Sustainable Investing with ESG Rating Uncertainty

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Abstract

This paper analyzes the asset pricing and portfolio implications of an important barrier to sustainable investing—uncertainty about the corporate ESG profile. In equilibrium, ESG uncertainty increases risk aversion and market premium and decreases demand for stocks. ESG uncertainty also tilts the negative ESG-CAPM alpha relation and affects individual stocks' systematic risk exposures. Employing the standard deviation of ESG ratings from six major providers as a proxy for ESG uncertainty, we provide evidence supporting the model predictions. Our findings help reconcile the mixed evidence on the cross-sectional ESG-alpha relation and suggest that ESG uncertainty could distort the risk-return trade-off.

Keywords: ESG, Rating Uncertainty, Effective Risk Aversion, Portfolio Choice, Capital Asset Pricing Model

JEL: G11, G12, G24, M14, Q01

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1 Introduction

The global financial market has experienced exponential growth in sustainable investing, an investment approach that considers environmental, social, and governance (ESG) factors in portfolio selection and management. Since the launch of United Nations Principles for Responsible Investment (PRI) in 2006, the number of signatories has grown from 734 in 2010 to 1,384 in 2015 and 3,038 in 2020, with total assets under management of US$21 trillion in 2010, US$59 trillion in 2015, and US$103 trillion in 2020.[1] In line with the increasing concerns about global warming, BlackRock CEO Larry Fink wrote in a recent annual letter that climate change will force businesses and investors to shift their strategies, leading to a "fundamental reshaping of finance" and "significant reallocation of capital".[2]

As the ESG objective is becoming a primary focus in asset management, the reallocation of capital has major implications for portfolio decisions and asset pricing. However, ESG investors often confront a substantial amount of uncertainty about the true ESG profile of a firm. In the absence of a reliable measure of the true ESG performance, any attempt to quantify it needs to cope with incomplete and opaque ESG data and nonstructured methodologies. A meaningful illustration of this phenomenon is the pronounced divergence across ESG rating agencies. For instance, Berg et al. (2020) document that the average correlation between six major rating providers is only 0.54.[3] From an investor's perspective, such uncertainty about corporate ESG profiles could be an important barrier to sustainable investing. However, to date, there has been little attention devoted to the role of ESG uncertainty in portfolio decisions and asset pricing.[4]

This paper aims to fill this gap by analyzing the equilibrium implications of ESG uncertainty for both the aggregate market and the cross-section. We first study the aggregate market through a mean-variance setup that consists of the market portfolio and a riskless asset. Due to uncertainty about the ESG profile, a brown-averse agent who extracts nonpecuniary benefits from holding green stocks perceives equities to be riskier. In addition, the agent's demand for equities consists of two components: (1) the usual demand when ESG preferences are muted and (2) a demand for a pseudo asset with a positive payoff for a green market and a negative payoff for a brown market as well as volatility that evolves from uncertainty about the market ESG score. Aggregating these components, we show that the

[1] See, `https://www.unpri.org/pri`.

[2] See, `https://www.blackrock.com/corporate/investor-relations/larry-fink-ceo-letter`.

[3] See, e.g., Chatterji et al. (2016), Mackintosh (2018), Doyle (2018), and Gibson et al. (2020).

[4] Pastor et al. (2020) account for the possibility that investors can disagree about a firm's ESG profile, but the ESG score is *certain* in their setup because investors are dogmatic about their ESG perceptions and can observe each other's perceived ESG values. Relative to their important work, we focus on *uncertainty* about the corporate ESG profile.

overall demand for equities falls due to ESG uncertainty, even when the market is green.

We then formulate the market premium in equilibrium. While the higher risk induced by ESG uncertainty essentially commands a higher market premium, there is an offsetting force when the market is green because an ESG investor extracts nonpecuniary benefits from holding green stocks. The ultimate implications of ESG preferences with uncertainty for the market premium are thus inconclusive. When the market is green neutral, however, the equity premium rises due to uncertainty. For perspective, when ESG uncertainty is not accounted for and the market is green (green neutral), the market risk does not change, the demand for risky assets rises (does not change), and the market premium drops (does not change) relative to ESG indifference.

We further derive a CAPM representation where both alpha and the effective beta vary with firm-level ESG uncertainty. When ESG uncertainty is not accounted for, the CAPM alpha exclusively reflects the agent's willingness to hold green stocks due to nonpecuniary benefits, and the ESG-alpha relation is negative.[5] Accounting for ESG uncertainty, the equilibrium alpha varies with both the ESG score and uncertainty. Hence, the eventual *unconditional* ESG-alpha relation is inconclusive.

We move on to empirically test the model implications using U.S. common stocks from 2002 to 2019. We collect ESG ratings from six major rating agencies, including Asset4 (Refinitiv), MSCI KLD, MSCI IVA, Bloomberg, Sustainalytics, and RobecoSAM. We employ the average (standard deviation of) ESG ratings across rating agencies to proxy for the firm-level ESG rating (ESG uncertainty). Consistent with existing studies, we confirm that there are substantial variations across different rating providers, while the average rating correlation is 0.48. The variations are quite persistent throughout the entire sample period.

We first calibrate the model for plausible values of the equity premium, market volatility, and risk aversion. The investment universe consists of a riskless asset along with 25 portfolios sorted by ESG rating and ESG uncertainty. Our calibration considers two distinct agents who observe the returns on investable assets. One agent accounts for ESG preferences with uncertainty in assessing the risk-return profile of the optimal portfolio, while the other is ESG neutral. Accounting for ESG uncertainty significantly reduces the perceived maximal Sharpe ratio from 0.28 to 0.21 per month and reduces the certainty equivalent rate of return, which corresponds to the maximal expected utility, from 2.00% to 1.26% per month. Our findings are robust to various scenarios when the market is either green neutral or green, as well as when we permit short selling or impose nonnegativity constraints on stock holdings. The calibration results reinforce the notion that ESG uncertainty could distort the risk-return trade-off and reduce economic welfare.

[5] See, e.g., Heinkel et al. (2001), Pastor et al. (2020), and Pedersen et al. (2020).

We further examine how the ESG score and uncertainty affect investor demand, cross-sectional return predictability, the systematic risk exposure of individual stocks, and market premium. Consistent with the model prediction, we find that in the presence of uncertainty about the ESG profile, the demand for risky assets declines. For instance, stocks in the top (bottom) ESG rating quintile display institutional ownership of 73% (71%) when ESG uncertainty is low and 65% (65%) when uncertainty is high. The ownership gap between high- and low-ESG-uncertainty portfolios is statistically significant and economically meaningful, accounting for 7% to 11% of the average institutional ownership. The results are particularly strong among stocks with extreme ESG ratings, as their investors are likely to be more sensitive to ESG information.

We next examine the cross-sectional implications of ESG uncertainty. We first sort stocks into quintile portfolios based on their ESG uncertainty. Within each uncertainty group, we further sort stocks into quintile portfolios according to their ESG ratings. We find that the ESG rating is negatively associated with future performance *only* among stocks with low ESG uncertainty. For instance, brown stocks outperform green stocks by 0.59% per month in raw return and 0.40% per month in CAPM-adjusted return. However, the negative return predictability of ESG ratings does not hold for the remaining firms. Our findings thus support the model predictions, i.e., brown stocks outperform green stocks in the absence of uncertainty about the ESG profile. In the presence of ESG uncertainty, the ESG-alpha relation can be ambiguous. The results are robust to adjusting for alternative risk factors and controlling for other firm characteristics in Fama and MacBeth (1973) regressions.

In equilibrium, beta varies with ESG uncertainty. We find that stocks with higher ESG ratings exhibit lower beta. More importantly, *only* green firms are perceived to be riskier when uncertainty is high. Such asymmetric impact highlights the importance of ESG uncertainty, as green firms could be disproportionally penalized due to ambiguity in their ESG profiles.

Finally, considering the aggregate market, we find that the market premium increases with ESG uncertainty after controlling for the market-wide ESG rating. ESG uncertainty also discourages aggregate investor participation. The overall empirical findings are in line with the model predictions for both the aggregate market and the cross-section.

This paper contributes to several strands of the literature. First, we explicitly account for uncertainty about the ESG profile in equilibrium asset pricing for both the aggregate market and the cross-section. Prior work has focused on investors' ESG preferences (e.g., Heinkel et al. (2001) and Pastor et al. (2020)), while our model predictions and calibration results highlight the importance of considering ESG uncertainty when analyzing sustainable investing. Specifically, effective risk aversion increases with ESG uncertainty, while investor demand for equity falls. ESG uncertainty also affects the market premium in aggregate, as well as the CAPM alpha and effective beta in the cross-section.

Second, we contribute to the growing literature on the cross-sectional return predictability of the ESG profile. Prior studies document weak return predictability of the overall ESG rating (e.g., Pedersen et al. (2020)) and mixed evidence based on different ESG proxies (e.g., Gompers et al. (2003); Hong and Kacperczyk (2009); Bolton and Kacperczyk (2020)). Our contribution is to propose that ESG uncertainty could tilt the ESG-performance relationship and serve as a potential mechanism to explain the opposing findings. We show that ESG ratings are negatively associated with future performance when there is little uncertainty and that the ESG-performance relationship could be insignificant or positive when uncertainty increases. Thus, the sin premium presented by Hong and Kacperczyk (2009) could be attributed to the notion that sin stocks (i.e., companies involved in producing alcohol, tobacco, and gaming) are clearly defined and thus subject to minimal disagreement among investors. On the other hand, other ESG profiles could be more challenging to measure or rely on nonstandardized information and methodologies, thereby displaying more uncertainty and mixed evidence on return predictability.

To the extent that ESG uncertainty will decrease with a better understanding of a firm's true ESG profile, our work enriches academic and policy discussions in that context. Despite the rapid growth in the sustainable investing and ESG data markets,[6] the comparability of ESG information remains a critical issue. Due to the lack of standards governing the reporting of ESG information, it is not a trivial task to compare the ESG data of two different companies (Amel-Zadeh and Serafeim (2018)). In addition, the construction of ESG ratings is nonregulated, and methodologies can be opaque and proprietary, leading to substantial divergence across data providers (e.g., Mackintosh (2018); Berg et al. (2020)). Our findings imply that the lack of consistency across ESG rating agencies makes sustainable investing riskier and hence reduces investor participation and potentially hurts economic welfare. Moreover, green firms are less likely to benefit from a lower cost of capital in the presence of uncertainty about their ESG profiles, which could further limit their capacity to make socially responsible investments and generate real social impact.

The remainder of this paper is organized as follows. Section 2 presents the model. Section 3 describes the data and the main variables used. Section 4 calibrates the model and explores its quantitative implications. Section 5 empirically examines how ESG ratings and uncertainty affect investor demand, cross-sectional return predictability, and systematic risk exposure. Section 6 investigates the market implications in terms of the equity premium and

[6] the estimated spending on ESG data was US$617 million in 2019 and could approach US$1 billion by 2021. See http://www.opimas.com/research/547/detail/.

aggregate demand. The conclusion follows in Section 7.

2 ESG and Market Equilibrium

This section develops the economic setup. We start with a single risky asset, i.e., the market portfolio, and a riskless asset. We derive the optimal portfolio and discuss the implications of uncertainty about the ESG profile for the market premium, the capital allocation line (CAL), and economic welfare. The single-asset setup is then extended to consider multiple risky assets and heterogeneous economic agents who differ in their initial wealth, risk aversion, and ESG preferences. We analyze the implications of ESG uncertainty for the demand of individual stocks, derive an asset pricing model for the cross-section of stock returns, and discuss incremental effects of ESG uncertainty on the alpha and beta components of returns.

2.1 One Risky Asset

Consider a single-period economy in which an agent trades at time 0 and liquidates the position at time 1. Let $\tilde{r}_M$ denote the random rate of return on the market portfolio in excess of the riskless rate, r_f.[7] Then, let $\tilde{g}_M$ denote a noisy signal on the ESG score at time 0. For instance, the signal can be an ESG score provided by one of the ESG rating agencies. We model the excess market return and the ESG signal as

$$\tilde{r}_M = \mu_M + \tilde{\epsilon}_M, \tag{1}$$

$$\tilde{g}_M = \mu_{g,M} + \tilde{\epsilon}_{g,M}, \tag{2}$$

where $E(\tilde{r}_M) = \mu_M$ is the expected market excess return, $E(\tilde{g}_M) = \mu_{g,M}$ is the expected value of the market ESG score, and $\tilde{\epsilon}_M$ and $\tilde{\epsilon}_{g,M}$ are zero-mean residuals. The residuals are assumed to be independent. Note, in particular, that $\tilde{\epsilon}_M$ represents the time 0 uncertainty about the market return that resolves at time 1, while $\tilde{\epsilon}_{g,M}$ represents a very different type of uncertainty about the ESG profile that does not essentially resolve. We therefore assume that the residuals obey independent univariate normal distributions, with σ_M and $\sigma_{g,M}$ denoting the standard deviation of return and the uncertainty about the market ESG profile, respectively. It is assumed that all the model parameters are known to the optimizing agent. Thus, the firm's ESG score is perceived to be a random draw from a known distribution.

In the empirical analysis that follows, $\mu_{g,M}$ and $\sigma_{g,M}$ are proxied by the average and standard deviation, respectively, of ESG ratings across six major agencies. From an investor's

[7] Consistent with static setups, we do not formulate intertemporal preferences; hence, the riskless rate is exogenously specified.

perspective, a higher $\sigma_{g,M}$ indicates more disagreement among ESG raters and hence more uncertainty about the true ESG performance of the market.

Following Pastor et al. (2020), we consider an optimizing agent who derives nonpecuniary benefits from holdings stocks based on their time 0 ESG characteristics. Moreover, preferences are formulated through the exponential utility (CARA) function

$$V\left(\tilde{W}_1, x\right) = -e^{-A\tilde{W}_1 - BW_0 x \tilde{g}_M}, \tag{3}$$

where $\tilde{W}_1 = W_0 \left(1 + r_f + x\tilde{r}_M\right)$ is the terminal wealth, W_0 is the initial wealth, x is the fraction of wealth invested in the risky asset, A stands for the agent's absolute risk aversion, and B characterizes the nonpecuniary benefits that the agent derives from stock holdings. Positive (negative) B indicates that the agent extracts benefits from holding green (brown) stocks. Hence, B can be interpreted as the absolute brown aversion. Slightly departing from Pastor et al. (2020), we formulate preferences for ESG to be wealth-dependent. Then, the expression BW_0 represents the relative brown aversion.

Observe from equation (3) that the investment in the riskless asset does not contribute to the portfolio's ESG profile, as perceived by the agent, because we implicitly assume that the riskless asset is ESG neutral. As ESG scores are ordinal in nature, the choice of considering the riskless asset as a reference level does not imply loss of generality. In addition, to capture the ESG benefits and costs from investing in the market, we allow the market portfolio to depart from ESG neutrality.

The agent picks x attempting to maximize the expected value of preferences in equation (3). The first-order condition suggests that the optimal portfolio in the presence of ESG uncertainty is given by

$$x^* = \frac{1}{\gamma} \frac{\mu_M + b\mu_{g,M}}{\sigma^2_{M,U}}, \tag{4}$$

where $b = \frac{B}{A}$, $\gamma = AW_0$ stands for the relative risk aversion and $\sigma^2_{M,U} = Var\left(\tilde{r}_M + b\tilde{g}_M\right)$ is the market variance, as *perceived* by the agent. That is, the *ex ante* stock return volatility is no longer σ_M because of ESG uncertainty. As $\tilde{r}_M$ and $\tilde{g}_M$ are noncorrelated, it follows that $\sigma^2_{M,U} > \sigma^2_M$ as long as $b \neq 0$.

In what follows, we consider a positive market premium (i.e., $\mu_M > 0$) and assume that the investor is brown-averse (i.e., $b > 0$). A positive market premium is plausible in the presence of risk aversion. The brown aversion assumption is sensible, albeit it is useful merely for illustration. Additionally, to distill the incremental effects of ESG uncertainty, we consider two benchmark cases. In the first, the agent is ESG indifferent, and in the second, preference for ESG is accounted for, while the ESG profile is known for certain. The latter case is studied by Pastor et al. (2020) in a multiple-security setup.

Equation (4) presents the optimal stock position in the presence of uncertainty about the ESG profile. The risky asset is perceived to be a package of two distinct securities. The first delivers the market return $\tilde{r}_M$, while the second reflects exposure to ESG uncertainty and yields $b\tilde{g}_M$. The latter component can be interpreted as investing b units in a pseudo asset that pays $\tilde{g}_M$ per unit. As b increases, i.e., when the ratio between brown aversion and risk aversion increases, the ESG component becomes more meaningful in investment decisions. Stock investing is thus driven by the relative risk aversion, γ, and the *perceived* price of risk of the portfolio that yields $\tilde{r}_M + b\tilde{g}_M$.

To further illustrate the mechanism in which ESG uncertainty comes into play, we rewrite the optimal portfolio as

$$x^* = \frac{1}{\gamma_{\mathit{eff}}} \frac{\mu_M + b\mu_{g,M}}{\sigma_M^2}, \tag{5}$$

where $\gamma_{\mathit{eff}} = \gamma \frac{\sigma_{M,U}^2}{\sigma_M^2}$ stands for the effective risk aversion. When the ESG profile is uncertain, the effective risk aversion exceeds the actual risk aversion γ.

To give perspective on the notion of effective risk aversion, consider the case that incorporates ESG preferences but excludes uncertainty. Then, the perceived volatility of the stock return is still σ_M. Conforming to intuition, the demand for stocks rises as b rises and the market is green. Essentially, stocks are more attractive to a green-loving agent.

When ESG uncertainty is accounted for, however, this intuition is no longer binding. To illustrate, we consider two limiting cases. In the first, b grows with no bound. The investor then avoids equities, i.e., $\lim\limits_{b\to\infty} \frac{1}{\gamma} \frac{\mu_M + b\mu_{g,M}}{\sigma_{M,U}^2} = 0$. Similarly, when uncertainty rises with no bound, the demand for stocks evaporates. That is, both increasing brown aversion and increasing uncertainty translate into increasing effective risk aversion. Altogether, in the presence of ESG uncertainty, a brown-averse agent could substantially reduce stock investing, even when the market is green.

Moving beyond the two limiting cases, we further examine portfolio tilts in the presence of ESG uncertainty. For that purpose, we rewrite the optimal portfolio as

$$x^* = \frac{1}{\gamma} \frac{\mu_M}{\sigma_M^2} \left(1 + b\frac{\mu_{g,M}}{\mu_M}\right) - \frac{1}{\gamma} \frac{\mu_M + b\mu_{g,M}}{\sigma_{M,U}^2} b^2 \frac{\sigma_{g,M}^2}{\sigma_M^2}. \tag{6}$$

Preferences for ESG generate two incremental terms relative to the benchmark case of ESG indifference. The first term, $\frac{1}{\gamma}\frac{b\mu_{g,M}}{\sigma_M^2}$, corresponds to the benchmark case with ESG preferences when the ESG profile is known for certain. It suggests that as b rises, the demand for the risky asset rises and portfolio tilt intensifies. The second term in equation (6) purely reflects the incremental effect of uncertainty. The ratio $\frac{\sigma_{g,M}^2}{\sigma_M^2}$ stands for the notion that ESG uncertainty makes equity returns appear, *ex ante*, riskier. As a consequence, the incremental effect of ESG uncertainty on stock investing is negative.

In addition, when the market is green neutral (i.e., $\mu_{g,M} = 0$) and when the ESG profile is known for certain, stock investing is unaffected relative to ESG indifference. The presence of uncertainty about ESG is associated with portfolio tilts and discourages participation in the equity market.

We now turn to analyze the equilibrium implications. It is assumed that, in equilibrium, the representative agent's wealth is fully invested in the market portfolio. Thus, equalizing the optimal stock allocation in equation (4) to 1 yields the market premium. The market premiums for the cases of ESG indifference (I), ESG preference with no uncertainty (N), and ESG preference with uncertainty (U) are given by

$$\mu_M^I = \gamma\sigma_M^2, \tag{7}$$

$$\mu_M^N = \gamma\sigma_M^2 - b\mu_{g,M}, \tag{8}$$

$$\mu_M^U = \gamma_{\mathit{eff}}\sigma_M^2 - b\mu_{g,M}. \tag{9}$$

Retaining the assumptions of a green market and a brown-averse agent, the market premium in equation (8) diminishes relative to (7). This is because an agent who extracts nonpecuniary benefits from holding green stocks is willing to compromise on the equity premium relative to an ESG indifferent agent. If the market is green neutral, the equity premium is unchanged even when ESG preferences are accounted for.

Further accounting for uncertainty in equation (9), there are two conflicting forces. On the one hand, the market is perceived to be riskier; thus, it commands a higher market premium. On the other hand, the agent extracts nonpecuniary benefits from holdings in the green market, decreasing the market premium. The overall effect is inconclusive. If the market is green neutral, the equity premium increases relative to both benchmark cases due to the increasing risk channel.

The same conflicting forces exert influence on the Sharpe ratio (slope of the CAL) when accounting for ESG uncertainty, SR^U, relative to ESG indifference, SR^I. Given market return volatility, σ_M, it follows that $\frac{SR^U}{SR^I} = \frac{\gamma_{\mathit{eff}}}{\gamma} - \frac{b\mu_{g,M}}{\gamma\sigma_M^2}$. The first term is greater than one and reflects the increase in effective risk aversion and thus in the market premium. The second reflects the decrease in the market premium due to the nonpecuniary benefits from ESG investing.

In the presence of ESG preferences, the market risk premium thus incorporates an ESG-related alpha that can be defined as

$$\alpha_M^N = \mu_M^N - \mu_M^I = -b\mu_{g,M}, \tag{10}$$

$$\alpha_M^U = \mu_M^U - \mu_M^I = \sigma_M^2 \left(\gamma_{\mathit{eff}} - \gamma\right) - b\mu_{g,M}. \tag{11}$$

The no-uncertainty case is associated with a negative alpha when the market is green and the agent is brown-averse, while alpha is zero when the market is green neutral. With ESG uncertainty, alpha is positive when the market is green neutral. Otherwise, with a green market and a brown-averse agent, alpha is inconclusive due to the conflicting forces.

The single-security economy establishes a solid benchmark in which to comprehend the multi-asset setup to be developed later in the text. While the cross-sectional ESG-alpha relation is negative when ESG uncertainty is not accounted for, the single-security case provides the first clue that (1) alpha of a green stock could turn positive in the presence of ESG uncertainty and (2) the ESG-alpha relation could vary with ESG uncertainty.

Uncertainty about the ESG profile also has welfare implications. As we derive in Appendix A.1, the certainty equivalent rates of return in the three cases considered are

$$CE^I = \frac{1}{2\gamma}\left(\frac{\mu_M^I}{\sigma_M}\right)^2, \tag{12}$$

$$CE^N = \frac{1}{2\gamma}\left(\frac{\mu_M^N + b\mu_{g,M}}{\sigma_M}\right)^2, \tag{13}$$

$$CE^U = \frac{1}{2\gamma}\left(\frac{\mu_M^U + b\mu_{g,M}}{\sigma_{M,U}}\right)^2. \tag{14}$$

The equilibrium welfare difference $CE^N - CE^I$ turns out to be zero because, in general equilibrium, the reduced market premium in equation (8) counters the positive effect of holding green stocks on welfare. On the other hand, in a partial equilibrium setup (in which the agent is price taker: $\mu_M^N = \mu_M^I$), the welfare gap turns positive for a brown-averse agent with holdings in the green market.

In general equilibrium, the incremental contribution to welfare of ESG uncertainty is instead positive, as $CE^U - CE^N = \frac{\gamma}{2}\left(\sigma_{M,U}^2 - \sigma_M^2\right)$. The reason is that the increase in the market premium in equation (9) has a stronger impact on welfare than the increase in equity risk caused by ESG uncertainty. On the other hand, in a partial equilibrium setup (in which the agent is a price taker: $\mu_M^U = \mu_M^N$), the welfare implication of ESG uncertainty becomes negative because market risk increases. To illustrate, consider two agents who observe market return realizations. One agent accounts for ESG uncertainty to assess the risk-return profile of the investment, while the other agent does not. Both agents extract nonpecuniary benefits from holding green stocks. Then, uncertainty distorts the perceived risk-return trade-off and reduces economic welfare.

Collectively, uncertainty about the ESG profile affects portfolio selection, the market premium, CAL, and economic welfare. From a general equilibrium perspective, consider a brown-averse investor with holdings in the green market: (1) without uncertainty, the stock investment increases, the market premium declines, and welfare is unchanged relative to ESG indifference, and (2) with uncertainty, the stock investment decreases and the market premium can go either way, while welfare improves relative to ESG indifference. If we take the cost of equity capital fixed and consider a partial equilibrium setup, accounting for ESG preferences in a green market improves economic welfare relative to ESG indifference, while such welfare improvement deteriorates with ESG uncertainty.

2.2 A Multi-Asset Economy

We move on to formulate an economy populated with I optimizing agents, N risky assets, and a riskless asset. We aim to derive an asset pricing model for the cross-section of equity returns in the presence of ESG uncertainty, while we also extend the analysis of portfolio selection. First, it is useful to account for heterogeneous agents in the single-asset setup. Thus, consider I agents indexed by $i = 1, \dots, I$, who differ in their initial wealth $W_{i,0}$, absolute risk aversion A_i, and absolute brown aversion B_i. Market clearing requires that $\sum_{i=1}^{I} w_i x_i^* = 1$, where $w_i = \frac{W_{i,0}}{W_0}$ is the fraction of agent i's initial wealth relative to total aggregate wealth. With heterogeneous agents, the market premium under ESG uncertainty in equation (9) can be re-expressed as $\mu_M^U = \gamma_M \sigma_{M,U}^2 - b_M \mu_{g,M}$, where $\gamma_M = (\sum_{i=1}^{I} w_i \gamma_i^{-1})^{-1}$ is the aggregate relative risk aversion, $b_M = \frac{\sum_{i=1}^{I} w_i \gamma_i^{-1} b_i}{\sum_{i=1}^{I} w_i \gamma_i^{-1}}$ is the aggregate brown aversion, and $b_i = \frac{B_i}{A_i}$. Note that b_M is the harmonic weighted average of b_i, with weights that are equal to the product of the agents' risk tolerance and initial wealth.

Next, we model the excess returns and ESG signals on N assets as

$$\tilde{\boldsymbol{r}} = \boldsymbol{\mu}_r + \tilde{\boldsymbol{\epsilon}}_r, \tag{15}$$

$$\tilde{\boldsymbol{g}} = \boldsymbol{\mu}_g + \tilde{\boldsymbol{\epsilon}}_g, \tag{16}$$

where $\boldsymbol{\mu}_r$ is an N vector of expected excess returns and $\boldsymbol{\mu}_g$ is an N vector of expected ESG scores. The residuals from both equations are assumed to obey independent N-variate normal distributions. The $N \times N$ covariance matrix of returns is denoted by $\boldsymbol{\Sigma}_r$, and the $N \times N$ covariance matrix of ESG signals is denoted by $\boldsymbol{\Sigma}_g$.

Similar to equation (3), the agent maximizes an exponential utility function, $V\left(\tilde{W}_{i,1}, \boldsymbol{X}_i\right) =$

$-e^{-A_i\tilde{W}_{i,1}-B_iW_{i,0}\boldsymbol{X}_i'\tilde{\boldsymbol{g}}}$, where $\tilde{W}_{i,1} = W_{i,0}\left(1 + r_f + \boldsymbol{X}_i'\tilde{\boldsymbol{r}}\right)$ is the terminal wealth and $\boldsymbol{X}_i$ is the $N \times 1$ vector of portfolio weights per investor i.

Proposition 1 describes the optimal portfolio in the presence of multiple risky assets. The proof is in Appendix A.2.

Proposition 1. *The optimal portfolio strategy of investor i is given by*

$$\boldsymbol{X}_i^* = \frac{1}{\gamma_i}\boldsymbol{\Sigma}_i^{-1}\left(\boldsymbol{\mu}_r + b_i\boldsymbol{\mu}_g\right), \tag{17}$$

where $\boldsymbol{\Sigma}_i = \boldsymbol{\Sigma}_r + b_i^2\boldsymbol{\Sigma}_g$ is the covariance matrix of $\tilde{\boldsymbol{r}} + b_i\tilde{\boldsymbol{g}}$.

This portfolio strategy is the multi-asset version of equation (4). It suggests that in the presence of ESG uncertainty, investors perceive asset returns to be the sum of (1) N stock returns and (2) N pseudo asset returns given by $b_i\tilde{\boldsymbol{g}}$. Several implications arise. First, infinitely brown-averse agents act as if they were infinitely risk averse, as $\lim_{b_i\to\infty}\boldsymbol{X}_i^* = \boldsymbol{0}$. Second, in another extreme case when ESG uncertainty grows with no bound for all stocks, economic agents avoid stocks altogether. Third, in intermediate cases, uncertainty about ESG profiles tends to reduce the demand for both green and brown stocks.

To highlight the incremental contribution of ESG uncertainty, we can rewrite equation (17) as

$$\boldsymbol{X}_i^* = \frac{1}{\gamma_i}\boldsymbol{\Sigma}_r^{-1}\left(\boldsymbol{\mu}_r + b_i\boldsymbol{\mu}_g\right) + \frac{1}{\gamma_i}\boldsymbol{\Psi}_{i,U}\left(\boldsymbol{\mu}_r + b_i\boldsymbol{\mu}_g\right), \tag{18}$$

where $\boldsymbol{\Psi}_{i,U} = -b_i^2\boldsymbol{\Sigma}_r^{-1}\boldsymbol{\Sigma}_g\boldsymbol{\Sigma}_r^{-1}\left(\mathbf{I}_N + b_i^2\boldsymbol{\Sigma}_g\boldsymbol{\Sigma}_r^{-1}\right)^{-1}$ and $\mathbf{I}_N$ stands for the $N\times N$ identity matrix.

The first term of the optimal portfolio also appears in Pastor et al. (2020) (equation (4)). The second is the maximum Sharpe ratio portfolio in the ESG uncertainty-return universe. This term comes into play when there is ESG uncertainty ($\boldsymbol{\Sigma}_g \neq \boldsymbol{0}$) and when $b_i \neq 0$.

To analyze fund separation, consider the following decomposition of the optimal portfolio:

$$\boldsymbol{X}_i^* = \lambda^r\boldsymbol{\Gamma}_{i,\mathit{eff}}^{-1}\frac{\boldsymbol{\Sigma}_r^{-1}\boldsymbol{\mu}_r}{\mathbf{1}'\boldsymbol{\Sigma}_r^{-1}\boldsymbol{\mu}_r} + \lambda^g b_i\boldsymbol{\Gamma}_{i,\mathit{eff}}^{-1}\frac{\boldsymbol{\Sigma}_r^{-1}\boldsymbol{\mu}_g}{\mathbf{1}'\boldsymbol{\Sigma}_r^{-1}\boldsymbol{\mu}_g}, \tag{19}$$

where $\lambda^r = \mathbf{1}'\boldsymbol{\Sigma}_r^{-1}\boldsymbol{\mu}_r$, $\lambda^g = \mathbf{1}'\boldsymbol{\Sigma}_r^{-1}\boldsymbol{\mu}_g$, and $\boldsymbol{\Gamma}_{i,\mathit{eff}} = \gamma_i\left(\mathbf{I}_N + b_i^2\boldsymbol{\Sigma}_r^{-1}\boldsymbol{\Sigma}_g\right)$.

The model implies that each agent holds three portfolios: (1) a riskless asset, (2) the maximum Sharpe ratio portfolio in the risk-return space, and (3) the maximum Sharpe ratio portfolio in the risk-ESG space. Note that ESG uncertainty affects the demand for risky assets through the effective risk aversion channel, denoted by the $N \times N$ matrix $\boldsymbol{\Gamma}_{i,\mathit{eff}}$. Effective risk aversion appears in both risky asset portfolios. If all agents have the same b_i, the effective risk aversion matrix (excluding γ_i) is common to all agents, and therefore, a three-fund separation is obtained. Otherwise, the proportions invested in the two risky portfolios are agent-specific and, hence, fund separation is not obtained.

It is also useful to consider a simplified case of two risky assets (along with a riskless asset): one is green, while the other is brown, with expected excess returns denoted by $\mu_{r,green}$ and $\mu_{r,brown}$, respectively. We assume that asset returns are uncorrelated and have identical variance that is equal to σ_r^2. Further, we assume that ESG scores are uncorrelated with each other and have variances denoted by $\sigma^2_{g,green}$ and $\sigma^2_{g,brown}$. We finally assume that the mean ESG scores are $\mu_g > 0$ for the green firm and $-\mu_g$ for the brown firm.

The two-asset optimal strategy (derivation in Appendix A.3) is formulated as

$$X^*_{i,green} = \frac{1}{\gamma_{i,\mathit{eff},green}} \frac{\mu_{r,green} + b_i \mu_g}{\sigma_r^2}, \tag{20}$$

$$X^*_{i,brown} = \frac{1}{\gamma_{i,\mathit{eff},brown}} \frac{\mu_{r,brown} - b_i \mu_g}{\sigma_r^2}, \tag{21}$$

where $\gamma_{i,\mathit{eff},green} = \gamma_i \left(1 + b_i^2 \frac{\sigma^2_{g,green}}{\sigma_r^2}\right)$ and $\gamma_{i,\mathit{eff},brown} = \gamma_i \left(1 + b_i^2 \frac{\sigma^2_{g,brown}}{\sigma_r^2}\right)$ are the effective risk aversion parameters corresponding to green and brown investing. The optimal portfolio illustrates that demand falls with higher ESG uncertainty but rises with higher ESG scores. The notion is that when targeting an ESG level, uncertainty about the precise ESG profile should be accounted for.

2.3 CAPM with ESG Uncertainty

The next two propositions illustrate the cross-sectional asset pricing implications of ESG preferences, first excluding and then accounting for ESG uncertainty. The proofs are in Appendix A.4 and A.5.

Proposition 2. *Excluding ESG uncertainty, the equilibrium expected returns of the risky assets are given by*

$$\boldsymbol{\mu}_r^N = \boldsymbol{\beta}^N \mu_M^N - b_M \left(\boldsymbol{\mu}_g - \boldsymbol{\beta}^N \mu_{g,M}\right), \tag{22}$$

where $\mu_M^N = \gamma_M \left(\sigma_M^N\right)^2 - b_M \mu_{g,M}$ *is the equilibrium market premium,* $(\sigma_M^N)^2 = (\boldsymbol{X}_M^N)' \boldsymbol{\Sigma}_r \boldsymbol{X}_M^N$ *is the market return variance,* $\boldsymbol{\beta}^N = \frac{\boldsymbol{\Sigma}_r \boldsymbol{X}_M^N}{(\sigma_M^N)^2}$ *is the* N*-vector of market beta,* $\mu_{g,M} = (\boldsymbol{X}_M^N)' \boldsymbol{\mu}_g$ *is the aggregate market greenness,* $\boldsymbol{X}_M^N = \sum_{i=1}^I w_i \boldsymbol{X}_i^N$ *is the* N*-vector of aggregate market positions in risky assets,* $\gamma_M = (\sum_{i=1}^I w_i \gamma_i^{-1})^{-1}$ *is the aggregate risk aversion, and* $b_M = \frac{\sum_{i=1}^I w_i \gamma_i^{-1} b_i}{\sum_{i=1}^I w_i \gamma_i^{-1}}$ *is the aggregate brown aversion.*

Expected returns are affected by ESG preferences through (1) the modified market premium and (2) the alpha component that stands for excess return unexplained by $\boldsymbol{\beta}^N \mu_M^N$.

Alpha depends on the effective ESG score, i.e., the difference between the firm's own ESG score and the market ESG score multiplied by the stock's beta. A numerical example is useful to illustrate. Assume a stock with $\beta^N = 1.2$ and $\mu_{g,M} = 2$. As long as the ESG score is below 2.4, the stock has a positive alpha even when the stock is green. The threshold value 2.4 reflects zero alpha, while alpha turns negative if the ESG score goes above the threshold. For instance, if the ESG score is 3 (2), the effective ESG score is 0.6 (-0.4), and alpha is negative (positive). Altogether, it is not the firm's own ESG score that dictates the sign and magnitude of alpha. Instead, it is the effective ESG score.

Note that in the presence of ESG preferences and certainty about the ESG profile, the beta measuring exposure to total market risk, $\boldsymbol{\beta}^N$, coincides with the CAPM beta. This is because, as shown earlier, the perceived return on any security is equal to the sum of (1) the actual return and (2) the pseudo asset return that is proportional to the ESG score, while the ESG score is nonrandom. That is, in the absence of ESG uncertainty, the covariance and variance terms used to define the beta are unchanged. With uncertainty, the ESG score is random; hence, the resulting beta is no longer identical to the standard CAPM beta.

As derived by Pastor et al. (2020), in the absence of ESG uncertainty, equilibrium expected returns compensate for exposures to (1) the market risk factor and (2) an ESG-based factor. When ESG uncertainty is in play, fund separation is no longer obtained, and thus, we cannot express expected returns in a multifactor model. Instead, we focus on a CAPM-type representation, where expected returns are expressed as the sum of two components: the first reflects the exposure to the market factor, while the second is a nonzero alpha that stands for (1) nonpecuniary benefits from ESG investing and (2) an additional risk premium attributable to ESG uncertainty. The following proposition explains the equilibrium expected returns with ESG uncertainty, which is the core of our analysis.

Proposition 3. *With ESG uncertainty, the equilibrium expected excess returns of the risky assets are formulated as*

$$\boldsymbol{\mu}_r^U = \boldsymbol{\beta}^U \mu_M^U + \left(\boldsymbol{\beta}_{\mathit{eff}} - \boldsymbol{\beta}^U\right) \mu_M^U - \left(\boldsymbol{\mu}_{g,U} - \boldsymbol{\beta}_{\mathit{eff}}\, \mu_{g,M,U}\right), \tag{23}$$

where $\mu_M^U = \gamma_{M,\mathit{eff}} \left(\sigma_M^U\right)^2 - \mu_{g,M,U}$ *is the equilibrium market premium and* $\boldsymbol{\beta}^U = \frac{\boldsymbol{\Sigma}_r \boldsymbol{X}_M^U}{(\sigma_M^U)^2}$ *is the* N*-vector of the equilibrium CAPM beta. The other quantities used to define expected returns are described in Appendix A.5.*

Equation (23) formulates the expected returns on N risky assets as the sum of three terms. We discuss below the economic intuition of the beta pricing specification while narrowing down the focus to the case in which agents have homogeneous preferences (γ and b equal across agents). The first term depends on the market beta $\boldsymbol{\beta}^U$ and compensates for the exposure to market risk, as in the standard CAPM. ESG uncertainty indirectly affects the magnitude of this term through the equilibrium market premium μ_M^U. The second term arises from ESG uncertainty, which makes the effective beta, $\boldsymbol{\beta}_{\mathit{eff}}$, different from the CAPM beta. The vector of effective beta is given by $\frac{(\boldsymbol{\Sigma}_r + b^2 \boldsymbol{\Sigma}_g)\boldsymbol{X}_M^U}{(\sigma_M^U)^2 + (\sigma_{g,M}^U)^2}$. In the presence of ESG uncertainty, the perceived return on an arbitrary asset consists of two components: (1) the actual return and (2) b times the ESG score of that asset. Because ESG scores for the market and individual assets are random, both the covariance and variance terms used to compute the market beta depart from the standard case. The effective beta tends to be higher than the CAPM beta for stocks with high ESG uncertainty, while it does not explicitly depend on the ESG score. The third term in equation (23), which is equal to $-b\left(\boldsymbol{\mu}_g - \boldsymbol{\beta}_{\mathit{eff}}\,\mu_{g,M}\right)$ for homogeneous agents, accounts for the effective ESG scores of the assets. The mechanism is analogous to that in equation (22), with the effective beta replacing the market beta.

To provide more intuition on the implications of ESG uncertainty for alpha and beta, we revisit the simplified two-risky-asset setup. Assuming homogeneous preferences across agents, expected returns on the green and brown assets are formulated as (derivation in Appendix A.6)

$$\mu_{r,green}^U = \gamma\left(\sigma_M^U\right)^2 \beta_{green}^U \left(1 + b^2 \frac{\sigma_{g,green}^2}{\sigma_r^2}\right) - b\mu_g, \tag{24}$$

$$\mu_{r,brown}^U = \gamma\left(\sigma_M^U\right)^2 \beta_{brown}^U \left(1 + b^2 \frac{\sigma_{g,brown}^2}{\sigma_r^2}\right) + b\mu_g, \tag{25}$$

where β_{green}^U and β_{brown}^U are the equilibrium CAPM betas. While the second term in equations (24) and (25) suggests a negative relation between the mean ESG score and alpha, the rising effective risk aversion and effective betas in the first term may increase expected returns to the extent that even a green asset could deliver a positive alpha. This effect appears in the first term and is captured by the coefficients $1 + b^2 \frac{\sigma_{g,green}^2}{\sigma_r^2}$ and $1 + b^2 \frac{\sigma_{g,brown}^2}{\sigma_r^2}$, which depend on asset-specific ESG uncertainty. Ultimately, a green firm with high ESG uncertainty could deliver a higher alpha than a brown firm with low uncertainty.

3 Data

3.1 Data Sources

Our sample consists of all NYSE/AMEX/Nasdaq common stocks with share codes 10 or 11; daily and monthly stock data are obtained from the Center for Research in Security Prices (CRSP). We collect ESG rating data from six data vendors, including Asset4 (Refinitiv), MSCI KLD, MSCI IVA, Bloomberg, Sustainalytics, and RobecoSAM. These data providers represent the major players in the ESG rating market, and their ratings are widely used by practitioners as well as a growing number of academic studies (e.g., Eccles and Stroehle (2018); Berg et al. (2020); Gibson et al. (2020)).

Quarterly and annual financial statement data come from the COMPUSTAT database. Analyst forecast data come from the Institutional Brokers' Estimate System (I/B/E/S). We also acquire quarterly institutional equity holdings from the Thomson-Reuters Institutional Holdings (13F) database.[8] The full sample period ranges from 2002 to 2019. Our sample begins in 2002, as we require ESG ratings from at least two data vendors.

3.2 Main Variables

We focus on the overall ESG rating from each data provider, i.e., "ESG Combined Score" from Asset4, "ESG Rating" from MSCI IVA, "ESG Disclosure Score" from Bloomberg, "Sustainalytics Rank" from Sustainalytics, and "RobecoSAM Total Sustainability Rank" from RobecoSAM.[9] For MSCI KLD data, we construct an aggregate ESG rating by summing all strengths and subtracting all concerns (e.g., Lins et al. (2017); Berg et al. (2020)).

ESG rating agencies may differ in sample coverage and rating scale. Panel A of Appendix Table B.1 reports the number of U.S. common stocks covered by each data vendor over time. In addition, Asset4, Bloomberg, Sustainalytics, and RobecoSAM apply a scale from 0 to 100, MSCI IVA uses a seven-tier rating scale from the best (AAA) to the worst (CCC), and the MSCI KLD rating ranges from -11 to $+19$ in our sample. Panel B further demonstrates that requiring a common sample covered by all data vendors could significantly reduce the sample size and shorten the sample period. Therefore, we focus on pairwise ESG rating disagreement and then average across all rater pairs. In our context, disagreement among ESG raters proxies for uncertainty about a firm's ESG profile; hence, we label such disagreement ESG uncertainty to be consistent with the model terminology.

Specifically, we obtain 14 rater pairs from the six data providers.[10] To achieve comparability across rating agencies, we proceed as follows. For each rater pair-year, we sort all stocks covered by both raters according to the original rating scale of the respective data provider

[8]The institutional ownership data come from money managers' quarterly 13F filings with the U.S. Securities and Exchange (SEC). The database contains the positions of all institutional investment managers with more than \$100 million U.S. dollars under discretionary management. All holdings worth more than \$200,000 U.S. dollars or 10,000 shares are reported in the database.

[9]Although the Bloomberg ESG disclosure score measures the extent of disclosure of ESG-related data by a company, it is positively associated with ESG quality due to the largely voluntary nature of ESG disclosure requirements (López-de-Silanes et al. (2020)).

[10]There are 14 (instead of 15) rater pairs because MSCI KLD data are only available until 2015, while RobecoSAM data start in 2016, as shown in Panel A of Appendix Table B.1.

and calculate the percentile rank (normalized between 0 and 1) for each stock-rater pair. Then, for each stock, we compute the pairwise rating uncertainty as the standard deviation of the ranks provided by the two raters in the pair. Finally, we compute the firm-level ESG rating uncertainty as the average pairwise rating uncertainty across all rater pairs. Similarly, we compute the pairwise average rank and then average across all rater pairs to obtain the firm-level ESG rating. Table 1 provides detailed definitions for each variable.

For perspective, Panels A and B of Table 2 present the pairwise ESG uncertainty and correlation of ESG ratings, respectively. The average correlation across all rater pairs is 0.48 and ranges from 0.25 to 0.71. MSCI KLD and MSCI IVA exhibit the lowest correlation and the highest rating disagreement with other raters, and the average correlation is 0.38 and 0.34, respectively. On the other hand, ratings provided by Sustainalytics and RobecoSAM are more correlated with those of other raters, and the average correlation is 0.59 and 0.56, respectively. Our findings are largely consistent with the existing literature and echo the growing concerns related to the lack of agreement across ESG rating agencies (e.g., Chatterji et al. (2016); Amel-Zadeh and Serafeim (2018); Berg et al. (2020); Gibson et al. (2020)).

Table 2, Panel C reports the summary statistics for the stock-level data used in the paper. We report the mean, standard deviation, median, and quantile distribution of the annual ESG rating and ESG rating uncertainty and other stock characteristics. The average ESG rating is 0.46, and the ESG rating uncertainty is 0.18. As an example, a company that is ranked by two data providers at the 33^{rd} and 59^{th} percentiles would generate a rating uncertainty of 0.18.

4 Calibration

We calibrate the model to quantitatively assess the implications of ESG rating uncertainty for the risk-return trade-off and economic welfare. Prior work offers reasonable estimates for relative risk aversion, market premium, and market volatility. However, the ESG-based parameters, namely, $\frac{B}{A}$, $\mu_{g,M}$, $\sigma^2_{g,M}$, and stock-level counterparts, are largely unknown. In the data section above, we describe ways to map ESG ratings into scores for individual securities, and the market-level ESG rating follows through aggregation. However, the resulting quantities are not on the scale of equity returns and are ordinal in nature. That is, a higher ESG rating indicates greener stocks, while a higher standard deviation among raters amounts to greater uncertainty. Thus, stock-level and market-level ratings as well as measures of rating uncertainty can comfortably be used in cross-sectional and time-series regressions to evaluate the implications of the model. In the calibration experiments, an additional transformation is required to make the ESG information interpretable from a return perspective. We provide the steps below.

We start with equation (9) and rewrite it as

$$\gamma = \frac{\mu_M^U + \frac{B}{A}\mu_{g,M}}{\sigma_M^2 + \left(\frac{B}{A}\right)^2 \sigma_{g,M}^2}. \tag{26}$$

We fix the annual mean and standard deviation of the equity premium to be 7% and 16%, respectively, and pick $\gamma = 2$, within reasonable previous measures.[11] We then consider two distinct investors who observe the same return realizations on investable assets. One investor accounts for ESG preferences in assessing the risk-return profile of the optimal portfolio, while the other investor is ESG neutral. For the former investor, in the presence of ESG uncertainty, the market is essentially riskier, as formulated earlier, regardless of whether the market is green, brown, or neutral.

We analyze three values for $\frac{B}{A}$, namely, 0.5, 1, and 2, with the higher measure representing a stronger preference for green stocks. We first assume that the market is green neutral and use equation (26) to recover market-level ESG uncertainty $\sigma_{g,M}$. At the stock level, we tilt the mean ESG scores and rescale the ESG variances so that their cross-sectional averages conform to the market-wide ESG mean and variance, respectively. We next relax the assumption that the market is green neutral and introduce a positive ESG tilt. To do so, we set the market-level quantity $\frac{B}{A}\mu_{g,M}$ to be 1% per year, meaning that $\mu_{g,M}$ is unique and positive for each of the $\frac{B}{A}$ values. We again adjust the stock-level mean ESG scores $\boldsymbol{\mu}_g$ so that their cross-sectional average equals $\mu_{g,M}$. The calibration experiment is conducted from a partial equilibrium perspective, as we shut down the channel of higher market risk triggering a higher market premium.[12] Then, we can make a fair comparison between two agents who observe returns on investable stocks and form estimates for the first and second moments.

Our investment universe consists of a riskless asset and 25 equity portfolios independently sorted on the ESG rating and rating uncertainty. Summary statistics for the equity portfolios are presented in Table 2, Panel D. At this point, we are ready to generate the efficient frontier of risky assets, as formulated in the theory section. Altogether, we generate $6 \times 3 \times 2$ efficient frontiers, corresponding to the market being green neutral (3 cases with respect to $\frac{B}{A}$ values) and displaying a positive ESG tilt (also 3 cases), all of which are interacted with (1) ESG indifference, (2) ESG preferences without uncertainty, and (3) ESG preferences

[11] See Mehra and Prescott (1985).

[12] From a general equilibrium perspective, we can learn from Section 2.1 that welfare actually increases in the presence of ESG uncertainty, as long as the market premium reflects the increasing risk due to ESG uncertainty.

with uncertainty, as well as conducted with and without nonnegativity constraints on equity positions.

For each portfolio, we report in Table 3 the monthly Sharpe ratio, the monthly *perceived* Sharpe ratio (i.e., the Sharpe ratio accounting for ESG-adjusted returns, $\tilde{\boldsymbol{r}} + \frac{B}{A}\tilde{\boldsymbol{g}}$),[13] and the certainty equivalent monthly return (derivation in Appendix A.7), with Panel A for the market being green neutral and Panel B for the market being green on average. ESG I, ESG N, and ESG U represent ESG indifference, ESG preferences without uncertainty, and ESG preferences with uncertainty, respectively. By construction, as it is consistent with the investor's objective, the return-based Sharpe ratio is the highest for ESG I. However, accounting for ESG preferences is typically associated with higher perceived Sharpe ratios, and we find a larger increase from ESG I to ESG N when $\frac{B}{A}$ is higher and when the market is greener. More remarkably, ESG uncertainty considerably harms investment opportunities. To illustrate, consider the case when $\frac{B}{A} = 1$. The monthly perceived Sharpe ratio for ESG N is 0.46, and it sharply falls to 0.22 when uncertainty is accounted for. Results for the welfare drop are just as striking. For instance, the certainty equivalent drops from 5.39% to 1.32% per month. The certainty equivalent loss increases with the ratio $\frac{B}{A}$.

Unconstrained mean-variance portfolios are often associated with extreme stock positions and thus possibly inflated *ex ante* Sharpe ratios and welfare.[14] Thus, as a robustness check, we repeat the calibration exercise accounting for nonnegativity constraints. Indeed, in the presence of portfolio constraints, the *ex ante* Sharpe ratios uniformly drop. Nevertheless, the maximal perceived Sharpe ratio falls from 0.28 (ESG N) to 0.21 (ESG U) per month when ESG uncertainty is accounted for. The corresponding certainty equivalent return significantly drops from 2.00% to 1.26%. That is, ESG uncertainty leads to a nearly 9% annual drop in the certainty equivalent rate of return.

As shown in Panel B, the findings are stronger when the market displays a positive ESG tilt. Take the constrained case with $\frac{B}{A} = 1$ as an example. Accounting for ESG uncertainty reduces the maximal perceived Sharpe ratio from 0.29 to 0.22 per month and reduces the certainty equivalent rate of return from 2.26% to 1.30% per month. Overall, we reinforce the observation that the lack of consistency in ESG ratings could distort the risk-return trade-off and reduce economic welfare.

[13] When ESG preferences without uncertainty are considered, the perceived Sharpe ratio is the ratio between the ESG-adjusted expected portfolio return and the non-uncertainty-adjusted standard deviation of the portfolio return. When the agent accounts for ESG uncertainty, it is the ratio between the ESG-adjusted expected portfolio return and the uncertainty-adjusted standard deviation of the portfolio return.

[14] Although our propositions do not require short-sale constraints, we provide a comprehensive set of calibration results with and without nonnegativity constraints. The difficulty in estimating the mean return and the covariance matrix is discussed by Merton (1980) and Green and Hollifield (1992), among others.

5 Investor Demand, Stock Return, and Risk

5.1 Investor Demand

We start with the first testable hypothesis generated from the model, i.e., investor demand for risky assets diminishes with ESG rating uncertainty due to higher effective risk aversion, as formulated in Proposition 1 along with equations (20) and (21). In particular, we rely on institutional ownership to proxy for investors' interest in owning a stock. At the end of each year t, we independently sort stocks into quintile portfolios based on their ESG rating and rating uncertainty to generate 25 (5×5) portfolios. The low- (high)-ESG-rating and ESG-rating-uncertainty portfolios comprise the bottom (top) quintile of stocks based on the ESG rating and ESG rating uncertainty, respectively. We compute the quarterly institutional ownership in year $t + 1$ for each of the 25 portfolios and the difference in institutional ownership between low- and high-ESG-rating portfolios ("LMH") as well as between high- and low-ESG-rating-uncertainty portfolios ("HML"). The standard errors in all estimations are corrected for autocorrelation using the Newey and West (1987) method.

As shown in Table 4, ESG rating uncertainty reduces investor demand, especially for stocks with extreme ESG ratings. For instance, green stocks (i.e., stocks in the top ESG rating quintile) with low rating uncertainty display institutional ownership of 73%, while this figure declines to 65% for green stocks with high rating uncertainty. Moving to brown stocks (i.e., stocks in the bottom ESG rating quintile), institutional ownership is 71% when rating uncertainty is low and declines to 65% when rating uncertainty is high. The ownership gap between high- and low-uncertainty portfolios is statistically significant and economically meaningful, accounting for 7% to 11% of the average institutional ownership in our sample. Not surprisingly, investor demand is less affected among stocks ranked in the middle 60% in terms of ESG ratings, as such investment may not be ESG-driven, and hence, rating uncertainty plays a minor role in asset allocation decisions. Our findings suggest that although institutional investors are likely to be more sophisticated and have access to privileged information, uncertainty about corporate ESG profiles remains an important barrier to their investment. This could further limit their capacity to engage in ESG issues and improve the ESG performance of the firm (e.g., Dimson et al. (2015); Dyck et al. (2019); Chen et al. (2020)).

In addition, we do not find strong evidence that institutional investors are in favor of greener firms, partially because we focus on the subset of stocks covered by at least two ESG rating agencies and employ the average ESG rating across all data providers. However, in line with our working hypothesis, we find that the ownership gap between low- and high-ESG rating portfolios attenuates when rating uncertainty increases. When uncertainty is low, green stocks display 2.6% higher institutional ownership than brown stocks, while the ownership gap declines to 0.7% when rating uncertainty is high. As more institutions seek sustainable investing, it is likely that ESG-induced investor demand will play a more prominent role in the future. Overall, our findings support the model prediction that ESG rating uncertainty reduces investor demand, especially when investors are sensitive to ESG information. We will further examine the asset pricing implications of ESG uncertainty in the next subsection.

5.2 Cross-Sectional Return Predictability

In line with Pastor et al. (2020), our model predicts a negative relationship between the ESG rating and CAPM alpha when there is no uncertainty in ESG ratings (Proposition 2). Negative return predictability stems from nonpecuniary benefits from holding green stocks. However, the ESG-alpha relationship is less clear in the presence of ESG uncertainty due to the conflicting forces of the uncertainty-adjusted stock beta and ESG rating (Proposition 3).

We assess return predictability using a conventional portfolio sort. In particular, at the end of each year t, we sort stocks into quintile portfolios based on their ESG rating uncertainty. Within each rating uncertainty group, we further sort stocks into quintile portfolios according to their ESG ratings and generate 25 (5×5) portfolios.[15] The low- (high)-ESG-rating and ESG-rating-uncertainty portfolios comprise the bottom (top) quintile of stocks based on the ESG rating and ESG rating uncertainty, respectively. We compute the value-weighted monthly return in year $t+1$ for each of the 25 portfolios. Within each quintile of portfolios sorted by ESG rating uncertainty, we also implement the zero-cost trading strategy by taking long positions in the bottom quintile of stocks (lowest ESG rating) and selling short stocks in the top quintile (highest ESG rating). The payoff of the long-short investment strategy is computed as the low (bottom quintile) minus high (top quintile) portfolio return ("LMH"), indicating the return predictability of ESG ratings after controlling for rating uncertainty.

In addition to raw portfolio returns, we report risk-adjusted returns from **(1)** the CAPM, i.e., only adjusting for the market factor (MKT, defined as the excess return on the value-weighted CRSP market index over the one-month Treasury bill rate); **(2)** the Fama-French-Carhart 4-factor model (FFC) consisting of the market factor (MKT), the size factor (SMB, defined as small minus big firm return premium), the book-to-market factor (HML, defined as the high book-to-market minus the low book-to-market return premium) (Fama and French (1993)), and Carhart (1997) the momentum factor (MOM, defined as the winner minus loser

[15] We employ a conditional sort to better control for rating uncertainty, while an independent sort yields similar findings (Table 2, Panel D3).

return premium); and **(3)** the Fama-French 6-factor model (FF6) consisting of the market factor (MKT), the size factor (SMB), the book-to-market factor (HML), the profitability factor (RMW, defined as the robust minus weak return premium), the investment factor (CMA, defined as the conservative minus aggressive return premium), and the momentum factor (MOM) (Fama and French (2018)).[16] The standard errors in all estimations are corrected for autocorrelation using the Newey and West (1987) method.

Table 5 reports the results, with Panel A for raw return, Panel B for CAPM-adjusted return, Panel C for FFC-adjusted return, and Panel D for FF6-adjusted return. Several findings are worth noting. First, the ESG rating is negatively associated with future performance among stocks with low rating uncertainty, and the long-short portfolio return is significant at 0.59% per month. Brown stocks (i.e., stocks in the bottom ESG rating quintile) continue to outperform green stocks (i.e., stocks in the top ESG rating quintile) after adjusting for risk exposures, i.e., the long-short portfolio yields a CAPM-adjusted (FFC-adjusted, FF6-adjusted) return of 0.40% (0.46%, 0.50%) per month.[17]

Second, the negative return predictability of ESG ratings no longer holds for the remaining firms and even turns positive in some cases. For perspective, we also consider a univariate portfolio sort based on ESG ratings and report similar statistics in the column titled "All". The ESG rating does not predict stock returns for the full sample, which is consistent with the existing literature showing weak return predictability of the overall ESG rating (e.g., Pedersen et al. (2020)) and mixed evidence based on different ESG proxies (e.g., Gompers et al. (2003); Hong and Kacperczyk (2009); Bolton and Kacperczyk (2020)). Our results further highlight the importance of rating uncertainty, as it not only affects investor demand but also has meaningful asset pricing implications, i.e., the negative ESG-alpha relation *only* exists among stocks with low rating uncertainty. The lack of consistency across ESG rating agencies could be a barrier for investors who have to balance information on ESG scores and uncertainty when making portfolio decisions.

Additionally, we consider a univariate portfolio sort based on ESG uncertainty and report the results in the row titled "All". Returns are increasing in ESG uncertainty, even though the patterns are not always monotonic. Furthermore, the high-minus-low ESG uncertainty portfolio shows a monthly CAPM alpha of 0.23% that is statistically significant at the 10% level, supporting the model prediction that market alpha increases with ESG rating uncer-

[16] We thank Kenneth French for making the common factor returns available via his website: `https://mba.tuck.dartmouth.edu/pages/faculty/ken.french/data_library.html`.

[17] As our model is derived in market equilibrium, it is based on one market factor. However, the economic magnitude and statistical significance in FFC-adjusted and FF6-adjusted returns reinforce our conclusion that accounting for rating uncertainty can be useful even for investors who use multiple investment factors in their portfolio decisions.

tainty. Collectively, our findings support the model predictions, i.e., brown stocks outperform green stocks *only* in the absence of rating uncertainty, and ESG uncertainty could tilt this relationship via conflicting forces, as illustrated in Proposition 3.

As a robustness check, we perform regression analysis to further control for other firm characteristics. Specifically, we estimate the following monthly Fama and MacBeth (1973) regression:

$$\begin{aligned} Perf_{i,m} = \alpha_0 + \beta_1 ESG_{i,m-1} + \beta_2 ESG_{i,m-1} \times Low\ ESG\ Uncertainty_{i,m-1} \\ + \beta_3 Low\ ESG\ Uncertainty_{i,m-1} + \boldsymbol{\beta}_4' \boldsymbol{M}_{i,m-1} + e_{i,m}, \end{aligned} \tag{27}$$

where $Perf_{i,m}$ refers to the excess return or CAPM-adjusted return of stock i in month m, $ESG_{i,m-1}$ refers to the ESG rating, $Low\ ESG\ Uncertainty_{i,m-1}$ refers to a dummy variable that takes a value of 1 if the ESG rating uncertainty is in the bottom quintile across all stocks in that month and 0 otherwise. The vector $\boldsymbol{M}$ stacks all other control variables, including the *Log(Size)*, *Log(BM)*, *6M Momentum*, *Log(Illiquidity)*, *Gross Profitability*, *Corporate Investment*, *Leverage*, *Log(Analyst Coverage)* and *Analyst Dispersion*. The parameter of interest is β_2. Since the model predicts a negative ESG-performance relationship when there is no rating uncertainty, we should see a negative value of β_2. Table 1 provides detailed definitions for each variable. We also report Newey and West (1987) adjusted t-statistics.

We tabulate the results in Table 6, with models 1 to 4 for excess return and models 5 to 8 for CAPM-adjusted return. As expected, the ESG rating does not predict stock returns for the full sample. More importantly, the ESG rating is negatively associated with future stock performance when rating uncertainty is low. This relation is significant across all regression specifications after controlling for other potential sources of uncertainty about corporate ESG profiles and disagreement on firm fundamentals, such as analyst dispersion. Overall, we confirm the early results in the portfolio sort and provide supporting evidence for the ESG-adjusted CAPM after considering rating uncertainty.

5.3 Systematic Risk Exposure

Beyond financial performance, extensive literature also documents that a better ESG profile reduces a firm's risk exposure (e.g., Albuquerque et al. (2019); Hoepner et al. (2019); Ilhan et al. (2020)). Intuitively, given the high uncertainty in ESG issues, a higher standard of corporate ESG practice helps mitigate legal, regulatory, operational, and financial risks. Albuquerque et al. (2019) show that firms with a high corporate social responsibility (CSR) score display higher profit margins, less cyclical profits, and lower systematic risk. Our model further considers the uncertainty in ESG ratings and implies that such uncertainty also contributes to a firm's perceived systematic risk, i.e., uncertainty-adjusted stock beta, as illustrated in Proposition 3 and equations (24) and (25).

We implement a portfolio analysis similar to that in Table 5 and report the average stock beta for each of the 25 portfolios first sorted by ESG rating uncertainty and then by ESG ratings. The stock beta is estimated from daily stock returns in a 12-month rolling window, following Hong and Sraer (2016). We tabulate the results in Table 7. Consistent with existing studies, stocks with a higher ESG rating exhibit lower systematic risk, and this finding holds for all quintile portfolios sorted by rating uncertainty.

More importantly, the beta spread between brown and green stocks declines with rating uncertainty, i.e., from 0.25 for low-uncertainty stocks to 0.09 for high-uncertainty stocks. This pattern is due to a significant increase in green firms' risk exposure when ESG uncertainty is high, i.e., the beta increases from 1.04 for low-uncertainty stocks to 1.16 for high-uncertainty stocks. In contrast, rating uncertainty does not affect systematic risk among brown firms. Our findings imply that rating uncertainty increases the ambiguity of firms' ESG profile, and this effect is likely to be stronger for green firms, as they were originally perceived to be safer. Such asymmetric impact also highlights the importance of rating uncertainty, as green firms could be disproportionally punished for this uncertainty. As a result, green firms are less likely to benefit from a lower cost of capital, which could further limit their capacity to make socially responsible investments and generate real social impact.

6 Aggregate Market Implications

6.1 Market Premium

Our model describes a single-period economy and thus does not provide implications for time-series dynamics. Still, it does facilitate some comparative statics. In particular, equation (9) indicates that (1) the market premium should increase with ESG uncertainty due to higher effective risk aversion, (2) the market premium should decrease with ESG rating due to nonpecuniary benefits from holding green stocks, and (3) the effective risk aversion channel should be stronger when market volatility is low.

To test the model predictions, we consider a regression analysis while explicitly controlling for the usual aggregate predictors.[18] Specifically, we estimate the following monthly

[18] See, e.g., Avramov (2002); Van Binsbergen and Koijen (2010).

regression:

$$
\begin{aligned}
RMRF_m = \alpha_0 &+ \beta_1 ESG_{m-1} + \beta_2 ESG\ Uncertainty_{m-1} \\
&+ \beta_3 ESG\ Uncertainty_{m-1} \times High\ VIX_{m-1} + \boldsymbol{\beta}_4' \boldsymbol{M}_{m-1} + e_m,
\end{aligned} \tag{28}
$$

where $RMRF_m$ refers to the market excess return in month m, defined as the CRSP value-weighted index return minus the one-month Treasury bill rate. ESG_{m-1} and $ESG\ Uncertainty_{m-1}$ refer to the value-weighted average of ESG ratings and ESG rating uncertainty across all stocks, respectively. $High\ VIX_{m-1}$ refers to a dummy variable that takes a value of 1 if the monthly VIX index of implied volatilities of S&P 500 index options is in the top quintile over the entire sample period and 0 otherwise.[19] $\boldsymbol{M}_{m-1}$ refers to a set of other proxies for market conditions, including the lagged market premium; the dividend price ratio (DP), defined as the difference between the log of 12-month dividends and the log of prices; the term spread ($TERM$), defined as the difference between the average yield of 10-year Treasury bonds and three-month T-bills; and the default spread (DEF), defined as the difference between the average yield of bonds rated BAA and AAA by Moody's. We also report Newey and West (1987) adjusted t-statistics.[20]

The results are presented in Panel A of Table 8. We find that the market premium increases with ESG rating uncertainty after controlling for market-wide ESG ratings and macroeconomic conditions. As shown in Model 2, a one-standard-deviation increase in rating uncertainty is related to a 0.65% higher market premium per year.[21] Furthermore, we do not find strong evidence of a negative relationship between market premium and ESG rating or the substitution effect between rating uncertainty and market volatility (indicated by the β_3 coefficient), although the signs are consistent with the model predictions, as indicated in models 3 to 5 (when we jointly consider ESG rating and uncertainty). The lack of statistical significance could be due to our relatively short sample period. In addition, at the market level, the nonpecuniary benefits may not be strong enough because the market is not sufficiently green. Either way, we confirm the model prediction that the market premium is higher in the presence of ESG uncertainty.

[19] We obtain the monthly VIX index from the CBOE website: `http://www.cboe.com/products/vix-index-volatility/vix-options-and-futures/vix-index/vix-historical-data`.

[20] Conducting the diagnostic test of Amihud and Hurvich (2004), we find no evidence of small sample bias in the estimated slope coefficient due to high autocorrelation in the predictive variable.

[21] The impact of rating uncertainty is 0.65%, computed as $0.481 \times 0.112 \times 12$, where 0.481 is the regression coefficient in Model 2, and 0.112 is the standard deviation of *ESG Uncertainty*, as shown in Panel C of Table 2.

6.2 Aggregate Investor Demand

Finally, we investigate whether and how rating uncertainty affects aggregate investor demand over time. We employ the same regression specification as in equation (28), but we replace the dependent variable with market-level institutional ownership IO_m, defined as the value-weighted average of institutional ownership across all stocks.

The results are tabulated in Panel B of Table 8. Consistent with the model prediction that rating uncertainty reduces investor demand due to higher effective risk aversion, we find a significant negative relationship between rating uncertainty and institutional ownership over time. As shown in Model 2, a one-standard-deviation increase in rating uncertainty is related to 6% lower institutional ownership, which is economically sizable and translates into an 8% decline relative to average institutional ownership. Although it seems puzzling that the ESG rating level also reduces aggregate demand, unreported results show an insignificant relationship when we do not control for macroeconomic conditions. In addition, we do not find strong evidence regarding the substitution effect between rating uncertainty and market volatility. Overall, our findings complement the analysis in Table 4 that explores heterogeneous investor demand across firms and confirm that rating uncertainty discourages investor participation in the stock market.

7 Conclusion

We comprehensively analyze the equilibrium implications of ESG rating uncertainty for portfolio choice and asset pricing. Starting with the market portfolio as the single risky asset, we show that rating uncertainty leads to higher effective risk aversion and a higher market premium, as well as lower investor demand. Next, we consider multiple risky assets and heterogeneous economic agents and derive an ESG-augmented CAPM for the cross-section of stock returns. In particular, we propose that ESG uncertainty could tilt the ESG-CAPM alpha relationship and serve as a potential channel to explain the mixed evidence in prior studies.

We collect ESG ratings from six major rating agencies and employ the standard deviation of the ratings to proxy for ESG uncertainty. We then calibrate the model to assess its quantitative implications in the presence of rating uncertainty. Our findings reinforce the notion that ESG uncertainty could distort the risk-return trade-off and reduce economic welfare. We also empirically test the model implications and provide supporting evidence. First, ESG rating uncertainty reduces investor demand for stocks, especially among stocks with extreme ESG ratings. Second, brown stocks outperform green stocks *only* when rating uncertainty is low, and the negative return predictability of ESG ratings does not hold for the remaining firms. Third, *only* green stocks are perceived to be riskier when uncertainty is high and hence are less likely to benefit from a lower cost of capital. Finally, rating uncertainty has an aggregate impact on the entire market. Higher rating uncertainty is associated with higher market premium and lower investor demand for risky assets. Overall, our analysis suggests that rating uncertainty has important implications for asset allocation, investor welfare, and equilibrium asset pricing.

Our findings echo the growing concerns regarding the lack of consistency of ESG information disclosure and ratings provided by different rating agencies. In the presence of rating uncertainty, on the one hand, investors are less likely to make ESG investments and actively engage in corporate ESG issues. On the other hand, green firms are disproportionally penalized and less likely to generate real social impact. As the amount of sustainable investing is expected to keep growing, the overall impact will become even more striking. Viewed from this perspective, our results provide a conservative assessment of rating uncertainty.

Our paper also suggests avenues for future research. While existing work studying equilibrium with ESG focuses on a single-period environment, it would be natural to extend ESG equilibrium to multiperiod dynamic setups. Then, the market ESG can display time variation, which would give rise to an incremental asset pricing factor. It would also be instructive to account for investors' learning about the ESG profile of a firm. These and other topics in dynamic asset pricing are left for future research.

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Table 1: Variable Definitions

Variables	**Definitions**
A. ESG Rating Measures	
ESG	We collect ESG rating data from six data vendors: Asset4 (Refinitiv), MSCI KLD, MSCI IVA, Bloomberg, Sustainalytics, and RobecoSAM. For each rater pair-year, we sort all stocks covered by both raters according to the original rating scale of the respective data provider and calculate the percentile rank (normalized between 0 and 1) for each stock-rater pair. Then for each stock, we compute the pairwise average rating as the average rank across the two raters in the pair. Finally, we compute the firm-level ESG rating as the average pairwise rank across all rater pairs.
ESG Uncertainty	For each rater pair-year, we sort all stocks covered by both raters according to the original rating scale of the respective data provider and calculate the percentile rank (normalized between 0 and 1) for each stock-rater pair. Then, for each stock, we compute the pairwise rating uncertainty as the standard deviation of the ranks provided by the two raters in the pair. Finally, we compute the firm-level ESG rating uncertainty as the average pairwise rating divergence across all rater pairs.
B. Other Stock Characteristics	
Excess Return	Stock return minus the one-month Treasury bill rate in a given month.
CAPM-Adjusted Return	Stock excess return minus the product of a stock's beta and excess return on the market in a given month. The excess return on the market is computed as the CRSP value-weighted index return minus the one-month Treasury bill rate. The beta of the stock is estimated in a five-year rolling window.
IO	The institutional ownership in a given quarter q, computed as follows: $IO_{i,q} = \sum_f SHR_{i,f,q}/SHROUT_{i,q}$, where $SHR_{i,f,q}$ refers to the number of shares of stock i held by institution f in quarter q, and $SHROUT_{i,q}$ refers to the shares outstanding at the same time.
Log(Size)	The logarithm of stock market capitalization, computed as the number of common shares outstanding times the share price as reported in CRSP.
Log(BM)	The logarithm of the book-to-market ratio of a stock, where the book-to-market ratio is computed as the book value of equity divided by market capitalization at fiscal year-end, following Fama and French (2015).
6M Momentum	Formation period return for six-month momentum in a given month m, computed as the cumulative return from month $m-6$ to month $m-1$, following Jegadeesh and Titman (1993).
Log(Illiquidity)	The logarithm of stock illiquidity. Stock illiquidity in a given month m is computed as follows: $ILLIQ_{i,m} = \left(\sum_{d\in m} \lvert R_{i,d,m}\rvert / VOLD_{i,d,m}\right)/D_{i,m} \times 10^8$, where $R_{i,d,m}$ refers to the percentage return of stock i in day d of month m, $VOLD_{i,d,m}$ refers to the dollar trading volume at the same time, and $D_{i,m}$ is the number of trading days for stock i in month m, following Amihud (2002).
Gross Profitability	Gross profitability in a given year t, computed as follows: $GP_{i,t} = \left(REVT_{i,t} - COGS_{i,t}\right)/ASSET_{i,t}$, where $REVT_{i,t}$ refers to the total revenue (COMPUSTAT annual item REVT) of stock i in year t, $COGS_{i,t}$ refers to the cost of goods sold (item COGS), and $ASSET_{i,t}$ is the total assets (item AT), following Novy-Marx (2013).
Corporate Investment	Corporate investment in a given quarter q, computed as follows: $CI_{i,q} = PPE_{i,q} - \left(PPE_{i,q-1} + PPE_{i,q-2} + PPE_{i,q-3}\right)/3$, where $PPE_{i,q}$ refers to the ratio of change in net property, plant, and equipment (COMPUSTAT quarterly item PPENTQ) divided by sales (item SALEQ) of stock i in quarter q. If SALEQ is 0 or negative, then replace SALEQ with 0.01, following Titman et al. (2004).
Leverage	Total liabilities (COMPUSTAT annual item LT) divided by market capitalization at fiscal year-end, following Bhandari (1988).
Log(Analyst Coverage)	The logarithm of the number of analysts following the firm as reported in I/B/E/S in each quarter.
Analyst Dispersion	The standard deviation of analysts' earnings (earnings per share, EPS) forecasts divided by the absolute value of the median earnings forecast as reported in I/B/E/S in each quarter.
Beta	Stock beta in a given month m, computed as follows using a 12-month rolling window: $R^e_{i,d,m} = \alpha_{i,m} + \sum_{k=0}^{5} \beta_{i,k,m} RMRF_{d-k,m} + e_{i,d,m}$, where $R^e_{i,d,m}$ refers to the excess return of stock i in day d of month m, computed as the stock return minus the one-month Treasury bill rate. $RMRF_{d-k,m}$ refers to the excess market return on day $d-k$, computed as the value-weighted return of all CRSP firms incorporated in the U.S. and listed on the NYSE, Amex, and Nasdaq minus the one-month Treasury bill rate. Stock beta is the sum of the six coefficients, i.e., $\beta_{i,m} = \sum_{k=0}^{5} \beta_{i,k,m}$, following Hong and Sraer (2016).

Table 2: Summary Statistics

We collect ESG rating data from six data vendors: Asset4 (Refinitiv), MSCI KLD, MSCI IVA, Bloomberg, Sustainalytics, and RobecoSAM. Panel A reports the average ESG rating uncertainty for each rater pair. For each rater pair-year, we sort all stocks covered by both raters according to the original rating scale of the respective data provider and calculate the percentile rank (normalized between 0 and 1) for each stock-rater pair. Then, for each stock, we compute the pairwise rating uncertainty as the standard deviation of the ranks provided by the two raters in the pair. Finally, we compute the average ESG rating uncertainty across all stocks for each rater pair-year and average them over time. In Panel B, we compute the correlation in the percentile ranks for each rater pair-year and then average them over time. Panel C presents the summary statistics for the stock-level data used in the paper. We report the mean, standard deviation, median, and quantile distribution of the annual ESG rating and ESG rating uncertainty, monthly stock performance, quarterly institutional ownership, and other annual and monthly stock characteristics. Panel D presents the summary statistics for the portfolio-level data used in the paper. At the end of year t, stocks are independently sorted into quintiles according to their ESG ratings and ESG rating uncertainty to generate 25 (5×5) portfolios. We report the value-weighted ESG rating, ESG rating uncertainty, and return in year $t+1$ for each of the 25 portfolios. Our sample period ranges from 2002 to 2019. Table 1 provides detailed definitions for each variable.

Panel A: Pairwise ESG Rating Uncertainty

	Asset4	MSCI KLD	MSCI IVA	Bloomberg	Sustainalytics	RobecoSAM
Asset4	-	0.185	0.185	0.134	0.144	0.149
MSCI KLD	0.185	-	0.180	0.183	0.151	-
MSCI IVA	0.185	0.180	-	0.195	0.171	0.181
Bloomberg	0.134	0.183	0.195	-	0.133	0.138
Sustainalytics	0.144	0.151	0.171	0.133	-	0.119
RobecoSAM	0.149	-	0.181	0.138	0.119	-

Panel B: Pairwise ESG Rating Correlation

	Asset4	MSCI KLD	MSCI IVA	Bloomberg	Sustainalytics	RobecoSAM
Asset4	-	0.321	0.326	0.639	0.595	0.547
MSCI KLD	0.321	-	0.349	0.310	0.547	-
MSCI IVA	0.326	0.349	-	0.253	0.411	0.353
Bloomberg	0.639	0.310	0.253	-	0.677	0.645
Sustainalytics	0.595	0.547	0.411	0.677	-	0.707
RobecoSAM	0.547	-	0.353	0.645	0.707	-

Panel C: Quantile Distribution of Stock Characteristics

	Mean	Std.Dev.	Quantile Distribution				
			10%	25%	Median	75%	90%
ESG	0.461	0.202	0.219	0.310	0.437	0.595	0.753
ESG Uncertainty	0.180	0.112	0.051	0.097	0.162	0.246	0.330
Return	1.049	11.171	-11.257	-4.627	1.005	6.443	12.964
Excess Return	0.980	11.174	-11.330	-4.698	0.936	6.373	12.897
CAPM-Adjusted Return	-0.195	9.796	-10.840	-5.028	-0.231	4.410	10.128
IO	0.734	0.256	0.343	0.636	0.811	0.920	0.996
Log(Size)	14.726	1.608	12.703	13.575	14.669	15.792	16.890
Log(BM)	-0.772	0.808	-1.819	-1.243	-0.688	-0.213	0.149
6M Momentum	0.054	0.264	-0.235	-0.085	0.045	0.175	0.333
Log(Illiquidity)	-7.119	2.079	-9.698	-8.647	-7.278	-5.736	-4.303
Gross Profitability	0.313	0.303	0.037	0.109	0.273	0.460	0.696
Corporate Investment	0.159	7.035	-0.077	-0.018	0.000	0.018	0.092
Leverage	1.596	3.222	0.090	0.227	0.546	1.378	4.558
Log(Analyst Coverage)	2.175	0.815	1.099	1.609	2.303	2.773	3.135
Analyst Dispersion	0.121	0.365	0.007	0.014	0.030	0.079	0.224
Beta	1.198	0.649	0.499	0.774	1.107	1.515	2.013

Table 2 (continued)

Panel D: Portfolio Characteristics Sorted by ESG Rating and ESG Uncertainty					
Rank of ESG Rating	Rank of ESG Uncertainty				
	Low	2	3	4	High
Panel D1: ESG Rating					
Low	0.252	0.259	0.277	0.287	0.305
2	0.368	0.386	0.384	0.390	0.373
3	0.474	0.479	0.467	0.487	0.483
4	0.575	0.589	0.600	0.603	0.597
High	0.848	0.811	0.753	0.732	0.702
Panel D2: ESG Uncertainty					
Low	0.135	0.146	0.179	0.215	0.275
2	0.159	0.152	0.172	0.207	0.317
3	0.131	0.156	0.179	0.207	0.293
4	0.139	0.136	0.172	0.208	0.295
High	0.093	0.114	0.160	0.193	0.260
Panel D3: Return					
Low	1.117	1.149	0.733	1.003	0.916
2	1.353	1.133	0.976	1.061	0.831
3	1.009	0.855	0.951	1.101	1.050
4	0.857	0.856	1.169	1.147	0.916
High	0.664	0.784	0.840	1.158	1.026

Table 3: Sharpe Ratio and Welfare Calibration

We report the monthly Sharpe ratio, the monthly perceived Sharpe ratio, which accounts for ESG-adjusted returns, $\tilde{\boldsymbol{r}} + \frac{B}{A}\tilde{\boldsymbol{g}}$, and the certainty equivalent return for an investment universe consisting of a riskless asset (one-month Treasury bill) as well as 25 portfolios sorted on ESG ratings and ESG rating uncertainty. The annual mean and standard deviation of the equity premium are set to be 7% and 16%, respectively, while $\gamma = 2$. We consider three values for $\frac{B}{A}$, i.e., 0.5, 1 and 2, with the higher measure representing a stronger preference for green stocks. Altogether, we generate $6 \times 3 \times 2$ efficient frontiers, corresponding to the market being green neutral (Panel A, 3 cases with respect to $\frac{B}{A}$ values) and green on average (Panel B, also 3 cases); all of these case are interacted with ESG indifference (ESG I), ESG preferences without uncertainty (ESG N), and ESG preferences with uncertainty (ESG U) and conducted with (Unconstrained) and without nonnegativity constraints (Constrained) on equity positions.

	Panel A: Green-Neutral Market					
	Unconstrained			Constrained		
	ESG I	ESG N	ESG U	ESG I	ESG N	ESG U
	Sharpe Ratio					
$\frac{B}{A} = 0.5$	0.43	0.40	0.23	0.24	0.24	0.22
$\frac{B}{A} = 1$	0.43	0.31	0.21	0.24	0.23	0.20
$\frac{B}{A} = 2$	0.43	0.15	0.18	0.24	0.20	0.18
	Perceived Sharpe Ratio					
$\frac{B}{A} = 0.5$	0.43	0.41	0.20	0.24	0.25	0.20
$\frac{B}{A} = 1$	0.43	0.46	0.22	0.24	0.28	0.21
$\frac{B}{A} = 2$	0.43	0.68	0.29	0.24	0.33	0.26
	Certainty Equivalent Return (%)					
$\frac{B}{A} = 0.5$	4.71	4.37	1.14	1.57	1.72	1.11
$\frac{B}{A} = 1$	4.71	5.39	1.32	1.57	2.00	1.26
$\frac{B}{A} = 2$	4.71	11.54	2.18	1.57	2.84	1.84
	Panel B: Green Market					
	Unconstrained			Constrained		
	ESG I	ESG N	ESG U	ESG I	ESG N	ESG U
	Sharpe Ratio					
$\frac{B}{A} = 0.5$	0.43	0.39	0.21	0.24	0.24	0.21
$\frac{B}{A} = 1$	0.43	0.31	0.21	0.24	0.23	0.20
$\frac{B}{A} = 2$	0.43	0.15	0.19	0.24	0.20	0.19
	Perceived Sharpe Ratio					
$\frac{B}{A} = 0.5$	0.43	0.43	0.21	0.24	0.27	0.21
$\frac{B}{A} = 1$	0.43	0.48	0.22	0.24	0.29	0.22
$\frac{B}{A} = 2$	0.43	0.69	0.27	0.24	0.35	0.26
	Certainty Equivalent Return (%)					
$\frac{B}{A} = 0.5$	4.71	4.65	1.18	1.57	1.97	1.17
$\frac{B}{A} = 1$	4.71	5.76	1.33	1.57	2.26	1.30
$\frac{B}{A} = 2$	4.71	12.07	1.95	1.57	3.17	1.81

Table 4: Institutional Ownership Sorted by ESG Rating and Uncertainty

At the end of year t, stocks are independently sorted into quintiles according to their ESG ratings and ESG rating uncertainty to generate 25 (5×5) portfolios. The low- (high)-ESG-rating and ESG-rating-uncertainty portfolios comprise the bottom (top) quintile of stocks based on the ESG rating and ESG rating uncertainty, respectively. This table reports the quarterly institutional ownership in year $t+1$ for each of the 25 portfolios and the difference in institutional ownership between low- and high-ESG-rating portfolios ("LMH") as well as between high- and low-ESG-rating-uncertainty portfolios ("HML"). Table 1 provides detailed definitions for each variable. Newey-West adjusted t-statistics are shown in parentheses. Numbers with "*", "**", and "***" are significant at the 10%, 5%, and 1% levels, respectively.

Rank of ESG Rating	Rank of ESG Uncertainty						
	Low	2	3	4	High	HML	t-stat
Low	0.705	0.736	0.729	0.724	0.654	-0.051***	(-2.75)
2	0.703	0.741	0.774	0.778	0.715	0.012	(1.18)
3	0.737	0.759	0.745	0.770	0.730	-0.007	(-0.87)
4	0.763	0.758	0.749	0.746	0.737	-0.026***	(-2.89)
High	0.730	0.742	0.743	0.727	0.647	-0.084*	(-1.91)
LMH	-0.026	-0.006	-0.014	-0.003	0.007		
	(-1.25)	(-0.44)	(-0.85)	(-0.14)	(0.11)		

Table 5: Stock Returns Sorted by ESG Rating and Uncertainty

At the end of year t, stocks are first sorted into quintiles according to their ESG rating uncertainty. Within each ESG rating uncertainty group, stocks are further sorted into quintiles according to their ESG ratings to generate 25 (5×5) portfolios. The low- (high)-ESG-rating and ESG-rating-uncertainty portfolios comprise the bottom (top) quintile of stocks based on the ESG rating and ESG rating uncertainty, respectively. Panel A reports the value-weighted monthly return in year $t+1$ for each of the 25 portfolios, as well as the investment strategy of going long (short) the low- (high)-ESG-rating stocks ("LMH"). The column "All" reports similar statistics for portfolios sorted by ESG ratings only. The row "All" reports returns for portfolios sorted by ESG uncertainty only, as well as the investment strategy of going long (short) the high (low) ESG-uncertainty stocks ("HML"). In Panels B to D, portfolio returns are further adjusted by the CAPM, Fama-French-Carhart 4-factor model (FFC), and Fama-French 6-factor model (FF6). Table 1 provides detailed definitions for each variable. Newey-West adjusted t-statistics are shown in parentheses. Numbers with "*", "**", and "***" are significant at the 10%, 5%, and 1% levels, respectively.

Panel A: Return

ESG Rating	ESG Uncertainty: Low	2	3	4	High	All
Low	1.235***	1.113***	0.767**	0.875**	0.760**	0.923**
	(2.95)	(2.99)	(1.98)	(2.30)	(2.32)	(2.58)
2	1.245***	1.026***	1.093***	1.043***	1.095***	0.963***
	(3.36)	(2.84)	(3.30)	(2.74)	(2.91)	(2.85)
3	1.096***	0.965***	1.050***	1.104***	0.949***	1.021***
	(2.69)	(2.83)	(2.86)	(2.89)	(3.15)	(3.11)
4	0.730**	0.695*	1.105***	1.019***	0.990***	1.017***
	(2.09)	(1.81)	(2.90)	(2.96)	(2.68)	(3.42)
High	0.642*	0.842**	0.855***	1.184***	0.854***	0.805**
	(1.97)	(2.53)	(3.06)	(3.62)	(2.81)	(2.57)
LMH	0.594***	0.271	-0.088	-0.309	-0.094	0.118
	(2.72)	(1.30)	(-0.39)	(-1.43)	(-0.42)	(0.78)

ESG Rating	ESG Uncertainty: Low	2	3	4	High	HML
All	0.753**	0.875***	0.935***	1.083***	0.940***	0.187
	(2.31)	(2.61)	(3.07)	(3.28)	(3.29)	(1.40)

Panel B: CAPM-Adjusted Return

ESG Rating	ESG Uncertainty: Low	2	3	4	High	All
Low	0.168	0.064	-0.311*	-0.141	-0.101	-0.101
	(0.93)	(0.40)	(-1.82)	(-0.89)	(-0.58)	(-0.84)
2	0.187	0.076	0.115	0.042	0.151	-0.008
	(1.16)	(0.38)	(0.77)	(0.29)	(0.77)	(-0.07)
3	0.040	-0.031	0.002	0.064	0.079	0.053
	(0.23)	(-0.20)	(0.02)	(0.46)	(0.42)	(0.64)
4	-0.192	-0.389***	0.108	0.040	0.006	0.095
	(-1.24)	(-3.28)	(0.55)	(0.34)	(0.03)	(1.32)
High	-0.230*	-0.063	-0.012	0.245*	-0.001	-0.095
	(-1.95)	(-0.55)	(-0.10)	(1.83)	(-0.01)	(-1.49)
LMH	0.398*	0.128	-0.299	-0.387*	-0.100	-0.006
	(1.86)	(0.58)	(-1.25)	(-1.75)	(-0.42)	(-0.04)

ESG Rating	ESG Uncertainty: Low	2	3	4	High	HML
All	-0.155**	-0.090	-0.003	0.120*	0.071	0.226*
	(-1.98)	(-1.20)	(-0.04)	(1.72)	(0.84)	(1.67)

Panel C: FFC-Adjusted Return

ESG Rating	ESG Uncertainty: Low	2	3	4	High	All
Low	0.214	0.054	-0.329*	-0.115	-0.113	-0.091
	(1.28)	(0.37)	(-1.91)	(-0.76)	(-0.64)	(-0.76)
2	0.209	0.099	0.095	0.062	0.140	-0.005
	(1.37)	(0.49)	(0.69)	(0.44)	(0.70)	(-0.04)
3	0.111	0.006	0.018	0.090	0.048	0.051
	(0.65)	(0.05)	(0.16)	(0.65)	(0.26)	(0.63)
4	-0.215	-0.344***	0.172	0.093	0.042	0.124*
	(-1.41)	(-2.94)	(0.92)	(0.77)	(0.20)	(1.71)
High	-0.246**	-0.041	0.012	0.304**	-0.012	-0.090
	(-2.13)	(-0.39)	(0.10)	(2.25)	(-0.09)	(-1.61)
LMH	0.459**	0.095	-0.341	-0.419*	-0.101	-0.002
	(2.30)	(0.49)	(-1.42)	(-1.96)	(-0.42)	(-0.01)

ESG Rating	ESG Uncertainty: Low	2	3	4	High	HML
All	-0.162**	-0.064	0.013	0.163**	0.056	0.218
	(-2.15)	(-0.89)	(0.17)	(2.44)	(0.66)	(1.65)

Panel D: FF6-Adjusted Return

ESG Rating	ESG Uncertainty: Low	2	3	4	High	All
Low	0.251	0.091	-0.327*	-0.155	-0.030	-0.092
	(1.49)	(0.65)	(-1.88)	(-1.02)	(-0.15)	(-0.78)
2	0.189	0.193	0.019	0.055	0.131	-0.001
	(1.15)	(1.03)	(0.13)	(0.37)	(0.65)	(-0.01)
3	0.113	0.031	0.043	0.171	-0.009	0.052
	(0.69)	(0.22)	(0.36)	(1.24)	(-0.05)	(0.61)
4	-0.179	-0.301***	0.145	0.094	0.119	0.117
	(-1.24)	(-2.62)	(0.77)	(0.77)	(0.58)	(1.60)
High	-0.250**	-0.017	-0.049	0.297**	-0.084	-0.094*
	(-2.13)	(-0.16)	(-0.39)	(2.04)	(-0.65)	(-1.71)
LMH	0.501**	0.109	-0.277	-0.452**	0.054	0.003
	(2.36)	(0.61)	(-1.14)	(-2.02)	(0.22)	(0.02)

ESG Rating	ESG Uncertainty: Low	2	3	4	High	HML
All	-0.154**	-0.027	-0.045	0.157**	0.035	0.189
	(-2.02)	(-0.38)	(-0.58)	(2.38)	(0.41)	(1.42)

Table 6: ESG Rating, Uncertainty, and Stock Returns

This table presents the results of the following monthly Fama-MacBeth regressions, as well as their corresponding Newey-West adjusted t-statistics:

$$Perf_{i,m} = \alpha_0 + \beta_1 ESG_{i,m-1} + \beta_2 ESG_{i,m-1} \times \textit{Low ESG Uncertainty}_{i,m-1} + \beta_3 \textit{Low ESG Uncertainty}_{i,m-1} + \boldsymbol{\beta}_4' \boldsymbol{M}_{i,m-1} + e_{i,m},$$

where $Perf_{i,m}$ refers to the excess return (models 1 to 4) or CAPM-adjusted return (models 5 to 8) of stock i in month m, $ESG_{i,m-1}$ refers to the ESG rating, $\textit{Low ESG Uncertainty}_{i,m-1}$ refers to a dummy variable that takes a value of 1 if the ESG rating uncertainty is in the bottom quintile across all stocks in that month and 0 otherwise. The vector $\boldsymbol{M}$ stacks all other control variables, including the Log(Size), Log(BM), 6M Momentum, Log(Illiquidity), Gross Profitability, Corporate Investment, Leverage, Log(Analyst Coverage) and Analyst Dispersion. Table 1 provides detailed definitions for each variable. Numbers with "*", "**", and "***" are significant at the 10%, 5%, and 1% levels, respectively.

Stock Returns Regressed on Lagged ESG Rating and ESG Uncertainty

	Excess Return				CAPM-Adjusted Return			
	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8
ESG	0.002	0.098	0.062	0.199	0.042	0.139	0.162	0.301
	(0.01)	(0.65)	(0.33)	(1.03)	(0.23)	(0.91)	(0.77)	(1.65)
ESG × Low ESG Uncertainty			-0.163*	-0.223*			-0.254**	-0.312**
			(-1.91)	(-1.75)			(-2.26)	(-2.36)
Low ESG Uncertainty			0.114*	0.109			0.125**	0.114
			(1.86)	(1.38)			(2.20)	(1.61)
Log(Size)	-0.100	-0.036	-0.101	-0.038	-0.044	0.111	-0.044	0.111
	(-1.28)	(-0.27)	(-1.30)	(-0.29)	(-0.59)	(0.77)	(-0.60)	(0.77)
Log(BM)	0.001	0.009	-0.001	0.008	-0.021	0.019	-0.024	0.017
	(0.01)	(0.14)	(-0.01)	(0.12)	(-0.19)	(0.18)	(-0.21)	(0.17)
6M Momentum	0.336	0.188	0.335	0.194	0.275	0.105	0.276	0.111
	(0.70)	(0.40)	(0.69)	(0.42)	(0.50)	(0.20)	(0.50)	(0.21)
Log(Illiquidity)		0.056		0.056		0.103**		0.103**
		(1.00)		(1.03)		(2.17)		(2.15)
Gross Profitability		0.178		0.180		0.355*		0.359*
		(0.99)		(1.00)		(1.83)		(1.85)
Corporate Investment		0.037		0.037		-0.005		-0.007
		(0.49)		(0.50)		(-0.08)		(-0.09)
Leverage		-0.037		-0.037		-0.034		-0.034
		(-0.78)		(-0.79)		(-0.73)		(-0.73)
Log(Analyst Coverage)		-0.019		-0.019		-0.174		-0.175
		(-0.15)		(-0.14)		(-1.40)		(-1.41)
Analyst Dispersion		-0.536***		-0.539***		-0.828***		-0.831***
		(-2.67)		(-2.71)		(-4.37)		(-4.37)
Constant	2.309*	1.800	2.281*	1.775	0.591	-0.555	0.533	-0.614
	(1.71)	(1.09)	(1.70)	(1.09)	(0.46)	(-0.31)	(0.42)	(-0.34)
Obs	283,671	254,873	283,671	254,873	272,728	245,451	272,728	245,451
R-squared	0.045	0.080	0.048	0.082	0.043	0.076	0.045	0.078

Table 7: Stock Beta Sorted by ESG Rating and Uncertainty

At the end of year t, stocks are first sorted into quintiles according to their ESG rating uncertainty. Within each ESG rating uncertainty group, stocks are further sorted into quintiles according to their ESG ratings to generate 25 (5×5) portfolios. The low- (high)-ESG-rating and ESG-rating-uncertainty portfolios comprise the bottom (top) quintile of stocks based on the ESG rating and ESG rating uncertainty, respectively. This table reports the average monthly stock beta in year $t+1$ for each of the 25 portfolios, and the difference in average beta between low- and high-ESG-rating portfolios ("LMH") as well as between high- and low-ESG-rating-uncertainty portfolios ("HML"). Table 1 provides detailed definitions for each variable. Newey-West adjusted t-statistics are shown in parentheses. Numbers with "*", "**", and "***" are significant at the 10%, 5%, and 1% levels, respectively.

Rank of ESG Rating	Rank of ESG Uncertainty						
	Low	2	3	4	High	HML	t-stat
Low	1.291	1.293	1.256	1.214	1.240	-0.050	(-1.65)
2	1.248	1.206	1.240	1.204	1.184	-0.064**	(-2.33)
3	1.231	1.184	1.198	1.189	1.199	-0.032	(-1.10)
4	1.122	1.133	1.154	1.169	1.173	0.050***	(3.52)
High	1.041	1.050	1.049	1.127	1.155	0.114***	(5.59)
LMH	0.249***	0.243***	0.207***	0.087***	0.085***		
	(9.55)	(9.32)	(8.02)	(5.20)	(4.92)		

Table 8: Market Premium and Aggregate Institutional Ownership

Panel A presents the results of the following monthly time-series regressions, as well as their corresponding Newey-West adjusted t-statistics:

$$RMRF_m = \alpha_0 + \beta_1 ESG_{m-1} + \beta_2 ESG\ Uncertainty_{m-1} + \beta_3 ESG\ Uncertainty_{m-1} \times High\ VIX_{m-1} + \boldsymbol{\beta}_4' \boldsymbol{M}_{m-1} + e_m,$$

where $RMRF_m$ refers to the market premium in month m, defined as the CRSP value-weighted index return minus the one-month Treasury bill rate. ESG_{m-1} and $ESG\ Uncertainty_{m-1}$ refer to the value-weighted average of ESG rating and ESG rating uncertainty across all stocks, respectively. $High\ VIX_{m-1}$ refers to a dummy variable that takes a value of 1 if the VIX index is in the top quintile over the entire sample period and 0 otherwise. $\boldsymbol{M}_{m-1}$ refers to a set of other proxies for market conditions, including lagged market premium; dividend price ratio (DP), defined as the difference between the log of dividends and the log of prices; term spread (TERM), defined as the difference between the average yield of 10-year Treasury bonds and three-month T-bills, and default spread (DEF), defined as the difference between the average yield of bonds rated BAA and AAA by Moody's. Panel B reports similar statistics while replacing the dependent variable with market-level institutional ownership IO_m, defined as the value-weighted institutional ownership across all stocks. Table 1 provides detailed definitions for each variable. Numbers with "*", "**", and "***" are significant at the 10%, 5%, and 1% levels, respectively.

Panel A: Market Premium Regressed on Lagged ESG Rating and ESG Uncertainty

	Model 1	Model 2	Model 3	Model 4	Model 5
ESG	0.023		-0.122	-0.092	-0.072
	(0.15)		(-0.73)	(-0.56)	(-0.42)
ESG Uncertainty		0.481***	0.502***	0.508***	0.491**
		(2.85)	(2.82)	(2.79)	(2.55)
ESG Uncertainty × High VIX					-0.161
					(-0.43)
RMRF	0.145	0.164	0.167	0.213*	0.191*
	(1.40)	(1.62)	(1.62)	(1.74)	(1.94)
DP	0.096**	0.161***	0.169***	0.169***	0.156***
	(2.22)	(3.40)	(3.33)	(3.21)	(2.91)
TERM	0.072	0.003	0.035	-0.097	-0.021
	(0.32)	(0.02)	(0.16)	(-0.38)	(-0.09)
DEF	-2.769**	-4.154***	-4.388***	-5.531***	-4.658***
	(-2.17)	(-3.21)	(-3.10)	(-2.79)	(-3.25)
VIX				0.086	
				(1.29)	
High VIX					0.043
					(0.61)
Constant	0.397*	0.595***	0.701***	0.680***	0.620**
	(1.74)	(3.30)	(2.76)	(2.65)	(2.35)
Obs	193	193	193	193	193
R-squared	0.052	0.089	0.091	0.097	0.101

Table 8 (continued)

Panel B: Institutional Ownership Regressed on Lagged ESG Rating and ESG Uncertainty					
	Model 1	Model 2	Model 3	Model 4	Model 5
ESG	-0.523***		-0.399**	-0.434**	-0.483**
	(-2.83)		(-2.07)	(-2.40)	(-2.58)
ESG Uncertainty		-0.497**	-0.428**	-0.434**	-0.336*
		(-2.44)	(-1.98)	(-2.08)	(-1.77)
ESG Uncertainty × High VIX					-0.308
					(-0.58)
RMRF	0.158***	0.131***	0.139***	0.085	0.127***
	(3.08)	(2.62)	(2.77)	(1.39)	(2.64)
DP	0.304***	0.216***	0.242***	0.242***	0.260***
	(8.98)	(5.47)	(5.88)	(5.67)	(5.67)
TERM	-0.580*	-0.651**	-0.548	-0.394	-0.456
	(-1.69)	(-2.11)	(-1.64)	(-1.29)	(-1.38)
DEF	-7.109***	-4.967***	-5.730***	-4.400**	-5.669***
	(-7.42)	(-4.61)	(-4.89)	(-2.42)	(-4.92)
VIX				-0.100	
				(-0.99)	
High VIX					0.045
					(0.44)
Constant	2.319***	1.716***	2.060***	2.084***	2.166***
	(12.07)	(11.93)	(9.49)	(9.56)	(9.41)
Obs	193	193	193	193	193
R-squared	0.479	0.497	0.515	0.526	0.528

Appendix

A Proofs and Derivations

In all derivations that follow, the expectation operators are taken under the joint distribution of returns and ESG ratings.

A.1 Welfare in a One-Asset Economy

In the single-asset setup, the expected utility is given by

$$E\left[V\left(\tilde{W}_1, x^*\right)\right] = -E\left[e^{-A\tilde{W}_1 - BW_0 x^* \tilde{g}_M}\right]. \tag{A.1}$$

Considering the optimal solution (4) in the presence of ESG uncertainty, the value function can be evaluated as

$$E\left[V\left(\tilde{W}_1, x^*\right)\right] = -e^{-\gamma\left(1+r_f\right)-\gamma\left[\frac{1}{2\gamma}\left(\frac{\mu_M^U + b\mu_{g,M}}{\sigma_{M,U}}\right)^2\right]}. \tag{A.2}$$

Following Back (2010),[1] the term in square brackets represents the investor's certainty equivalent rate of return CE^U in (14). CE^N is obtained by replacing $\sigma_{M,U}$ with σ_M. CE^I is obtained by further imposing $b = 0$.

A.2 Proof of Proposition 1: Optimal Portfolio under ESG Uncertainty

The expected utility of agent i can be written as

$$\begin{aligned}
E\left[V\left(\tilde{W}_{i,1}, \boldsymbol{X}_i\right)\right] &= E\left[-e^{-A_i\tilde{W}_{i,1} - B_i W_{i,0} \boldsymbol{X}_i' \tilde{\boldsymbol{g}}}\right] \\
&= E\left[-e^{-A_i W_{i,0}\left(1+r_f+\boldsymbol{X}_i'\tilde{\boldsymbol{r}}\right) - B_i W_{i,0}\boldsymbol{X}_i'\tilde{\boldsymbol{g}}}\right] \\
&= -e^{-\gamma_i(1+r_f)} E\left[e^{-\gamma_i \boldsymbol{X}_i'(\tilde{\boldsymbol{r}} + b_i\tilde{\boldsymbol{g}})}\right].
\end{aligned} \tag{A.3}$$

where $\gamma_i = A_i\tilde{W}_{i,0}$ and $b_i = \frac{B_i}{A_i}$. Note that

$$\tilde{\boldsymbol{r}} + b_i\tilde{\boldsymbol{g}} \sim \mathcal{N}\left(\boldsymbol{\mu}_r + b_i\boldsymbol{\mu}_g, \boldsymbol{\Sigma}_i\right), \tag{A.4}$$

where

$$\boldsymbol{\Sigma}_i = \boldsymbol{\Sigma}_r + b_i^2\boldsymbol{\Sigma}_g. \tag{A.5}$$

[1] See equations 2.17 and 2.18 on page 39.

Then, the expected utility is expressed analytically

$$\begin{aligned} E\left[V\left(\tilde{W}_{i,1}, \boldsymbol{X}_i\right)\right] &= -e^{-\gamma_i(1+r_f)} E\left[e^{-\gamma_i \boldsymbol{X}_i'(\tilde{\boldsymbol{r}}+b_i\tilde{\boldsymbol{g}})}\right] \\ &= -e^{-\gamma_i(1+r_f)} e^{-\gamma_i \boldsymbol{X}_i'(\boldsymbol{\mu}_r+b_i\boldsymbol{\mu}_g)+\frac{\gamma_i^2}{2}\boldsymbol{X}_i'\boldsymbol{\Sigma}_i\boldsymbol{X}_i}. \end{aligned} \tag{A.6}$$

The investor chooses the optimal portfolio weights by minimizing the expression

$$-\gamma_i \boldsymbol{X}_i' \left(\boldsymbol{\mu}_r + b_i \boldsymbol{\mu}_g\right) + \frac{\gamma_i^2}{2} \boldsymbol{X}_i' \boldsymbol{\Sigma}_i \boldsymbol{X}_i. \tag{A.7}$$

The first-order condition is

$$0 = -\gamma_i \left(\boldsymbol{\mu}_r + b_i \boldsymbol{\mu}_g\right) + \gamma_i^2 \boldsymbol{\Sigma}_i \boldsymbol{X}_i. \tag{A.8}$$

The optimal portfolio that solves the above equation is then

$$\boldsymbol{X}_i^* = \frac{1}{\gamma_i} \boldsymbol{\Sigma}_i^{-1} \left(\boldsymbol{\mu}_r + b_i \boldsymbol{\mu}_g\right). \tag{A.9}$$

Then, we can write the variance of the return bundle as

$$\boldsymbol{\Sigma}_i = \boldsymbol{\Sigma}_r + b_i^2 \boldsymbol{\Sigma}_g, \tag{A.10}$$

and hence

$$\boldsymbol{\Sigma}_i^{-1} = \left(\boldsymbol{\Sigma}_r + b_i^2 \boldsymbol{\Sigma}_g\right)^{-1}. \tag{A.11}$$

We are looking for $\boldsymbol{\Psi}_{i,U}$ to solve the equation

$$\boldsymbol{\Sigma}_i^{-1} = \boldsymbol{\Sigma}_r^{-1} + \boldsymbol{\Psi}_{i,U}. \tag{A.12}$$

The solution is obtained as

$$\boldsymbol{\Psi}_{i,U} = \boldsymbol{\Sigma}_i^{-1} - \boldsymbol{\Sigma}_r^{-1} = -b_i^2 \boldsymbol{\Sigma}_r^{-1} \boldsymbol{\Sigma}_g \boldsymbol{\Sigma}_r^{-1} \left(\mathbf{I}_N + b_i^2 \boldsymbol{\Sigma}_g \boldsymbol{\Sigma}_r^{-1}\right)^{-1}. \tag{A.13}$$

The optimal strategy can finally be written as

$$\begin{aligned} \boldsymbol{X}_i^* &= \frac{1}{\gamma_i} \left(\boldsymbol{\Sigma}_r^{-1} + \boldsymbol{\Psi}_{i,U}\right) \left(\boldsymbol{\mu}_r + b_i \boldsymbol{\mu}_g\right) \\ &= \frac{1}{\gamma_i} \boldsymbol{\Sigma}_r^{-1} \left(\boldsymbol{\mu}_r + b_i \boldsymbol{\mu}_g\right) + \frac{1}{\gamma_i} \boldsymbol{\Psi}_{i,U} \left(\boldsymbol{\mu}_r + b_i \boldsymbol{\mu}_g\right). \end{aligned} \tag{A.14}$$

A.3 Optimal Portfolio in a Two-Asset Economy

In the two-risky-asset case, we assume that ESG rating uncertainty is in play and, for ease of notation, we drop the superscript ^{U}. Denoting by $\mathbf{I}_2$ the 2×2 identity matrix, we assume that

$$\mathbf{\Sigma}_r = \sigma_r^2 \mathbf{I}_2, \tag{A.15}$$

$$\mathbf{\Sigma}_g = \begin{bmatrix} \sigma^2_{g,green} & 0 \\ 0 & \sigma^2_{g,brown} \end{bmatrix}. \tag{A.16}$$

In this case, we have

$$\mathbf{\Sigma}_i = \mathbf{\Sigma}_r + b_i^2 \mathbf{\Sigma}_g = \begin{bmatrix} \sigma_r^2 + b_i^2 \sigma^2_{g,green} & 0 \\ 0 & \sigma_r^2 + b_i^2 \sigma^2_{g,brown} \end{bmatrix}, \tag{A.17}$$

and then

$$\mathbf{\Sigma}_i^{-1} = \begin{bmatrix} \frac{1}{\sigma_r^2 + b_i^2 \sigma^2_{g,green}} & 0 \\ 0 & \frac{1}{\sigma_r^2 + b_i^2 \sigma^2_{g,brown}} \end{bmatrix}, \tag{A.18}$$

$$\mathbf{\Gamma}^{-1}_{i,eff} = \frac{1}{\gamma_i} \left(\mathbf{I}_2 + b_i^2 \mathbf{\Sigma}_r^{-1} \mathbf{\Sigma}_g \right)^{-1} = \frac{1}{\gamma_i} \begin{bmatrix} \frac{1}{1 + b_i^2 \frac{\sigma^2_{g,green}}{\sigma_r^2}} & 0 \\ 0 & \frac{1}{1 + b_i^2 \frac{\sigma^2_{g,brown}}{\sigma_r^2}} \end{bmatrix}. \tag{A.19}$$

We also assume that a green firm has a mean ESG score $\mu_g > 0$, while the brown firm has a mean score $-\mu_g$. We can write the equilibrium strategy as

$$X^*_{i,green} = \frac{1}{\gamma_i} \frac{\mu_{r,green} + b_i \mu_g}{\sigma_r^2 \left(1 + b_i^2 \frac{\sigma^2_{g,green}}{\sigma_r^2} \right)}, \tag{A.20}$$

$$X^*_{i,brown} = \frac{1}{\gamma_i} \frac{\mu_{r,brown} - b_i \mu_g}{\sigma_r^2 \left(1 + b_i^2 \frac{\sigma^2_{g,brown}}{\sigma_r^2} \right)}. \tag{A.21}$$

Notice that, for $\sigma_{g,green}, \sigma_{g,brown} > 0$,

$$\lim_{b_i \to \infty} X^*_{i,green} = \lim_{b_i \to \infty} \frac{1}{\gamma_i} \frac{\mu^r_{green} + b_i \mu_g}{\sigma_r^2 \left(1 + b_i^2 \frac{\sigma^2_{g,green}}{\sigma_r^2} \right)} = 0, \tag{A.22}$$

$$\lim_{b_i\to\infty} X^*_{i,brown} = \lim_{b_i\to\infty} \frac{1}{\gamma_i} \frac{\mu^r_{brown} - b_i\mu_g}{\sigma_r^2\left(1 + b_i^2 \frac{\sigma^2_{g,brown}}{\sigma_r^2}\right)} = 0. \tag{A.23}$$

A.4 Proof of Proposition 2: Expected Returns without ESG Uncertainty

As the riskless asset is in zero net supply, the market portfolio consists exclusively of risky assets and is given by

$$\boldsymbol{X}_M^N = \sum_{i=1}^{I} \boldsymbol{X}_i^* \frac{W_{i,0}}{W_{M,0}} = \sum_{i=1}^{I} w_i \frac{1}{\gamma_i} \boldsymbol{\Sigma}_r^{-1}\left(\boldsymbol{\mu}_r^N + b_i \boldsymbol{\mu}_g\right), \tag{A.24}$$

where $w_i = \frac{W_{i,0}}{W_{M,0}}$ and $\boldsymbol{\mu}_r^N$ has to be determined in equilibrium. Then, it follows that

$$\frac{\boldsymbol{\Sigma}_r \boldsymbol{X}_M^N}{\left(\sigma_M^N\right)^2}\left(\sigma_M^N\right)^2 = \left(\sum_{i=1}^{I} w_i \frac{1}{\gamma_i}\right)\boldsymbol{\mu}_r^N + \left(\sum_{i=1}^{I} w_i \frac{b_i}{\gamma_i}\right)\boldsymbol{\mu}_g, \tag{A.25}$$

which entails that

$$\boldsymbol{\mu}_r^N = \frac{\boldsymbol{\Sigma}_r \boldsymbol{X}_M^N}{\left(\sigma_M^N\right)^2}\gamma_M\left(\sigma_M^N\right)^2 - b_M\boldsymbol{\mu}_g, \tag{A.26}$$

where $\gamma_M = \left(\sum_{i=1}^{I} w_i\gamma_i^{-1}\right)^{-1}$ and $b_M = \frac{\sum_{i=1}^{I} w_i\gamma_i^{-1} b_i}{\sum_{i=1}^{I} w_i\gamma_i^{-1}}$. The expected excess return of the market portfolio is

$$\mu_M^N = \left(\boldsymbol{X}_M^N\right)'\boldsymbol{\mu}_r^N = \gamma_M\left(\sigma_M^N\right)^2 - b_M\left(\boldsymbol{X}_M^N\right)'\boldsymbol{\mu}_g, \tag{A.27}$$

which yields

$$\mu_M^N + b_M\left(\boldsymbol{X}_M^N\right)'\boldsymbol{\mu}_g = \gamma_M\left(\sigma_M^N\right)^2, \tag{A.28}$$

and, finally,

$$\begin{aligned}\boldsymbol{\mu}_r^N &= \frac{\boldsymbol{\Sigma}_r \boldsymbol{X}_M^N}{\left(\sigma_M^N\right)^2}\left(\mu_M^N + b_M\left(\boldsymbol{X}_M^N\right)'\boldsymbol{\mu}_g\right) - b_M\boldsymbol{\mu}_g \\ &= \frac{\boldsymbol{\Sigma}_r \boldsymbol{X}_M^N}{\left(\sigma_M^N\right)^2}\mu_M^N + b_M\frac{\boldsymbol{\Sigma}_r \boldsymbol{X}_M^N}{\left(\sigma_M^N\right)^2}\left(\boldsymbol{X}_M^N\right)'\boldsymbol{\mu}_g - b_M\boldsymbol{\mu}_g.\end{aligned} \tag{A.29}$$

Remembering that $\boldsymbol{\beta}^N = \frac{\boldsymbol{\Sigma}_r \boldsymbol{X}_M^N}{\left(\sigma_M^N\right)^2}$ is the N-vector of market betas, this result follows.

A.5 Proof of Proposition 3: Expected Returns with ESG Uncertainty

Market clearing implies that, as the riskless asset is in zero net supply, the market portfolio consists exclusively of risky assets and is given by

$$\begin{aligned}
\boldsymbol{X}_M^U &= \sum_{i=1}^{I} w_i \boldsymbol{X}_i^* \\
&= \sum_{i=1}^{I} w_i \frac{1}{\gamma_i} \boldsymbol{\Sigma}_i^{-1} \left(\boldsymbol{\mu}_r^U + b_i \boldsymbol{\mu}_g\right) \\
&= \sum_{i=1}^{I} w_i \frac{1}{\gamma_i} \left(\boldsymbol{\Sigma}_r^{-1} + \boldsymbol{\Psi}_{i,U}\right) \left(\boldsymbol{\mu}_r^U + b_i \boldsymbol{\mu}_g\right) \\
&= \sum_{i=1}^{I} w_i \frac{1}{\gamma_i} \left(\mathbf{I}_N + \boldsymbol{\Psi}_{i,U} \boldsymbol{\Sigma}_r\right) \boldsymbol{\Sigma}_r^{-1} \boldsymbol{\mu}_r^U + \sum_{i=1}^{I} w_i \frac{b_i}{\gamma_i} \left(\mathbf{I}_N + \boldsymbol{\Psi}_{i,U} \boldsymbol{\Sigma}_r\right) \boldsymbol{\Sigma}_r^{-1} \boldsymbol{\mu}_g,
\end{aligned} \tag{A.30}$$

where $\boldsymbol{\mu}_r^U$ has to be determined in equilibrium. We introduce the following notations:

$$\boldsymbol{\Gamma}_{M,\mathit{eff}}^{-1} = \sum_{i=1}^{I} w_i \frac{1}{\gamma_i} \left(\mathbf{I}_N + \boldsymbol{\Psi}_{i,U} \boldsymbol{\Sigma}_r\right) \tag{A.31}$$

$$\mathbf{B}_{M,\mathit{eff}} = \sum_{i=1}^{I} w_i \frac{b_i}{\gamma_i} \left(\mathbf{I}_N + \boldsymbol{\Psi}_{i,U} \boldsymbol{\Sigma}_r\right). \tag{A.32}$$

We then have

$$\boldsymbol{X}_M^U = \boldsymbol{\Gamma}_{M,\mathit{eff}}^{-1} \boldsymbol{\Sigma}_r^{-1} \boldsymbol{\mu}_r^U + \mathbf{B}_{M,\mathit{eff}} \boldsymbol{\Sigma}_r^{-1} \boldsymbol{\mu}_g, \tag{A.33}$$

and hence

$$\frac{\boldsymbol{\Sigma}_r \boldsymbol{X}_M^U}{\left(\sigma_M^U\right)^2} \left(\sigma_M^U\right)^2 = \boldsymbol{\Sigma}_r \boldsymbol{\Gamma}_{M,\mathit{eff}}^{-1} \boldsymbol{\Sigma}_r^{-1} \boldsymbol{\mu}_r^U + \boldsymbol{\Sigma}_r \mathbf{B}_{M,\mathit{eff}} \boldsymbol{\Sigma}_r^{-1} \boldsymbol{\mu}_g, \tag{A.34}$$

where $\frac{\boldsymbol{\Sigma}_r \boldsymbol{X}_M^U}{\left(\sigma_M^U\right)^2}$ is the vector of equilibrium market betas, $\boldsymbol{\beta}^U$. Therefore, solving for the vector of expected excess returns $\boldsymbol{\mu}_r^U$:

$$\boldsymbol{\mu}_r^U = \left(\boldsymbol{\Sigma}_r \boldsymbol{\Gamma}_{M,\mathit{eff}}^{-1} \boldsymbol{\Sigma}_r^{-1}\right)^{-1} \frac{\boldsymbol{\Sigma}_r \boldsymbol{X}_M^U}{\left(\sigma_M^U\right)^2} \left(\sigma_M^U\right)^2 - \left(\boldsymbol{\Sigma}_r \boldsymbol{\Gamma}_{M,\mathit{eff}}^{-1} \boldsymbol{\Sigma}_r^{-1}\right)^{-1} \boldsymbol{\Sigma}_r \mathbf{B}_{M,\mathit{eff}} \boldsymbol{\Sigma}_r^{-1} \boldsymbol{\mu}_g \tag{A.35}$$

$$= \boldsymbol{\Sigma}_r \boldsymbol{\Gamma}_{M,\mathit{eff}} \boldsymbol{\Sigma}_r^{-1} \frac{\boldsymbol{\Sigma}_r \boldsymbol{X}_M^U}{\left(\sigma_M^U\right)^2} \left(\sigma_M^U\right)^2 - \boldsymbol{\Sigma}_r \boldsymbol{\Gamma}_{M,\mathit{eff}} \mathbf{B}_{M,\mathit{eff}} \boldsymbol{\Sigma}_r^{-1} \boldsymbol{\mu}_g. \tag{A.36}$$

In addition, we aggregate to obtain the market expected excess return μ_M^U:

$$\mu_M^U = \left(\boldsymbol{X}_M^U\right)' \boldsymbol{\mu}_r^U = \frac{\left(\boldsymbol{X}_M^U\right)' \boldsymbol{\Sigma}_r \boldsymbol{\Gamma}_{M,\mathit{eff}} \boldsymbol{X}_M^U}{\left(\boldsymbol{X}_M^U\right)' \boldsymbol{\Sigma}_r \boldsymbol{X}_M^U} \left(\sigma_M^U\right)^2 - \left(\boldsymbol{X}_M^U\right)' \boldsymbol{\Sigma}_r \boldsymbol{\Gamma}_{M,\mathit{eff}} \mathbf{B}_{M,\mathit{eff}} \boldsymbol{\Sigma}_r^{-1} \boldsymbol{\mu}_g. \tag{A.37}$$

Remembering that $\left(\sigma_M^U\right)^2 = \left(\boldsymbol{X}_M^U\right)' \boldsymbol{\Sigma}_r \boldsymbol{X}_M^U$,

$$\left(\frac{\left(\boldsymbol{X}_M^U\right)' \boldsymbol{\Sigma}_r \boldsymbol{\Gamma}_{M,\mathit{eff}} \boldsymbol{X}_M^U}{\left(\sigma_M^U\right)^2} \right)^{-1} \left(\mu_M^U + \left(\boldsymbol{X}_M^U\right)' \boldsymbol{\Sigma}_r \boldsymbol{\Gamma}_{M,\mathit{eff}} \mathbf{B}_{M,\mathit{eff}} \boldsymbol{\Sigma}_r^{-1} \boldsymbol{\mu}_g \right) = \left(\sigma_M^U\right)^2. \tag{A.38}$$

The vector of expected asset returns is then given by

$$\begin{aligned} \boldsymbol{\mu}_r^U = & \frac{\boldsymbol{\Sigma}_r \boldsymbol{\Gamma}_{M,\mathit{eff}} \boldsymbol{X}_M^U}{\left(\boldsymbol{X}_M^U\right)' \boldsymbol{\Sigma}_r \boldsymbol{\Gamma}_{M,\mathit{eff}} \boldsymbol{X}_M^U} \mu_M^U \qquad (A.39) \\ & - \left(\boldsymbol{\Sigma}_r \boldsymbol{\Gamma}_{M,\mathit{eff}} \mathbf{B}_{M,\mathit{eff}} \boldsymbol{\Sigma}_r^{-1} \boldsymbol{\mu}_g - \frac{\boldsymbol{\Sigma}_r \boldsymbol{\Gamma}_{M,\mathit{eff}} \boldsymbol{X}_M^U}{\left(\boldsymbol{X}_M^U\right)' \boldsymbol{\Sigma}_r \boldsymbol{\Gamma}_{M,\mathit{eff}} \boldsymbol{X}_M^U} \left(\boldsymbol{X}_M^U\right)' \boldsymbol{\Sigma}_r \boldsymbol{\Gamma}_{M,\mathit{eff}} \mathbf{B}_{M,\mathit{eff}} \boldsymbol{\Sigma}_r^{-1} \boldsymbol{\mu}_g \right). \end{aligned}$$

From (A.37) and (A.39), we can therefore write that the equilibrium market and stock expected excess returns are

$$\mu_M^U = \gamma_{M,\mathit{eff}} \left(\sigma_M^U\right)^2 - \mu_{g,M,U}, \tag{A.40}$$
$$\boldsymbol{\mu}_r^U = \boldsymbol{\beta}_{\mathit{eff}} \mu_M - \left(\boldsymbol{\mu}_{g,U} - \boldsymbol{\beta}_{\mathit{eff}} \mu_{g,M,U}\right), \tag{A.41}$$

where

$$\begin{aligned} \gamma_{M,\mathit{eff}} &= \frac{\left(\boldsymbol{X}_M^U\right)' \boldsymbol{\Sigma}_r \boldsymbol{\Gamma}_{M,\mathit{eff}} \boldsymbol{X}_M^U}{\left(\boldsymbol{X}_M^U\right)' \boldsymbol{\Sigma}_r \boldsymbol{X}_M^U} \\ \mu_{g,M,U} &= \left(\boldsymbol{X}_M^U\right)' \boldsymbol{\mu}_{g,U} \\ \boldsymbol{\mu}_{g,U} &= \boldsymbol{\Sigma}_r \boldsymbol{\Gamma}_{M,\mathit{eff}} \mathbf{B}_{M,\mathit{eff}} \boldsymbol{\Sigma}_r^{-1} \boldsymbol{\mu}_g \\ \boldsymbol{\beta}_{\mathit{eff}} &= \frac{\boldsymbol{\Sigma}_r \boldsymbol{\Gamma}_{M,\mathit{eff}} \boldsymbol{X}_M^U}{\left(\boldsymbol{X}_M^U\right)' \boldsymbol{\Sigma}_r \boldsymbol{\Gamma}_{M,\mathit{eff}} \boldsymbol{X}_M^U} \\ \boldsymbol{X}_M^U &= \boldsymbol{\Gamma}_{M,\mathit{eff}}^{-1} \boldsymbol{\Sigma}_r^{-1} \boldsymbol{\mu}_r + \mathbf{B}_{M,\mathit{eff}} \boldsymbol{\Sigma}_r^{-1} \boldsymbol{\mu}_g \\ \boldsymbol{\Gamma}_{M,\mathit{eff}}^{-1} &= \sum_{i=1}^{I} w_i \boldsymbol{\Gamma}_{i,\mathit{eff}}^{-1} \\ \mathbf{B}_{M,\mathit{eff}} &= \sum_{i=1}^{I} w_i b_i \boldsymbol{\Gamma}_{i,\mathit{eff}}^{-1} \\ \boldsymbol{\Gamma}_{i,\mathit{eff}} &= \gamma_i \left(\mathbf{I}_N + b_i^2 \boldsymbol{\Sigma}_r^{-1} \boldsymbol{\Sigma}_g\right). \end{aligned}$$

Under the hypothesis that agents are homogeneous in preferences ($\gamma_i = \gamma$ and $b_i = b$, $\forall i$), several simplifications are possible, leading to

$$\begin{aligned}
\gamma_{M,\mathit{eff}} &= \gamma \left(1 + b^2 \frac{\left(\boldsymbol{X}_M^U\right)' \boldsymbol{\Sigma}_g \boldsymbol{X}_M^U}{\left(\boldsymbol{X}_M^U\right)' \boldsymbol{\Sigma}_r \boldsymbol{X}_M^U}\right) = \gamma \left(1 + b^2 \frac{\left(\sigma_{g,M}^U\right)^2}{\left(\sigma_M^U\right)^2}\right) \\
\mu_{g,M,U} &= b \left(\boldsymbol{X}_M^U\right)' \boldsymbol{\mu}_g = b\mu_{g,M} \\
\boldsymbol{\mu}_{g,U} &= b\boldsymbol{\mu}_g \\
\boldsymbol{\beta}_{\mathit{eff}} &= \frac{\left(\boldsymbol{\Sigma}_r + b^2 \boldsymbol{\Sigma}_g\right) \boldsymbol{X}_M^U}{\left(\sigma_M^U\right)^2 + \left(\sigma_{g,M}^U\right)^2} \\
\boldsymbol{X}_M^U &= \boldsymbol{\Gamma}_{M,\mathit{eff}}^{-1} \boldsymbol{\Sigma}_r^{-1} \left(\boldsymbol{\mu}_r + b\boldsymbol{\mu}_g\right) \\
\boldsymbol{\Gamma}_{M,\mathit{eff}} &= \gamma \left(\mathbf{I}_N + b^2 \boldsymbol{\Sigma}_r^{-1} \boldsymbol{\Sigma}_g\right) \\
\mathbf{B}_{M,\mathit{eff}} &= b\boldsymbol{\Gamma}_{M,\mathit{eff}}^{-1}.
\end{aligned}$$

A.6 Expected Returns in a Two-Asset Economy

We attempt to determine the equilibrium expected excess returns of the two risky assets. Starting from the optimal portfolio for agent i in Proposition 1,

$$\boldsymbol{X}_i^* = \boldsymbol{\Gamma}_{i,\mathit{eff}}^{-1} \boldsymbol{\Sigma}_r^{-1} \left(\boldsymbol{\mu}_r + b_i \boldsymbol{\mu}_g\right), \tag{A.42}$$

we pre-multiply by $\boldsymbol{\Sigma}_r$ and aggregate across agents to obtain

$$\sum_{i=1}^{I} w_i \frac{\boldsymbol{\Sigma}_r \boldsymbol{X}_i^*}{\sigma_M^2} \sigma_M^2 = \sum_{i=1}^{I} w_i \boldsymbol{\Sigma}_r \boldsymbol{\Gamma}_{i,\mathit{eff}}^{-1} \boldsymbol{\Sigma}_r^{-1} \left(\boldsymbol{\mu}_r + b_i \boldsymbol{\mu}_g\right). \tag{A.43}$$

Recalling that $\boldsymbol{\Sigma}_r = \sigma_r^2 \mathbf{I}_2$ and defining $\boldsymbol{\beta} = \frac{\boldsymbol{\Sigma}_r \boldsymbol{X}_i^*}{\sigma_M^2}$, we get

$$\sigma_M^2 \boldsymbol{\beta} = \sum_{i=1}^{I} w_i \boldsymbol{\Sigma}_r \boldsymbol{\Gamma}_{i,\mathit{eff}}^{-1} \boldsymbol{\Sigma}_r^{-1} \boldsymbol{\mu}_r + \sum_{i=1}^{I} w_i \boldsymbol{\Sigma}_r \boldsymbol{\Gamma}_{i,\mathit{eff}}^{-1} \boldsymbol{\Sigma}_r^{-1} b_i \boldsymbol{\mu}_g. \tag{A.44}$$

Solving for $\boldsymbol{\mu}_r$ leads to the equilibrium expected excess returns

$$\begin{aligned}
\boldsymbol{\mu}_r = &\left(\sum_{i=1}^{I} w_i \boldsymbol{\Sigma}_r \boldsymbol{\Gamma}_{i,\mathit{eff}}^{-1} \boldsymbol{\Sigma}_r^{-1}\right)^{-1} \sigma_M^2 \boldsymbol{\beta} \\
&- \left(\sum_{i=1}^{I} w_i \boldsymbol{\Sigma}_r \boldsymbol{\Gamma}_{i,\mathit{eff}}^{-1} \boldsymbol{\Sigma}_r^{-1}\right)^{-1} \left(\sum_{i=1}^{I} w_i b_i \boldsymbol{\Sigma}_r \boldsymbol{\Gamma}_{i,\mathit{eff}}^{-1} \boldsymbol{\Sigma}_r^{-1}\right) \boldsymbol{\mu}_g.
\end{aligned} \tag{A.45}$$

Assuming that all agents have the same relative risk aversion and the same relative brown aversion ($\gamma_i = \gamma$ and $b_i = b$, $\forall i$), recalling (A.19), it turns out that

$$\boldsymbol{\Gamma}_{M,eff}^{-1} = \sum_{i=1}^{I} w_i \boldsymbol{\Gamma}_{i,eff}^{-1} = \frac{1}{\gamma} \begin{bmatrix} \frac{1}{1+b^2 \frac{\sigma_{g,green}^2}{\sigma_r^2}} & 0 \\ 0 & \frac{1}{1+b^2 \frac{\sigma_{g,brown}^2}{\sigma_r^2}} \end{bmatrix}. \tag{A.46}$$

The equilibrium expected excess returns in (A.45) can then be rewritten as

$$\boldsymbol{\mu}_r = \boldsymbol{\Gamma}_{M,eff} \boldsymbol{\beta} \sigma_M^2 - b \boldsymbol{\mu}_g. \tag{A.47}$$

It follows that

$$\mu_{r,green} = \gamma \beta_{green} \left(1 + b^2 \frac{\sigma_{g,green}^2}{\sigma_r^2}\right) \sigma_M^2 - b\mu_g, \tag{A.48}$$

$$\mu_{r,brown} = \gamma \beta_{brown} \left(1 + b^2 \frac{\sigma_{g,brown}^2}{\sigma_r^2}\right) \sigma_M^2 + b\mu_g. \tag{A.49}$$

A.7 Welfare in a Multi-Asset Economy

In the multi-asset setup, the expected utility is given by

$$E\left[V\left(\tilde{W}_{i,1}, \boldsymbol{X}_i^*\right)\right] = -E\left[e^{-A_i \tilde{W}_{i,1} - B_i W_{i,0} \left(\boldsymbol{X}_i^*\right)' \tilde{\boldsymbol{g}}}\right]. \tag{A.50}$$

Given the normality of the random variables, welfare can be evaluated explicitly as

$$E\left[V\left(\tilde{W}_{i,1}, \boldsymbol{X}_i^*\right)\right] = -e^{-\gamma_i \left(1+r_f\right) - \gamma_i \left[\left(\boldsymbol{X}_i'\right)^* \left(\boldsymbol{\mu}_r^U + b_i \boldsymbol{\mu}_g\right) - \frac{\gamma_i}{2} \left(\boldsymbol{X}_i'\right)^* \boldsymbol{\Sigma}_i \boldsymbol{X}_i^*\right]}. \tag{A.51}$$

Then, it follows that

$$CE_i = \left(\boldsymbol{X}_i^*\right)' \left(\boldsymbol{\mu}_r^U + b_i \boldsymbol{\mu}_g\right) - \frac{\gamma_i}{2} \left(\boldsymbol{X}_i^*\right)' \boldsymbol{\Sigma}_i \boldsymbol{X}_i^* = \frac{1}{2\gamma_i} \left(\boldsymbol{\mu}_r^U + b_i \boldsymbol{\mu}_g\right)' \boldsymbol{\Sigma}_i^{-1} \left(\boldsymbol{\mu}_r^U + b_i \boldsymbol{\mu}_g\right). \tag{A.52}$$

The certainty equivalent returns under ESG indifference, ESG preferences without uncertainty, and ESG preferences with uncertainty are respectively given by

$$CE_i^I = \frac{1}{2\gamma_i} \left(\boldsymbol{\mu}_r^I\right)' \boldsymbol{\Sigma}_r^{-1} \boldsymbol{\mu}_r^I, \tag{A.53}$$

$$CE_i^N = \frac{1}{2\gamma_i} \left(\boldsymbol{\mu}_r^N + b_i \boldsymbol{\mu}_g\right)' \boldsymbol{\Sigma}_r^{-1} \left(\boldsymbol{\mu}_r^N + b_i \boldsymbol{\mu}_g\right), \tag{A.54}$$

$$CE_i^U = \frac{1}{2\gamma_i} \left(\boldsymbol{\mu}_r^U + b_i \boldsymbol{\mu}_g\right)' \boldsymbol{\Sigma}_i^{-1} \left(\boldsymbol{\mu}_r^U + b_i \boldsymbol{\mu}_g\right). \tag{A.55}$$

For an individual i, the change in certainty equivalent return between ESG indifference and ESG preferences with uncertainty is therefore given by

$$CE_i^U - CE_i^I = \frac{1}{2\gamma_i} \left(\boldsymbol{\mu}_r^U + b_i \boldsymbol{\mu}_g\right)' \boldsymbol{\Sigma}_i^{-1} \left(\boldsymbol{\mu}_r^U + b_i \boldsymbol{\mu}_g\right) - \frac{1}{2\gamma_i} \left(\boldsymbol{\mu}_r^I\right)' \boldsymbol{\Sigma}_r^{-1} \boldsymbol{\mu}_r^I. \tag{A.56}$$

The welfare change is the difference between two squared Sharpe ratios scaled by the agent's risk aversion. The first is the *perceived* Sharpe ratio, reflecting the optimal portfolio that invests in N risky assets realizing $\tilde{\boldsymbol{r}} + b_i \tilde{\boldsymbol{g}}$, while the second Sharpe ratio emerges from the optimal portfolio of risky assets that excludes ESG considerations. Accounting for ESG uncertainty, the mix of green and brown firms plays an important role, and welfare increases as the prominence of green firms intensifies. However, when uncertainty is sufficiently high, welfare can drop even if all firms in the economy are green. Overall, the welfare change is inconclusive. For perspective, welfare rises for agents with ESG preferences but do not account for uncertainty, as analyzed by Pastor et al. (2020).

B Supplementary Analysis

To save space, we tabulate the supplementary analysis here and discuss only our main findings in the paper.

Table B.1: Number of Stocks Over Time

Panel A reports the number of stocks covered by each data vendor on a year-by-year basis. Panel B reports the number of stocks simultaneously covered by N data vendors on a year-by-year basis, where N ranges between 1 and 5.

Panel A: Number of Stocks Covered By Each Data Vendor

Year	Asset4	MSCI KLD	MSCI IVA	Bloomberg	Sustainalytics	RobecoSAM
2002	398	1,055	0	0	0	0
2003	400	2,805	0	0	0	0
2004	535	2,851	0	0	0	0
2005	600	2,687	0	125	0	0
2006	606	2,655	528	209	0	0
2007	620	2,566	609	709	0	0
2008	789	2,580	600	984	0	0
2009	892	2,598	599	1,065	0	0
2010	915	2,630	551	1,957	0	0
2011	912	2,472	537	2,077	0	0
2012	895	2,418	2,253	2,149	0	0
2013	890	2,125	2,388	2,242	0	0
2014	885	2,098	2,328	2,380	413	0
2015	1,436	2,124	2,282	2,514	441	0
2016	2,083	0	2,255	2,530	460	419
2017	2,218	0	2,139	2,658	452	616
2018	2,178	0	2,104	2,794	473	818
2019	1,225	0	2,136	1,845	486	1,380

Panel B: Number of Stocks Covered By Multiple Data Vendors

Year	$N = 1$	$N = 2$	$N = 3$	$N = 4$	$N = 5$	$N \geq 2$
2002	677	388	0	0	0	388
2003	2409	398	0	0	0	398
2004	2324	531	0	0	0	531
2005	2199	518	59	0	0	577
2006	2069	241	349	100	0	690
2007	1756	380	264	299	0	943
2008	1579	505	320	351	0	1,176
2009	1601	487	373	365	0	1,225
2010	1240	1,093	385	368	0	1,846
2011	1136	1,109	392	367	0	1,868
2012	631	702	1,060	625	0	2,387
2013	741	591	1,038	652	0	2,281
2014	781	586	1,030	289	381	2,286
2015	851	341	811	669	431	2,252
2016	797	645	1,119	87	391	2,242
2017	781	512	1,140	162	442	2,256
2018	817	425	1,042	336	446	2,249
2019	721	485	787	610	116	1,998