UNIMORE
UNIVERSITÀ DEGLI STUDI DI MODENA E REGGIO EMILIA

Dipartimento di Economia Marco Biagi

DEMB Working Paper Series

N. 246

A review of Ľuboš Pástor et al. (2021) model

Alessio Capriotti[1], Silvia Muzzioli[2]

September 2024

[1] University of Modena and Reggio Emilia, Department of Economics "Marco Biagi"
Email: alessio.capriotti@unimore.it
[4] University of Modena and Reggio Emilia, Department of Economics "Marco Biagi" and CEFIN
Email: silvia.muzzioli@unimore.it

ISSN: 2281-440X online

Finanziato dall'Unione europea NextGenerationEU | Ministero dell'Università e della Ricerca | Italiadomani Piano Nazionale di Ripresa e Resilienza | UNIMORE Università degli Studi di Modena e Reggio Emilia

A review of Ľuboš Pástor et al. (2021) model

Alessio Capriotti [a]
alessio.capriotti@unimore.it

Silvia Muzzioli [b]
silvia.muzzioli@unimore.it

September 30, 2024

Abstract

In this paper, we revise the asset pricing model of Ľuboš Pástor et al. (2021) by incorporating a penalty component into investors' utility functions when they invest in firms with lower ESG compliance (brown firms). Our model highlights the dual behavior of investors who gain utility from investing in green firms (fully ESG-compliant) while incurring disutility from holding brown firms. We introduce a formulation where firms' green characteristics are represented by a vector of ESG scores, with 1 for full compliance and 0 for non-compliance. The penalty is defined as a function of the deviation from full ESG compliance, adjusted for each investor's ESG preferences. This leads to a modified CAPM equation that reflects both the non-pecuniary benefits of green investments and the penalties for brown investments.

Keywords: *Asset pricing; Climate risk; ESG; Sustainable investing; Social impact*
JEL Classification: *G11; G12*

Introduction

In the context of the search for empirical evidence of a climate risk premium, where investors are willing to accept a lower return to protect themselves from climate risk, it is necessary to consider the economic rationale that could explain such a phenomenon. This topic has already been addressed by authors such as Gollier and Pouget (2014), Friedman and Heinle (2016), and Luo and Balvers (2017). We believe the central point lies in the structuring of investors' preferences, which may increasingly take into account the green aspects of the companies they invest in. However, it would be wrong to assume a total polarization between fully green investors and fully brown investors: if an investor is neutral to climate risk, they will, by definition, be neutral towards investing in both green and brown firms and may do so in a, let's say, random manner. It is therefore necessary to consider a utility function that incorporates an additional component reflecting a propensity to invest in green firms (which produce positive externalities) and a penalty for investing in brown firms, equal to the distance between the maximum value of ESG compliance and the actual value of the n-th firm, amplified by a multiplicative factor that measures investors' aversion to brown firms.
In this paper, we revisit the asset pricing model of Ľuboš Pástor et al. (2021) to account for an explicit penalty element in the agents' utility function when investing in stocks of firms that are not particularly green.

[a] Marco Biagi Department of Economics, University of Modena and Reggio Emilia, Italy.
[b] Corresponding author. Marco Biagi Department of Economics and CEFIN, University of Modena and Reggio Emilia, Italy

In this way, we are able to account for the dual behavioral orientation of each agent. In fact, even though we consider that investors are mindful of investing in green stocks due to social utility, we also consider that investors who claim to be green may experience a disutility if they invest in stocks of companies that are not fully ESG-compliant. In this sense, we model the disutility experienced by the i-th agent when going against their green preferences by investing in some brown firms, despite having a certain level of attentiveness to investing in green firms (which, instead, generates utility).
We consider the green factor of the n-th firms composing the investment portfolio as a vector of values between 0 and 1, where a value of 1 corresponds to fully ESG-compliant (green) firms and 0 to fully non-compliant (brown) firms. This allows us to capture intermediate levels of greenness, which the previous model does not explicitly consider. We derive a fundamental relationships for the CAPM alpha. Furthermore, we analyze the conditions for the existence of the greenium, i.e., negative alpha, by considering the average propensity to invest in green stocks and the multiplicative factor of the penalty incurred by investors.
The article is structured as follows: In Section 1 we present the main theoretical models that include a climate risk component in the determination of stock prices and the most recent studies related to the existence of a climate risk premium and the relative hedging strategies. In Section 2, we set up the model's assumptions and derive its fundamental relationships. In Section 3, we discuss the results obtained and we conclude.

1 Literature review

Policymakers and investors face considerable uncertainty in assessing the socio-economic and financial impacts of climate change. Traditional financial and economic models often fall short in capturing the complexities of climate risks and the opportunities that arise from the shift to a greener economy. These models typically rely on assumptions like equilibrium conditions, linear impacts, and representative agents, which do not account for the unpredictable and non-linear nature of climate change.
While several macroeconomic models, such as those by Nordhaus (1977), Nordhaus and Boyer (2000) and Nordhaus (2008), include climate risk as a key variable influencing economic growth (capital, consumption), relatively few studies explored how climate risks affect asset pricing.
One of the earliest contributions in this area is by Heinkel et al. (2001), who examined how exclusionary ethical investing impacts corporate behavior. They found that excluding firms with environmental issues from investment portfolios limits risk-sharing, driving down stock prices and increasing the cost of capital for environmentally harmful firms. Recent studies have advanced our understanding of climate risk in asset pricing.
For instance, Karydas and Xepapadeas (2022) developed a dynamic asset pricing model linking carbon emissions and portfolio composition to the likelihood of climate-related events. They demonstrated a positive climate risk premium and reduced participation of

carbon-intensive assets in the market.

Other approaches, such as Daniel et al. (2016), separate expected and unexpected components of climate risk. Using an Epstein-Zin utility function, they developed the EZ-Climate model, which optimizes over time as uncertainty about CO2 emissions and their effects on global temperature and damages is gradually resolved. Their model suggests that the optimal carbon price decreases as more information becomes available and technological advances are made.

der Ploeg et al. (2020) explored how asset prices and climate policy interact in a global economy with both green and carbon-intensive sectors. Their findings indicate that while diversification initially mitigates climate change damages, long-term trade-offs emerge. They also showed how temperature fluctuations negatively impact the risk-free rate and the risk premium.

More recent contributions have focused on how changing investor expectations and regulatory interventions impact asset prices. Ľuboš Pástor et al. (2021) demonstrated that investors' preferences for sustainability (or "green" preferences) influence asset prices by lowering the cost of capital for green firms. They implemented a CAPM model and found that green firms have lower CAPM alphas when risk aversion is low and ESG preferences are strong, while brown firms have positive alphas.

Giglio et al. (2021) extended the analysis to long-term investment horizons, estimating discount rates for real estate over timeframes relevant for climate change mitigation. Their work highlights the self-reinforcing nature of climate disasters, which increase the probability of subsequent climate shocks, affecting both consumption and real estate risk.

Additional noteworthy contributions come from Zerbib (2022), who developed a sustainable asset pricing model (S-CAPM) that incorporates heterogeneous investor preferences, showing how ESG factors affect financial performance through exclusion and taste premiums. Karydas and Xepapadeas (2022) further demonstrated that climate change heightens the frequency and unpredictability of extreme events, increasing the climate risk premium and contributing to declining real interest rates.

Overall, the body of research increasingly demonstrates that climate risks have a negative impact on key macroeconomic variables and financial markets. These risks manifest through direct effects, such as the destruction of capital, and indirect effects, such as changing investor preferences and regulatory shifts. The financial system is gradually adapting to these challenges, but uncertainty regarding the scale and timing of climate impacts remains a central issue for investors and regulators alike.

2 The Model

2.1 Model A

In a economy, each agent i can invest in stocks. The excess return over the risk-free rate r_f for the n-th firm is a $N \times 1$ vector equal to:

$$\underset{N\times 1}{r} = \underset{N\times 1}{\mu} + \underset{N\times 1}{\varepsilon} \Rightarrow \begin{bmatrix} r_1 \\ r_2 \\ \vdots \\ r_N \end{bmatrix} = \begin{bmatrix} \mu_1 \\ \mu_2 \\ \vdots \\ \mu_N \end{bmatrix} + \begin{bmatrix} \varepsilon_1 \\ \varepsilon_2 \\ \vdots \\ \varepsilon_N \end{bmatrix} \tag{1}$$

where $\varepsilon \sim N(0, \Sigma)$ and $r \sim N(\mu, \Sigma)$. Each agent i has the same utility function, that satisfy the neoclassical assumption of $\partial U(\cdot)/\partial W > 0$ and $\partial^2 U(\cdot)/\partial W^2 < 0$, as follows:

$$U(W_{t+1,i}, X_i) = -e^{-A_i W_{t+1,i} - b_i' X_i + k_i' X_i} \tag{2}$$

The wealth at time $t+1$ is equal to $W_{t+1,i} = W_{t,i}(1 + r_f + X_i' r)$ and X_i is the vector of portfolio weights. We define b_i as an $N \times 1$ vector of nonpecuniary benefits that the agent i derives from her stock holdings, equal to:

$$\underset{N\times 1}{b_i} = d_i \underset{N\times 1}{g} \tag{3}$$

where d_i is a positive scalar representing the specific individual degree "ESG-taste" or the degree to which the agent values the environmental, social, and governance (ESG) characteristics of the firms they invest in, while g contains the greenness score for each of the N firs, where each element $g_n \in [0, 1]$ represents the ESG compliance of the n-th firm: if $g_n = 1$, the firm is fully ESG compliance; if $g_n = 0$, the firm is completely ESG noncompliance. This framework allows for a range of ESG compliance levels among the firms, capturing various degrees of sustainability characteristics across the portfolio.

Furthermore, we consider a penalty for the i-th agent, defined by the vector k_i, expressed as:

$$\underset{N\times 1}{k_i} = \lambda_i \underset{N\times 1}{p} \tag{4}$$

where $\lambda_i \geq 0$ is the weight that the i-th agent assigns to the penalty they incur. The vector p is defined as the complement to 1 of the ESG score for each firm, i.e., each element of p is given by $p_n = 1 - g_n$. This penalty imposes a cost on the agent for holding stocks of companies with lower ESG scores, particularly brown firms, thereby discouraging investments in those firms.

We can rewrite the Equation 2 as follows:

$$U(X_i) = -e^{-A_i W_{t,i}(1 + r_f + X_i' r) - b_i' X_i + k_i' X_i} \tag{5}$$

Taking the expected value of the utility function:

$$\mathbb{E}[U(X_i)] = \mathbb{E}\left[-e^{a_i(1+r_f+X_i'r)-b_i'X_i+k_i'X_i}\right] = -e^{-a_i(1+r_f)}\mathbb{E}\left[e^{-a_iX_i'\left(r+\frac{1}{a_i}(b_i-k_i)\right)}\right]$$

where $a_i = A_iW_{t,i}$ is the relative risk aversion. Due to $\mathbb{E}[e^{-ax}] = e^{-a\mu_x+\frac{a^2}{2}\sigma_x^2}$, we obtain:

$$\mathbb{E}[U(X_i)] = -e^{-a_i(1+r_f)}e^{-a_iX_i'\left[\mu+\frac{1}{a_i}(b_i-k_i)\right]+\frac{1}{2}a_i^2X_i'\Sigma X_i} \quad (6)$$

We can achieve the first order condition through the first derivative of the expected utility functions with respect to X_i:

$$\frac{\partial\mathbb{E}[U(X_i)]}{\partial X_i} = 0 \Leftrightarrow -a_i\left[\mu+\frac{1}{a_i}(b_i-k_i)\right]+\frac{1}{2}a_i^2\left(2\Sigma X_i\right) = 0 \quad (7)$$

Solving the Equation 6 for X_i, we can obtain the agent i's equilibrium portfolio weights on the N stocks, equal to:

$$X_i = \frac{1}{a_i}\Sigma^{-1}\left(\mu+\frac{1}{a_i}(b_i-k_i)\right) \quad (8)$$

The n-th element of agent i's portfolio weight vector, X_i, is given by:

$$X_{i,n} = \frac{W_{t,i,n}}{W_{t,i}} \Rightarrow X_{i,n} = \begin{bmatrix} \frac{W_{t,i,1}}{W_{t,i}} \\ \frac{W_{t,i,2}}{W_{t,i}} \\ \vdots \\ \frac{W_{t,i,N}}{W_{t,i}} \end{bmatrix}$$

where $W_{t,i,1}$ represent the dollar amount invested by agent i in stock n. We consider $W_{t,n} = \int_i W_{t,i,n}di$ that denote the total amount invested in stock n by all agents. Defining ω_i as the ratio of agent i's initial wealth to total initial wealth $\omega_i = \frac{W_{t,i}}{W_t}$ where $W_t = \int_i W_{t,i}di$ and assuming a zero aggregate position in the risk less asset, market clearing require that w_m the $N \times 1$ vector of weights in the market portfolio of stocks, for each n firms, satisfies:

$$w_{m,n} = \frac{W_{t,n}}{W_t} = \frac{1}{W_t}\int_i W_{t,i,n}\,di = \int_i W_{t,i}X_{i,n}\,di = \int_i \frac{W_{t,i}}{W_t}X_{i,n}\,di = \int_i \omega_iX_i\,di \quad (9)$$

$$\underset{N\times 1}{w_m} = \int_i \omega_iX_{i,n}\,di = \begin{bmatrix} w_{m,1} \\ w_{m,2} \\ \vdots \\ w_{m,N} \end{bmatrix} = \begin{bmatrix} \int_i \omega_iX_{i,1} \\ \int_i \omega_iX_{i,2} \\ \vdots \\ \int_i \omega_iX_{i,N} \end{bmatrix} \quad (10)$$

Replacing Equation 8 into Equation 10 and assuming a costant relative risk aversion for all the agents, so $a_i = a$:

$$\begin{aligned} w_m &= \int_i \omega_i \left[\frac{1}{a}\Sigma^{-1}\left(\mu + \frac{1}{a}(b_i - k_i)\right)\right] di = \int_i \omega_i \left[\frac{1}{a}\Sigma^{-1}\left(\mu + \frac{1}{a}(d_i g - \lambda_i p)\right)\right] di = \\ &= \frac{1}{a}\Sigma^{-1}\mu \underbrace{\left(\int_i \omega_i di\right)}_{=1} + \frac{1}{a^2}\Sigma^{-1} g \underbrace{\left(\int_i \omega_i d_i di\right)}_{\bar{d}} - \frac{1}{a^2}\Sigma^{-1} p \underbrace{\left(\int_i \omega_i \lambda_i di\right)}_{\bar{\lambda}} = \\ &= \frac{1}{a}\Sigma^{-1}\mu + \frac{\bar{d}}{a^2}\Sigma^{-1} g - \frac{\bar{\lambda}}{a^2}\Sigma^{-1} p \end{aligned} \tag{11}$$

where $\bar{d}$ represent the wealth-weighted mean of ESG tastes d_i across agents, $\bar{\lambda}$ the wealth-weighted average of the weight that investors assign to the penalty incurred from investing in brown firms and $\iota' w_m = 1$, with ι denoting a $N \times 1$ vector of ones. Solving for μ and premultiplying by w'_m we obtain the market equilibrium premium:

$$\mu = a\Sigma w_m - \frac{\bar{d}}{a} g + \frac{\bar{\lambda}}{a} p \tag{12}$$

$$\mu_m = a \underbrace{w'_m \Sigma w_m}_{\sigma_m^2} - \frac{\bar{d}}{a} w'_m g + \frac{\bar{\lambda}}{a} w'_m p \tag{13}$$

Finally, imposing that the market portfolio is ESG-neutral $w'_m g = 0$ and "brown neutral" $w'_m p = 0$, we obtain from Equation 13:

$$a = \frac{\mu_m}{\sigma_m^2}$$

that insert into Equation 12 obtain the expected excess return in equilibrium, considering the market betas is equal to $\beta_m = \frac{\Sigma}{\sigma_m^2} w_m$

$$\mu = \frac{\mu_m}{\sigma_m^2}\Sigma w_m - \frac{\bar{d}}{a} g + \frac{\bar{\lambda}}{a} p = \mu_m \beta_m - \frac{\bar{d}}{a} g + \frac{\bar{\lambda}}{a} p \tag{14}$$

From equation Equation 14 follows that the CAPM alphas, defined as $\alpha = \mu - \mu_m \beta_m$ is equal to:

$$\alpha = -\frac{\bar{d}}{a} g + \frac{\bar{\lambda}}{a} p \tag{15}$$

As in Ľuboš Pástor et al. (2021), we obtain an alpha that depends on a negative component, since $\bar{d}$ is always positive, to which a positive component is added (innovatively). However, if we consider the alphas from Ľuboš Pástor et al. (2021), considering our hypothesis that the g vector contains only $g_n \in [0, 1]$, we must acknowledge that alpha exists for all g_n values greater than 0. In fact, if $g_n = 0$, the excess return is equal to zero, meaning the expected excess return is equal to its CAPM value. This implies that only fully "brown" firms do not experience a greenium, whereas even a low ESG firm ($g_n \to 0$) is sufficient to produce negative alphas.

Proposition 1 *If we consider a utility function like the one in Ľuboš Pástor et al. (2021), where no penalty is provided ($k_i = 0$), we obtain an alpha that is always negative, even for very low values of g_n, and at most a zero alpha when investing in a fully brown firm, due to the vector g includes values between 0 and 1, where 1 indicates a fully green company and 0 a fully brown one.*

In order to extend the possible situations in which a greenium may occur, we consider an additive agent-behavior component that accounts for investing in non-green firms as well. From Equation 15, we note that the lower the relative risk aversion, the higher the alpha. Furthermore, it holds that for each n-th firm:

$$\alpha_n = -\frac{\bar{d}}{a}g_n + \frac{\bar{\lambda}}{a}(1 - g_n) = \frac{1}{a}\left(-\bar{d}g_n + \bar{\lambda} - \bar{\lambda}g_n\right) = \frac{1}{a}\left[\bar{\lambda} - g_n(\bar{d} + \bar{\lambda})\right] \tag{16}$$

We can show several cases:

1. First, we notice that, if $g_n = 0$, the CAPM alphas is always positive, equal to:

$$\alpha_n = \frac{\bar{\lambda}}{a} \tag{17}$$

   while, if $g_n = 1$, then the CAPM alphas is always negative:

$$\alpha_n = -\frac{\bar{d}}{a} \tag{18}$$

2. If $g_n \in (0, 1)$, then the sign of the alpha depends on the parameters $\bar{\lambda}$ and $\bar{d}$. In fact, the condition that holds if alpha is negative is:

$$\bar{g}_n \geq \frac{\bar{\lambda}}{\bar{\lambda} + \bar{d}} \tag{19}$$

The Condition 19 allows us to analyze two situations, in addition to the two extreme cases represented by Equations 17 and 18: the first case concerns the situation where the weighted average value of the burden that all agents in the economy assign to the penalty for not investing in fully green stocks is greater than the weighted average value of the ESG preferences; the second case is the opposite. We find that Relation 19 holds in both cases. However, in the first case, a very high value of ESG characterization, attributed to the n-th company, is necessary to obtain a negative alpha, whereas in the second case, a very low level of greenness is sufficient to obtain a greenium (see Figure 1). This leads to the following propositions:

Proposition 2 *If we assume that agents, on average, do not assign any weight to the possibility of incurring a penalty from investing in non-green stocks, then the alpha of the n-th company is always negative or at most zero, when it is entirely brown.*

Proposition 3 *If we assume that, on average, agents assign some weight to the possibility of incurring a penalty for investing in non-fully green stocks, from which they derive disutility, and at the same time derive utility from investing in green stocks based on a certain average level of ESG preferences, then the alpha is always positive (i.e., the greenium does not exist) if the average ESG preferences are close to zero. On the other hand, it is negative for a low (high) value of* g_n *if the average weight assigned to the penalty (the average ESG preferences) is lower than the average ESG preferences (the average weight assigned to the penalty).*

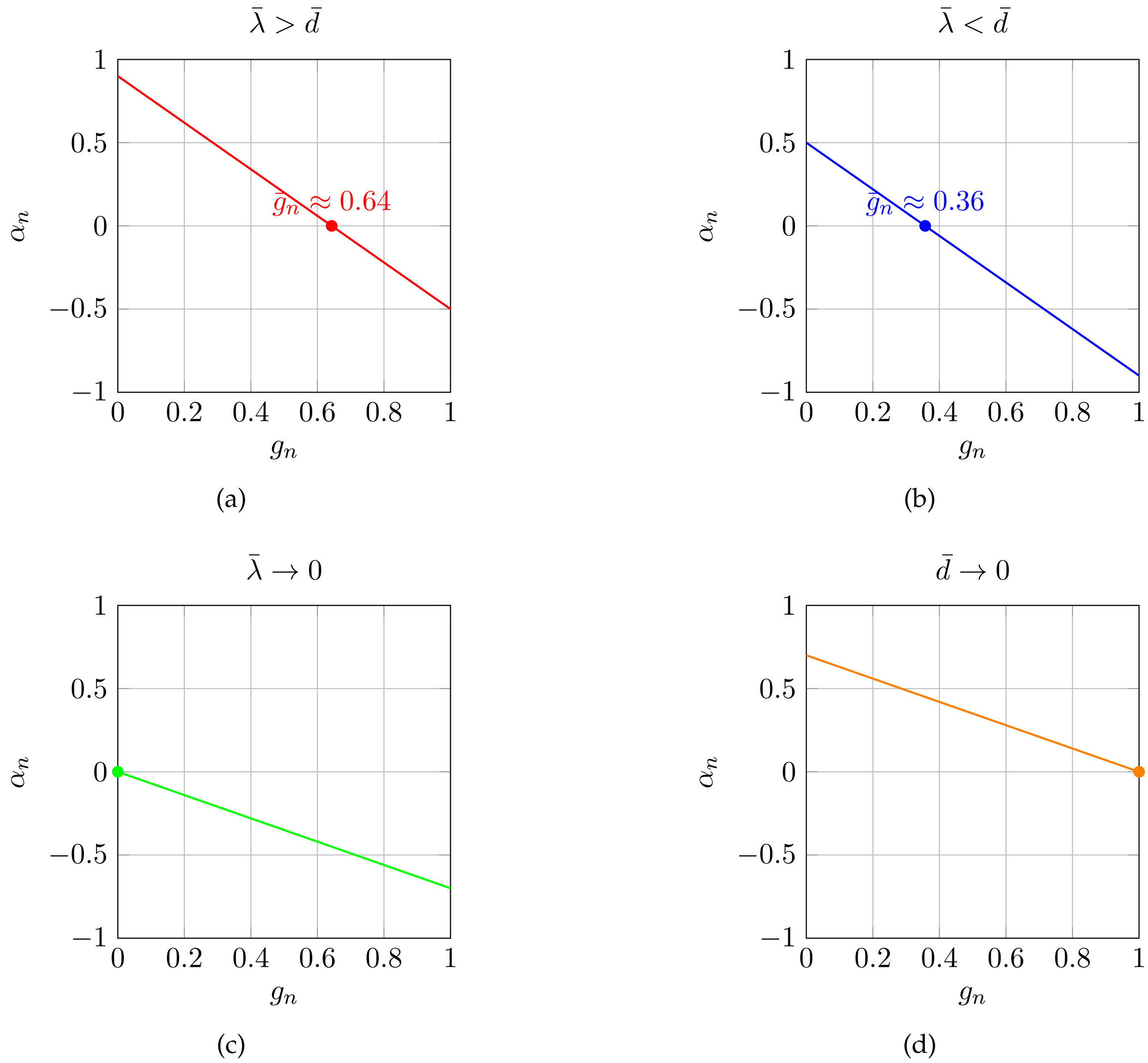

Figure 1: Plots of different $\bar{\lambda}$ and $\bar{d}$ cases.

2.2 Model B

We create a penalty function that penalizes inconsistency between green preferences and actual investment choices: The weight that agents assign to the penalty is explicitly a function of the agents' own ESG preferences, represented by a fraction f:

$$k_i = k(d_i) = \lambda_i(\iota - g) = \frac{d_i}{f}(\iota - g) \tag{20}$$

with $f \in \mathbb{N} \setminus \{0\}$, $d_i, \lambda_i \in [0,1]$ and $d_i \geq \lambda_i$. When $d_i = 0$, the agent has no preference for ESG-compliant firms, whereas when $d_i = 1$, the agent is fully aligned with investing in firms with high ESG ratings. When $\lambda_i = 0$, agents assign no weight to the penalty from investing in non-green assets, whereas when $\lambda_i = 1$, they assign the maximum possible weight. The parameter f represents a scaling factor for d_i: we assume that the disutility from investing in brown firms is directly linked to the agent's preference for ESG compliance.

From Equation 2, we have the term:

$$-b_i'X_i + k_i'X_i = (-d_i g' + \frac{d_i}{f}p')X_i = -d_i X_i'\left(g - \frac{1}{f}\iota + \frac{1}{f}g\right) = -\underbrace{\frac{d_i}{f}}_{\lambda_i}\underbrace{[(1+f)g - \iota]}_{\pi} \tag{21}$$

Using:

$$\int_i \omega_i \lambda_i di = \int_i \omega_i \frac{d_i}{f} di = \frac{1}{f}\int_i \omega_i d_i di \Rightarrow \bar{\lambda} = \bar{d}/f$$

the fundamental equations become:

$$X_i = \frac{1}{a_i}\Sigma^{-1}\left(\mu + \frac{d_i}{fa_i}\pi\right) = \frac{1}{a_i}\Sigma^{-1}\left(\mu + \frac{\lambda_i}{a_i}\pi\right) \tag{22}$$

$$w_m = \frac{1}{a}\Sigma^{-1}\mu + \frac{\bar{d}}{fa^2}\Sigma^{-1}\pi \tag{23}$$

$$\mu = a\Sigma w_m - \frac{\bar{d}}{fa}\pi \tag{24}$$

$$\mu_m = a\sigma_m^2 - \frac{\bar{d}}{fa}w_m'\pi \tag{25}$$

Imposing $w_m'\pi = 0$, we obtain that the CAPM alpha is equal to:

$$\alpha = -\frac{\bar{d}}{fa}\pi \tag{26}$$

For each n-th firm:

$$\alpha_n = -\frac{\bar{d}}{fa}[(1+f)g_n - 1] \tag{27}$$

First, we notice that the lower the average value of λ as a fraction of the average ESG preferences (i.e., when f is high), the higher the greenium (α). In fact:

$$\frac{\partial \alpha_n}{\partial f} = \frac{\bar{d}(g-1)}{af^2} \leq 0$$

Second, generally, the condition that holds to obtain a negative CAPM alpha is:

$$\bar{g}_n > \frac{1}{1+f} \tag{28}$$

From this, the following proposition follows:

Proposition 4 *The lower the weight that agents, on average, assign to the disutility they experience from investing in less-green firms (i.e., when f is high), the lower the ESG score required to achieve a negative alpha. This suggests that as agents become less sensitive to the disutility associated with non-green investments, a firm can obtain a negative excess return with a comparatively low ESG score.*

Third, if we consider $f = \frac{\bar{d}}{\bar{\lambda}}$, the Relation 28 is equal to Relation 19 and we obtain the same conclusions of **Proposition 3**.
Finally, if we impose that $d_i = \lambda_i$, then $f = 1$. In this case, the agents' ESG preferences are fully aligned with the weight of the penalty they assign to investing in less-green firms. We obtain that:

$$\alpha_n = -\frac{\bar{d}}{a}[2g_n - 1] \Rightarrow \alpha_n < 0 \Leftrightarrow g_n > 0.5 \tag{29}$$

Accordingly, we can state the following:

Proposition 5 *If the average weight that agents assign to the disutility of investing in less-green firms is equal to their degree of ESG preference, then a negative excess return will occur for the n-th firm if its ESG score is greater than 0.5: it is sufficient for a firm to have an ESG score slightly above the average/median for a greenium to occur.*

3 Discussion and Conclusions

Generally, we have to distinguish two different situations: a) investors climate risk adverse with strong green preferences and b) investors climate risk neutral with weak green preferences. If an investor prefers to invest in companies with a better environmental impact or that align with sustainable social and governance framework, because they place a high value on the positive externalities of the company's activities, they will likely choose to invest primarily in this type of stock rather than in companies that harm the environment or do not align to ethical social and governance principles.
If these preferences increase, and the number of investors with such preferences grows, the following is expected to occur:

1. Excess demand for "green" company stocks, leading to an increase in their price and a decrease in their expected return.

2. Excess supply of ”brown” company stocks, resulting in a decrease in their price and an increase in their expected return.

This scenario assumes that ”brown” companies do not modify their characteristics to become ”green.” This assumption is not entirely implausible, given that the production chain of some companies, such as metallurgical or petrochemical industries, are rigid and not easily adaptable to structural changes. Even if such changes are technically feasible, they would be costly, unless incentivized by government policies promoting green investments. Furthermore, it is important to note that some (general) investors consider it preferable to invest in ”green” companies due to the potential for legislative actions (such as carbon taxes or plastic taxes) that could negatively impact ”brown” companies. This is referred to transition risk. By investing in ”green” firms, these investors protect themselves from potential losses, even if this means accepting a lower return. Additionally, many ”green” companies tend to be relatively “young” and small, because they have not needed to replace old facilities with more eco-friendly ones because their buildings were built more recently. Alternatively, they may be large, well-capitalized firms capable of channelling significant investments into green technological innovation. Moreover, it is possible that an investor, upon receiving news about adverse extreme events, may increase their aversion to climate risk, even if initially it was very low or even non-existent. As a result, they might prefer to invest in companies that generate greater positive social externalities. Otherwise, an investor might also be inclined to change their geographic area of investment, favouring regions where extreme events are less frequent, thereby ignoring any change in their preferences.
In this paper, we revisit the work of Ľuboš Pástor et al. (2021) to place greater emphasis on investor preferences in CAPM asset pricing model. To achieve this, we proposed that the positive externality associated with a firm is determined by its degree of greenness, which is measured by the ESG score (where 0 indicates no compliance and 1 indicates full compliance). Secondly, we introduced a weight that agents assign to the likelihood of deviating from investing in green firms. This weight reflects how strongly an investor feels about maintaining their ESG preferences. Finally, we argued that the penalty for investing in brown firms is directly linked to individual preferences: if an agent has a high inclination to invest in green firms, they incur a higher penalty when they choose to invest in brown firms. The main results are collected in Table 1.

Table 1: Main results.

	Hp k_i	CAPM α	Greenium
Model A	$k_i = 0$	$\alpha_n = -\frac{\bar{d}}{a} g_n$	$\alpha_n < 0,\ \forall g_n \in (0,1]$
	$k_i = \lambda_i p$	$\alpha_n = -\frac{\bar{d}}{a} g_n + \frac{\bar{\lambda}}{a}(1-g_n)$	$\bar{g}_n \geq \frac{\bar{\lambda}}{\bar{\lambda}+\bar{d}}$
Model B	$k_i = \frac{d_i}{f} p$	$\alpha_n = -\frac{\bar{d}}{fa}\left[(1+f)g_n - 1\right]$	$\bar{g}_n > \frac{1}{1+f}$

In this way, we illustrated various scenarios where a greenium (negative excess return) can arise, particularly when considering intermediate levels of ESG scores. Furthermore, we establish broader economic reasons that can lead to the existence of a negative excess return.

References

Capriotti, A., Cipollini, A., and Muzzioli, S. (2024). Climate risk definition and measures: Asset pricing models and stock returns. Working paper, Dipartimento di Economia Marco Biagi.

Daniel, K. D., Litterman, R. B., and Wagner, G. (2016). Applying asset pricing theory to calibrate the price of climate risk. Working Paper 22795, National Bureau of Economic Research.

der Ploeg, R. V., Hambel, C., and Kraft, H. (2020). Asset Pricing and Decarbonization: Diversification versus Climate Action. Economics Series Working Papers 901, University of Oxford, Department of Economics.

Ferrara, M., Ciano, T., Capriotti, A., and Muzzioli, S. (2024). Climate change and asset pricing: A focused review of literature. Working paper, Dipartimento di Economia Marco Biagi.

Friedman, H. L. and Heinle, M. S. (2016). Taste, information, and asset prices: implications for the valuation of csr. *Review of Accounting Studies*, 21(3):740–767.

Giglio, S., Kelly, B., and Stroebel, J. (2021). Climate finance. *Annual Review of Financial Economics*, 13(Volume 13, 2021):15–36.

Gollier, C. and Pouget, S. (2014). The ”washing machine”: Investment strategies and corporate behavior with socially responsible investors. TSE Working Papers 14-457, Toulouse School of Economics (TSE).

Heinkel, R., Kraus, A., and Zechner, J. (2001). The effect of green investment on corporate behavior. *The Journal of Financial and Quantitative Analysis*, 36(4):431–449.

Karydas, C. and Xepapadeas, A. (2022). Climate change financial risks: Implications for asset pricing and interest rates. *Journal of Financial Stability*, 63:101061.

Luo, H. A. and Balvers, R. J. (2017). Social screens and systematic investor boycott risk. *Journal of Financial and Quantitative Analysis*, 52(1):365–399.

Nordhaus, W. D. (1977). Economic growth and climate: The carbon dioxide problem. *The American Economic Review*, 67(1):341–346.

Nordhaus, W. D. (2008). *A Question of Balance: Weighing the Options on Global Warming Policies*. Yale University Press, New Haven, CT.

Nordhaus, W. D. and Boyer, J. (2000). *Warming the World: Economic Models of Global Warming*. The MIT Press.

Zerbib, O. D. (2022). A sustainable capital asset pricing model (s-capm): Evidence from environmental integration and sin stock exclusion. *Proceedings of Paris December 2020 Finance Meeting EUROFIDAI - ESSEC*.

Ľuboš Pástor, Stambaugh, R. F., and Taylor, L. A. (2021). Sustainable investing in equilibrium. *Journal of Financial Economics*, 142(2):550–571.

Funding

This work was funded by European Union under the NextGeneration EU Programme within the Plan “PNRR - Missione 4 “Istruzione e Ricerca” - Componente C2 Investimento 1.1 “Fondo per il Programma Nazionale di Ricerca e Progetti di Rilevante Interesse Nazionale (PRIN)” by the Italian Ministry of University and Research (MUR), Project title: “Climate risk and uncertainty: environmental sustainability and asset pricing”. Project code ”P20225MJW8” (CUP: E53D23016470001), MUR D.D. financing decree n. 1409 of 14/09/2022.

The work was supported also by the University of Modena and Reggio Emilia for the FAR2022 and FAR2023 projects.

Conflict of interest

The authors declare that they have no conflict of interest.

Availability of data and materials

Not applicable.

Code availability

Not applicable.