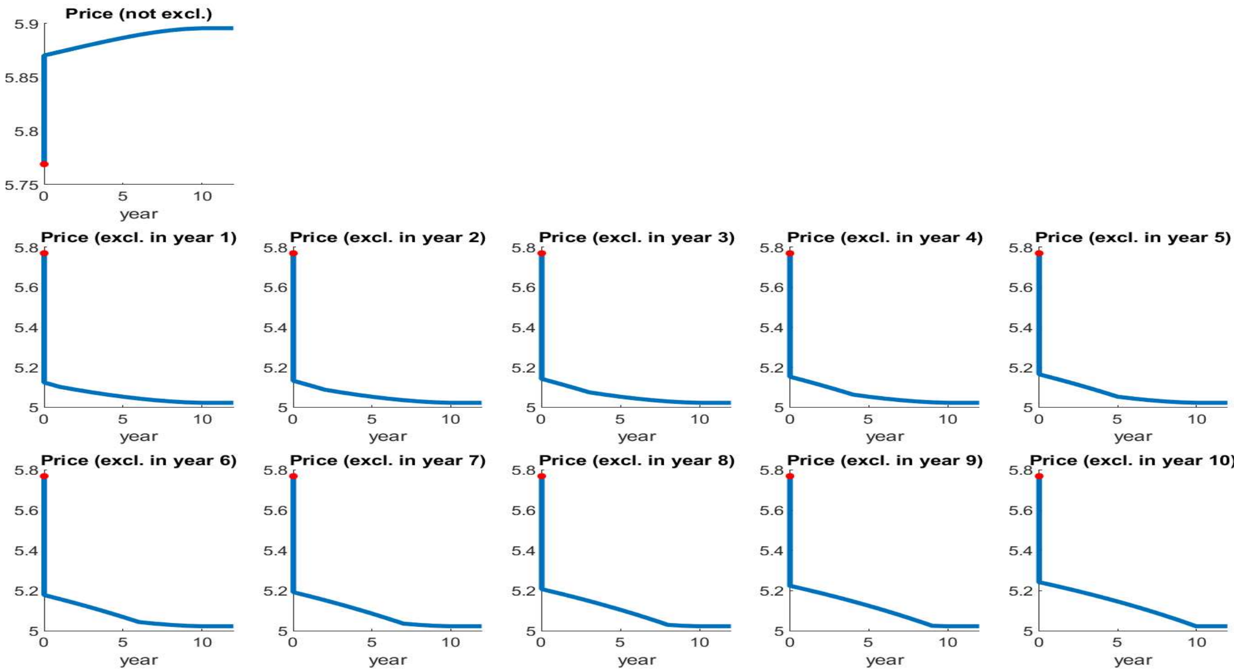
For $t \in [K'T, \infty)$, the solution is constant and equal to

$$\bar{S}_n + \sum_{j=s,c} b_n^j a_0^j + a_{n0}^i = \frac{\bar{D}_n + \sum_{j=s,c} b_n^j \kappa^j \bar{a}_{1K'}^j + \kappa_n^i \bar{D}_n^i \bar{a}_{n1K'}^i}{r}.$$

B Alternative Calibration

Figure B.1 is the counterpart of Figure 4 when the measure of green investors grows linearly from 10% in year 0 to 30% in year 10, and the ratio $\frac{\mu_{Ik}}{\mu_{Ak}+\mu_{Ik}}$ of the measure of passive investors to the total measure of active and passive investors is kept constant at 90%.

Top panel: Prices



Bottom panel: Expected returns

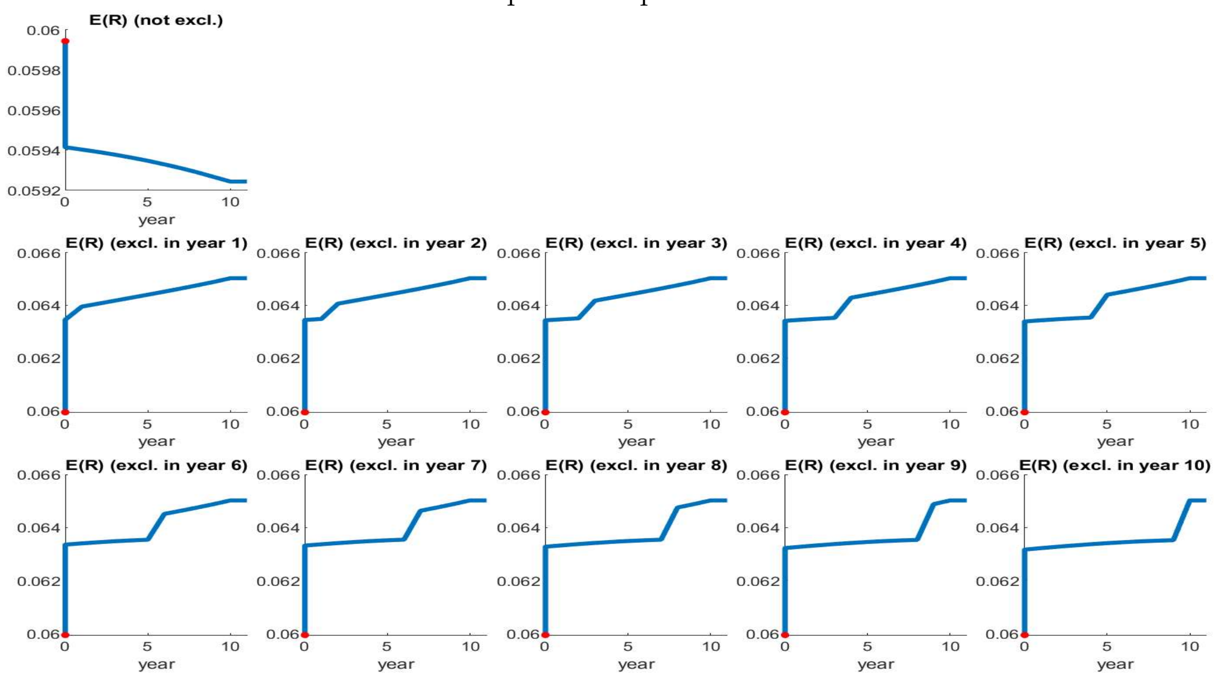


Figure B.1: Prices and expected returns for all stock groups, as a function of time, for $\sigma^s = 1.5$, target expected return 6%, target R-squared 25%, measure μ_{Gk} of green investors growing linearly from 10% in year 0 to 30% in year 10, and ratio $\frac{\mu_{Ik}}{\mu_{Ak}+\mu_{Ik}}$ of the measure of passive investors to the total measure of active and passive investors kept constant at 90%.