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Utility in the Age of Sustainability: A General Equilibrium Asset Pricing Model for ESG Investing

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1 Abstract

This thesis investigates the impact of incorporating investors' Environmental, Social, and Governance (ESG) preferences into a general equilibrium asset pricing model on the asset prices of green and brown assets. Extending the work of Pástor et al. (2021), this study delves into the intricacies of ESG preferences and their influence on market dynamics and asset pricing. The primary research question is: "*What is the effect of incorporating investors' Environmental, Social, and Governance (ESG) preferences in a general equilibrium asset pricing model on the asset prices of green and brown assets?*"

Three hypotheses were formulated to explore this question. The first hypothesis examines the effect of disaggregating ESG preferences into individual components (Environmental, Social, and Governance) on asset prices. This approach provides a more precise representation of investor preferences, leading to asset prices that better reflect the distinct ESG characteristics of firms. The second hypothesis investigates the role of relative ESG risk aversions. Accounting for ESG risk aversions among investors decreases the equity premium for green assets and increases it for brown assets, resulting in higher prices for green assets and lower prices for brown assets. The third hypothesis explores the impact of ESG aversion, revealing that investors with negative ESG tastes prioritize negative ESG impacts over positive impacts, resulting in higher prices for brown assets and lower prices for green assets.

The findings from testing these hypotheses underscore the importance of incorporating a wide spectrum of ESG tastes and ESG risk aversions into asset pricing models. The results indicate that these adjustments lead to a more accurate reflection of investor behavior and market dynamics. This research offers valuable insights for financial institutions, policymakers, and researchers, highlighting the complex interactions between ESG considerations and asset pricing. Future research should aim to empirically validate these models and develop theoretical frameworks with fewer stringent assumptions to capture real-world dynamics better.

2 Introduction

Eighty per cent of global investors now have sustainable investment policies in place (Bondar et al., 2024). According to a new study by Deloitte and Tufts University (2024), most professional investors globally have implemented ESG investment policies over the past several years. Consequently, financial markets worldwide are experiencing an extraordinary boom in new products and practices in response to this growing demand from investors for investments labelled as 'green', that is, committed to Environmental, Social and Corporate governance (ESG) principles (Hartzmark & Sussman, 2019; Krüger et al., 2018; Venturini, 2022). Regulators also increase their focus on ESG investing. For instance, on August 2nd, 2022, the 'Suitability Delegated Regulation' came into effect under the second Markets in Financial Instruments Directive (MiFID II) (Delegated Regulation (E.U.) 2017/565, 2021). Companies that fall under MiFID II must assess the suitability of their products and services for clients, ensuring that the client's ESG preferences are considered. A client's investment objectives must include the client's ESG preferences, and firms must state in reports how ESG preferences are incorporated and, if not, why. Firms selling MiFID II products must also integrate 'Sustainability Risks' in their organisational framework and risk management policy (Delegated Regulation (E.U.) 2017/565, 2021).

Although the attention on ESG activities by companies and investments has surged, it is still unclear what effects ESG preferences have on the fundamental value of asset prices. The dynamics of stock prices and the discount rates demanded by investors remain a significant challenge in financial economics. Since the dawn of the Capital Asset Pricing Model (CAPM) of Sharpe and Lintner (Lintner, 1965; Sharpe, 1964), researchers have strived to unravel the complexities of asset prices by developing several asset pricing theories. These theories are driven to clarify and determine the inherent value of assets within an uncertain market environment. Understanding the fundamental value enables the calculation of appropriate returns on investments. The accurate valuation of assets is essential, as incorrect pricing can lead to inefficiencies in investment and consumption within the real economy.

In this thesis, three versions of an asset pricing model (a general equilibrium asset pricing model) are created that incorporate the tastes and preferences of investors concerning the ESG performance of companies.

2.1 Research Problem & Motivation

The demand for green investments is increasing, reflecting investors' growing emphasis on sustainability and ethical business practices. As a result, ESG considerations are gradually becoming more important in investment decision-making, which has created the urge to adequately improve asset pricing models to account for these changing preferences and asset components. Pástor, Stambaugh and Taylor (2021) picked up the challenge and analysed the financial and non-financial effects of sustainable investing through an equilibrium asset pricing model. Based on agents' preferences, they show that agents' tastes for green assets impact asset prices. Agents are willing to pay more for greener firms, decreasing the firms' costs of capital and creating negative CAPM alphas for green assets. Consequently, agents with stronger ESG preferences have portfolios that tend toward green assets and earn lower expected returns.

Although agents receive negative CAPM alphas, they are not unhappy because they derive utility from their holdings. Pástor et al. (2021) propose a utility function that provides utility based on several factors. First, agents derive utility from the non-pecuniary benefits of holding green assets and disutility from holding brown assets. Second, agents care about financial wealth and, thus, the financial returns they make on their holdings. Then, they extend their model and include an increase in utility if a firm has a positive aggregate social impact. Lastly, agents additionally care about climate risk. This climate risk is modelled to decrease the agent's utility due to the lower quality of life caused by climate change.

The model of Pástor et al. (2021) is quite extensive and incorporates multiple variables into the employed utility function. However, there is still potential for further expansion and improvement of their model to accurately capture market conditions and investor preferences. The utility agents derived from green holdings go beyond the general 'ESG' tastes of the agent (see paragraph 3.3). Altering the model of Pástor et al. (2021) allows capturing a larger spectrum of elements associated with high ESG performance.

From a practical point of view, the implications of this research are multifaceted. A model that finds the fundamental value of green and brown assets provides regulators with tools to create policy interventions, promote the green transition, and improve corporate value creation. By adjusting their encouragement of ESG performance, according to the effect ESG performance will

have on the equity value, they can enhance market risk mitigation and promote sustainable economic growth.

For investors, including fund managers and pension funds, understanding the impact of ESG considerations on asset pricing is crucial for optimizing portfolio allocation and risk management strategies. Including ESG risks in discount rates can lead to improved decision-making by companies.

Moreover, this research contributes to the broader academic debate on asset pricing models and utility functions. By refining existing models to reflect modern market reality, the theoretical foundations of finance are improved, and practical insights are provided that bridge theory and practice.

In summary, this research seeks to fill a critical gap in current asset pricing models by exploring the implications of including ESG preferences of investors. In this way, this thesis aims to provide valuable insights for regulators, investors and researchers while improving the theoretical base of financial economics in the context of sustainability.

2.2 Research Objectives

The core idea of this thesis is to study the effect of ESG preferences on asset prices. To ensure the feasibility of this research and its contribution to filling the methodological gap, the fundamental concepts of this study are further specified in this paragraph. These concepts culminate in the research question of this thesis.

Firstly, this thesis is focused on creating a general equilibrium asset pricing model geared towards the fundamental value of equities. Under general equilibrium theory, prices are determined through market prices based on supply and demand. The fundamental value of an asset is the natural price, as defined by Adam Smith. The natural price gives the owner a sufficient profit, dependent on several commodity characteristics (Smith, 1776, p. 72).

Secondly, this thesis is specifically focused on incorporating the ESG preferences of investors in a general equilibrium asset pricing model and builds on the findings of Pástor et al. (2021).

Combining these concepts produces the following research question:

What is the effect of incorporating investors' Environmental, Social, and Governance (ESG) preferences in a general equilibrium asset pricing model on the asset prices of green and brown assets?

2.3 Research Methodology

The primary methodology is a qualitative theoretical approach where relevant literature is studied. Mathematical equations are then developed to create an equilibrium asset pricing model.

Most of the literature has been gathered through Business Source Complete, EconLit, RuQuest and Web of Science databases. The databases were searched using the terms 'asset pricing model', 'CAPM', and 'ESG preferences' and using various synonyms and combinations. The rest of the literature used has been found through snowballing and searching citations on the literature retrieved from the databases.

2.4 Thesis Outline

In the following chapters, a literature review will be provided (Chapter 3), and the hypotheses of this thesis will be developed (Chapter 4). Chapter 5 provides the results of this thesis. The results, including the limitations of this thesis, are discussed in Chapter 6. Chapter 7 provides a conclusion and the implications of this thesis.

3 Literature Review

3.1 Introduction

This literature review addresses the research question: *“What is the effect of incorporating ESG preferences of investors in a general equilibrium asset pricing model on the asset prices of green and brown assets?”* The literature review is segmented into four key areas: an overview of ESG investing, an analysis of common risks and benefits associated with ESG investing, an explanation of asset pricing models, and a discussion on incorporating ESG into these models.

3.2 ESG Investing

ESG investing uses environmental, social, and governance metrics to guide investment decisions. This approach is often quantified through ESG scores provided by third-party rating agencies, which aim to screen investments based on corporate policies and encourage responsible business practices. Evolving from Socially Responsible Investing (SRI), ESG investing has broadened the scope of ethical considerations and gained significant traction since the late 20th century (Townsend, 2020). As the Global Sustainable Investment Alliance (GSI) reported in 2022, the shift has resulted in substantial asset growth under management. In the five major markets, sustainable investment assets reached an impressive 21.9 trillion USD, marking a remarkable 20% increase from 2020 (Global Sustainable Investment Review 2022, 2023). This exponential growth signifies a broader recognition within the investment community regarding the significance of ESG factors in risk mitigation and positive financial opportunities. The increasing availability of ESG data has played a crucial role in facilitating this transition, enabling diverse investors to incorporate ESG considerations into their investment strategies (Global Sustainable Investment Review 2022, 2023).

3.3 Risks and Benefits of ESG Investing

This section delves into the dual facets of ESG investing, focusing on the associated risks and benefits. On the one hand, investors encounter challenges such as ESG divergence, where inconsistent ESG scores from different rating agencies create uncertainties about a company's

true ESG impact. This divergence, coupled with potential score inflation, complicates the evaluation of ESG performance. On the other hand, ESG investing offers substantial benefits, including non-pecuniary gains where investors derive satisfaction from aligning their investments with their ethical values. Furthermore, ESG considerations can positively influence a company's financial performance and provide significant risk management advantages.

3.3.1 ESG Divergence

One of the most significant risks associated with ESG investing is ESG divergence. ESG divergence occurs when ESG scores vary widely among different rating agencies, leading to uncertainty and confusion among investors about the true ESG impact of a company. Divergence in ESG ratings can stem from differences in methodologies, scope, and weighting of ESG factors used by rating agencies. This lack of standardization challenges investors to make informed decisions based on ESG criteria. The following discussion explores the causes and implications of ESG divergence in detail.

Berg, Kölbel, and Rigobon (2022) address the significant ESG divergence observed from various providers. Using data from six prominent ESG rating agencies, their study highlights substantial discrepancies, with correlations between ESG ratings ranging from 0.38 to 0.71. The authors attribute this variation primarily to differences in 'measurement,' accounting for 56% of the variability, as agencies use different indicators to evaluate equal ESG factors. 'Scope' divergence, which refers to the differences in the ESG aspects that agencies choose to consider, contributes 38% of the variability. The differences in the weighting of ESG components ('weights') only contribute 6%.

Next to divergence, ESG scores might be inflated based on company characteristics or a 'rater effect'. The rater effect is the tendency of ESG rating agencies to adjust the scores of specific ESG components based on the scores for other components (Berg et al., 2022). This effect shows the substantial conflict of interest rating agencies have by being paid by the companies they are rating (Berg et al., 2022). Drempevic, Klein, and Zwergel (2020) reveal a notable positive relationship between firm size and the ESG scores issued by rating agencies. Their results indicate a potential bias in ESG scoring that benefits larger corporations, potentially due to their higher capacity to report and handle ESG-related information.

The ESG divergence and score inflation pose significant challenges in evaluating a company's ESG performance. It can weaken companies' motivation to enhance their ESG practices and result in a fragmented market pricing of ESG actions (Berg et al., 2022). Standardised ESG measurements would simplify the assessment of a firm's ESG profile for investors and shareholders, provide borrowers and companies with more precise benchmarks, and encourage more focused efforts towards sustainability (Berg et al., 2022).

3.3.2 Non-pecuniary Benefits

One of the primary drivers behind the growth of ESG investments is the non-pecuniary utility investors, who derive from aligning their investments with their environmental, social, and governance preferences. This alignment reflects investors' ethical values and enhances shareholder welfare when firms incorporate these preferences into their strategies (Hart & Zingales, 2017). Several empirical studies support the significance of non-pecuniary benefits in ESG investing, demonstrating that investor preferences extend beyond conventional financial gains.

For instance, Bollen (2007) found that flows to socially responsible investment (SRI) mutual funds are less volatile than those to non-SRI funds. Renneboog et al. (2011) showed that these flows are less responsive to negative past performance. Additionally, investors in SRI funds indicate a willingness to forgo financial performance to align with their social preferences (Riedl & Smeets, 2017).

Amir and Serafeim (2018) present a thorough assessment of the reasons and methods through which investors use ESG information. They note a substantial increase in companies disclosing ESG data, from fewer than 20 in the early 1990s to nearly 9,000 by 2016. Ethical concerns drive ESG investment decisions (Amir & Serafeim, 2018). Nevertheless, the relevance of ESG to investment (financial) performance is shown to be the primary driver of ESG investments (Amir & Serafeim, 2018).

Barber et al. (2021) find that venture capital funds that aim for both financial return and social impact tend to earn lower returns than other funds. They argue that this discrepancy is due to the non-pecuniary satisfaction investors receive from investing in social impact funds.

Expanding on this work, Kräussl et al. (2024) explore investors' expectations, beliefs, and perceptions regarding ESG investing. Their review emphasises the importance of understanding investor psychology and the societal implications of investment choices (Kräussl et al., 2024). They show that nonpecuniary benefits, such as ethical alignment and social responsibility, are vital in shaping investor preferences and strategies in ESG investing (Kräussl et al., 2024).

Duchêne et al. (2022) add nuance to the debate by studying the impact of environmental externalities on portfolio decisions through an experiment involving finance professionals and students. Their findings reveal that participants accepted lower returns for investments with positive environmental impacts, illustrating the non-pecuniary benefits of such investments. However, they were reluctant to take higher risks for these benefits, especially when portfolios became riskier. This tendency is supported by Bansal et al. (2022), who show that investors' demand for SRI decreases in dire economic conditions, indicating that wealth influences the degree to which investors prioritize ESG criteria.

Overall, these studies collectively illustrate that non-pecuniary benefits play a significant role in the growth and dynamics of ESG investing, shaping investor behaviour and preferences in complex ways.

3.3.3 Financial Performance Benefits

Another primary driver behind the growth of ESG investing is its impact on financial performance. A significant body of research has explored the potential positive relationship between a company's financial performance (FP) and its ESG performance. Traditional neoclassical perspectives suggest that engaging in ESG activities imposes additional costs on companies, potentially leading to a decline in financial performance. For instance, investments to reduce emissions or increase resource efficiency might be seen as excessively costly compared to conventional methods, thereby affecting profitability (Hassel et al., 2005; Palmer et al., 1995; Semenova & Hassel, 2008; Rassier & Earnhart, 2011; Sueyoshi & Goto, 2010)

However, this classical view has been increasingly challenged. A meta-review by Friede et al. (2015) of over 2200 individual studies revealed a positive relationship between ESG and financial performance. Approximately 90% of these studies found a non-negative ESG–FP relation, with

79.2% showing positive findings and an average correlation of around 0.15, indicating stable positive correlations since the mid-1990s.

Building on Friede et al. (2015), Velte (2017) examined the connection between ESG factors and financial performance in German-listed companies. His analysis of 412 firm-year observations reveals that ESG positively impacts the Return on Assets (ROA). However, there is no significant effect on Tobin's Q. Furthermore when examining the individual components of ESG, governance performance emerges as the most influential factor on financial performance. Yoon, Lee, and Byun (2018) extended this analysis to the Korean market, showing that ESG practices contribute to firm market value. However, the impact varied depending on firm characteristics and industry ESG sensitivity, with governance practices driving market value for large family-run conglomerates (chaebols).

Despite these positive findings, the relationship between ESG and financial performance is not uniformly positive. Duque-Grisales and Aguilera-Caracuel (2021) provided a more nuanced view, showing a significant negative correlation between higher ESG scores and ROA for Latin American multinationals (Multilatinas). Their study highlighted the moderating effects of financial slack (liquid assets without specific commitments) and geographic international diversification on the ESG–FP relationship.

Adding further complexity, Fatemi et al. (2018) examined the role of ESG disclosure levels in firm value. They found that transparency in ESG practices could have dual effects. While it might reduce the perceived value of ESG strengths due to greenwashing concerns, it could also mitigate the negative impact of ESG weaknesses by demonstrating accountability. Xie et al. (2019) supported these findings, identifying an optimal level of ESG disclosure that balances operational efficiency and stakeholder insights without overwhelming them with irrelevant information or increasing administrative costs.

In summary, the financial performance benefits of ESG investing are multifaceted and context-dependent. While many studies indicate a positive relationship between ESG practices and economic performance, variations across markets, industries, and disclosure levels highlight the need for a nuanced understanding of how ESG factors influence financial outcomes.

3.3.4 Risk Management Benefits

Beyond direct financial performance and non-pecuniary benefits, ESG investing offers significant advantages in risk management. ESG factors can serve as a hedge against various risks, enhancing the stability and resilience of investments.

Historically, within the context of risk management, the focus lay on the hedging capabilities of Corporate Social Responsibility (CSR) activities. Godfrey et al. (2009) explored CSR as a risk management tool, proposing that CSR initiatives act as an 'insurance-like' safeguard for companies. Their study found that firms engaged in CSR activities experienced significantly less decline in Cumulative Abnormal Returns (CAR) around adverse events. CSR activities create positive perceptions among supervisory authorities and stakeholders, helping to mitigate penalties and negative judgments during challenging situations.

More recent studies have underscored the importance of ESG factors in corporate risk management. Sassen et al. (2016) analysed the influence of ESG factors on market-based firm risk in Europe, revealing a nuanced relationship between social performance and firm risk. Their study found that improving social performance decreases total and idiosyncratic risk, while environmental performance primarily reduces idiosyncratic risk. However, corporate governance performance did not significantly influence firm risk, highlighting the complex dynamics of ESG factors in risk mitigation.

Kumar et al. (2016) take a different approach by using a quantitative model to assess the risk-adjusted performance of companies that incorporate ESG factors compared to those that do not. Their research reveals that ESG companies display decreased volatility in stock performance when contrasted with their non-ESG counterparts, indicating a concrete advantage in risk mitigation. Remarkably, this risk reduction does not compromise returns: Kumar et al. find that ESG companies exhibited superior returns, challenging the traditional financial belief that lower risk inevitably leads to lower returns.

Verheyden, Eccles, and Feiner (2016) specifically focus on the quantitative impact of ESG screening on investment portfolios, offering valuable insights for risk management and investment strategy development. The results of their analysis show that portfolios that incorporate ESG screening not only maintain returns but also have the potential to improve risk-

adjusted returns. This improvement shows again that there could be a win-win game regarding ethical considerations and financial performance.

Lastly, Moalla and Dammak (2023) present a detailed analysis of the relationship between ESG performance and stock market volatility in the context of the COVID-19 pandemic. By examining 500 U.S. companies listed on the S&P 500, the authors find that strong ESG performance is associated with decreased stock price volatility during the pandemic. This decrease in volatility highlights the additional potential of using ESG investing as a risk management tool in times of crisis.

The negative implications of low ESG performance have also been studied. Luo and Balvers (2017) identified a premium for boycott risk, which arises when socially responsible investors avoid stocks of companies producing alcohol, tobacco, and gaming (sin stocks). His avoidance increases the risk for other investors, who demand extra compensation for holding these stocks, leading to a premium for systematic boycott risk. Hoepner et al. (2023) found that ESG engagement reduces firms' downside risk and exposure to a downside risk factor, which refers to the market's potential undervaluation of assets or sectors due to unforeseen challenges or liabilities faced by companies with poor ESG performance. These factors can negatively impact financial performance and market valuation.

In summary, ESG investing provides significant risk management benefits by reducing volatility, enhancing resilience during crises, and mitigating downside risks. These advantages, alongside the ethical and financial performance benefits, make ESG considerations an essential component of modern investment strategies.

3.4 Asset Pricing Models

An asset pricing model (APM) is a theoretical framework designed to determine the expected return on an asset, offering insights into the fundamental value of financial assets. The fundamental value of an asset is the natural price: a price that gives the owner a sufficient profit, dependent on several characteristics of the commodity (Smith, 1776). APMs are elementary tools in finance, aiding researchers, investors, portfolio managers, and policymakers in understanding how different risk factors influence asset prices. At their core, these models explain the variations

in asset prices and the relationship between expected returns and an asset's risk characteristics. By quantifying the connection between risk factors and return, APMs facilitate the construction of optimal portfolios, efficient capital allocation, and effective risk management strategies. They incorporate various economic and financial principles, such as market efficiency, investor behaviour, and equilibrium mechanisms. They provide a systematic approach to evaluating investment opportunities in complex financial markets.

The beginning of APMs lies in the work of Harry Markowitz (1952). His Modern Portfolio Theory introduced the concept of mean-variance efficiency, emphasizing the importance of diversification and the trade-off between risk and return. This trade-off involves distinguishing between several types of risks: systematic risks (which cannot be eliminated through diversification and are inherent to the market) and idiosyncratic risks (which are specific to a particular asset and can be mitigated through diversification). According to Markowitz, investors should choose portfolios not just based on expected return but also considering the variance of portfolio returns, leading to efficient portfolios that maximize returns for a given level of risk or minimize risk for a given level of return.

The Single Index Model is then introduced as a practical application of the Modern Portfolio Theory (Sharpe, 1963). Sharpe's model simplifies the complex covariance analysis required and proposes that the return on any asset can be described by its relationship with a single market index and a security-specific return. The computational requirements for portfolio optimization are drastically reduced, allowing for analysing a significantly larger number of securities.

3.4.1 Capital Asset Pricing Model

Building upon the foundational work of Markowitz and Sharpe, William Sharpe (1964) and John Lintner (1965) developed the Capital Asset Pricing Model (CAPM), marking a significant breakthrough in asset pricing theory. The CAPM theorizes a linear relationship between the expected return of an investment and its beta, a measure of the investment's systematic risk relative to the market. This revolutionary model provided a straightforward yet powerful framework to compute how market risk should be compensated in the expected returns of assets, distinguishing between diversifiable (unsystematic) and non-diversifiable (systematic) risks. The

introduction of CAPM was a critical moment in the evolution of financial theory, setting the stage for decades of research and debate (Rossi, 2016).

At its core, the CAPM posits that the expected return on an asset equals the risk-free rate plus the asset's beta times the market risk premium. The market risk premium is the difference between the expected return on the market portfolio and the risk-free rate.

The CAPM simplifies the complex task of evaluating risk by reducing it to a single factor: beta. Beta measures the sensitivity of an asset's returns to the market portfolio's returns. An asset with a beta greater than one is considered more volatile than the market, while an asset with a beta less than one is considered less volatile.

Black (1972) extended the CAPM by exploring the implications of limited borrowing on capital markets. He proposed a variant of the CAPM that accounts for scenarios where investors are restricted from borrowing at the risk-free rate. This variant led to a market equilibrium where the expected returns on assets are influenced by their market beta and other factors introduced by borrowing constraints.

3.5 Asset Pricing Models with ESG

Including environmental, social, and governance (ESG) factors in asset pricing models (APMs) is a relatively recent development from empirical work on the implications of ESG risks. As discussed in previous sections, ESG performance significantly affects various company risks, and evidence suggests that green assets often underperform compared to brown assets. This insight is supported by the findings of Barber et al. and Hong and Kacperczyk (2009), who noted that sin stocks often outperform non-sin firms.

Heinkel, Kraus, and Zechner (2001) model environmental ethics directly into the financial market's equilibrium framework. They demonstrate that through exclusionary practices, ethical investing can effectively alter a firm's cost of capital by reducing the pool of potential investors for non-compliant firms. This alteration incentivises polluting firms to adopt greener practices and attract ethical investors. Their approach quantifies the impact of green investment preferences on corporate behaviour in a risk-averse equilibrium setting.

Fama and French (2007) extended traditional asset pricing models by incorporating non-financial motivations and investor disagreements about future payoffs. Their model shows that when non-financial considerations influence many investors or hold divergent beliefs about future asset payoffs, notable differences in asset prices can emerge. This model also suggests that relative wealth and specific investor behaviours might explain some anomalies within the CAPM, such as size, value, and momentum effects.

Pedersen, Fitzgibbons, and Pomorski (2021) introduced a model incorporating ESG considerations into portfolio choice and asset prices. Their model defines an ESG-efficient frontier, helping investors maximize their portfolios' Sharpe ratios while achieving desired ESG levels. This approach reveals that assets with high ESG scores can have lower expected returns due to the non-pecuniary benefits of holding socially responsible investments. However, it may offer higher returns during positive ESG-related shocks, reflecting changes in consumer and investor preferences towards sustainability.

ESG criteria can also be implemented into an investor's utility function. Ahmed, Gao, and Satchell (2021) demonstrate that investors who value ESG factors alongside financial wealth can achieve enhanced utility without giving in on return performance. Pástor, Stambaugh, and Taylor (2021) continue the implementation of ESG considerations in investors' utility functions. Their model proposes that green assets have lower expected returns for two main reasons: investors derive utility from holding these assets, and these assets serve as a hedge against climate risk. Despite their lower expected returns, green assets can outperform when positive shocks to the ESG factor exist. This shock is manifested through the changes in consumers' and investors' preferences for green products and investments—this ESG factor and the market portfolio efficiently price assets within a two-factor model.

Their findings showed the implications of sustainable investing on both financial markets and real-world corporate behaviours. A notable outcome is the prediction that a substantial presence of green investors in the market can lower green firms' capital costs. These lower capital costs, in turn, incentivize firms to adopt greener practices, thereby having a tangible positive impact on the environment. The study also suggests that the size of the ESG investment industry is

contingent upon the variance in investors' ESG preferences, marking a significant contribution to understanding the economic forces behind the growing trend of sustainable investing.

Moreover, the model challenges conventional notions within asset pricing by demonstrating that the ESG factor does not solely operate on risk aversion but is fundamentally driven by investor utility derived from ESG characteristics. This insight provides a comprehensive framework to explain why investors might willingly accept lower expected financial returns in exchange for the non-pecuniary benefits of holding green assets.

Escobar-Anel (2022) explores integrating ESG considerations into portfolio optimization by assigning risk aversion levels to green and brown assets. He employs a multivariate utility model and demonstrates that investors' different risk preferences towards green and brown stocks significantly influence optimal asset allocation. The multivariate utility model leads to an increased investment in green assets when investors are less risk-averse towards them.

Grim, Renzi-Ricci, and Madamba (2023) create a model that allows investors to simultaneously optimize for financial goals and personal ESG tastes, eliminating the need for 'one size fits all' solutions. Practical case studies demonstrate that the intensity of non-pecuniary preferences, typical financial expectations, and risk preferences significantly influence optimal portfolio choices. One illustrative case study they conducted involves varying the ESG Propensity Score, which reflects an investor's non-financial utility from investing in ESG-aligned assets. They examine scenarios where this score is adjusted, showing how it affects the allocation to ESG versus conventional funds within a portfolio. The study highlights a trade-off between pecuniary and non-pecuniary preferences, revealing that as the non-pecuniary ESG preference increases, along with specific risk aversion levels, the optimal portfolio choice shifts towards a higher allocation in ESG investments.

One challenge in incorporating ESG factors into asset pricing models is the divergence and inflation of ESG scores. C. Fei and W. Fei (2024) addressed this issue by modelling the dynamics of principal-agent relationships under Knightian uncertainty, where the probability of outcomes is unknown. They showed that higher levels of uncertainty regarding ESG ratings encourage firms towards greener initiatives. However, this comes with a nuanced trade-off affecting expected returns for investors and the incentive mechanisms for managers.

Rojo-Suarez and Alonso-Conde (2024) implemented an expanded version of Pástor, Stambaugh, and Taylor's (2021) model to examine the influence of changing investor ESG preferences on the explanatory power of the market portfolio in asset pricing. Their findings indicate that as the market portfolio's 'greenness' increases, the traditional CAPM begins to capture ESG factors. Specifically, their analysis of U.S. equity markets revealed that brown assets display negative ESG betas, suggesting a negative price of ESG risk that trends towards zero over time. This implies that public efforts to enhance corporate ESG performance could effectively lower the cost of capital, especially during periods of decreasing corporate ESG performance.

These studies underscore the growing importance of integrating ESG factors into asset pricing models, providing a more comprehensive understanding of how these considerations affect financial decision-making and financial markets.

4 Hypotheses

4.1 First Hypothesis

Building upon the literature review of asset pricing models and the integration of ESG aspects into financial analysis, this research explores the nuanced impacts of ESG preferences on asset prices. The work of Pástor et al. (2021) is taken as the basis for considering how ESG preferences influence the prices of green and brown assets. The authors propose a specific utility function as a part of their model:

$$V(\tilde{W}_{1i}, X_i) = -e^{-A_i \tilde{W}_{1i} - b_i X_i} \quad (1)$$

This formula contains both a financial ($A_i \tilde{W}_{1i}$) and non-financial ($b_i X_i$) component. Specifically, the term \tilde{W}_{1i} denotes the wealth at time 1, which includes the return on the wealth from time 0 (W_{0i}). \tilde{W}_{1i} thus represents the financial outcome of the agent's investment decisions. An increase in \tilde{W}_{1i} results in a higher utility, as the exponential function $-e^{-A_i \tilde{W}_{1i} - b_i X_i}$ comes closer to zero due to the increased magnitude of the negative exponent. The parameter A_i , denoting absolute risk aversion, measures the agent's aversion to financial risk. A higher A_i signifies greater risk aversion.

The term $b_i X_i$ represents the nonpecuniary benefits derived from holding green stocks, where b_i captures the agent's preference for stocks with ESG attributes and X_i is the fraction of wealth allocated to these stocks. An increase in either b_i or X_i leads to a higher utility, as the enhanced nonpecuniary benefits are reflected in the exponent of the utility function. This effect underscores the agent's valuation of ESG benefits alongside financial returns.

The non-pecuniary ESG preference (b_i) is broad and does not separate the specific E, S, or G components. However, the stakeholder theory presented by Freeman and others stress that different stakeholders may prioritise E, S, and G factors differently, impacting their investment decisions (Donaldson & Preston, 1995; Freeman, 1994, 2010; Mitchell et al., 1997; Werhane & Edward Freeman, 1999a; Wood, 1991). This suggests that the separation of ESG preferences could more accurately reflect the complex preferences of investors, thereby potentially influencing asset prices. This diversity is not just a theoretical consideration but a practical reality (Daugaard et al., 2024). Sin stocks, for instance, have shown variation in their returns and pricing

due to divergent investor opinions on ESG matters (Hong & Kacperczyk, 2009). Therefore, recognizing differences in non-pecuniary E, S, and G preferences allows for a more precise mapping of investor utility functions and, consequently, would increase the ability to capture the complex relationship between investor preferences and asset prices. This thesis intends to study the effects of including such a divergence in E, S and G preferences of investors, and the according hypothesis is:

H1. The divergence of an agent's ESG preference into Environmental, Social and Governance preferences, incorporated in the agent's utility function, has an effect on the prices of green and brown assets.

The expectation is that incorporating distinct Environmental (E), Social (S), and Governance (G) preferences will provide a more detailed and accurate representation of investor utility. This approach will lead to a more differentiated market where green and brown assets are priced according to specific ESG components rather than a single aggregated score. While separating ESG scores may not drastically alter the overall range of asset prices, it is expected to result in prices that more realistically reflect the current spectrum of green and brown assets. This differentiation should allow for a more precise alignment of asset prices with investor preferences based on each asset's distinct E, S, and G attributes.

4.2 Second Hypothesis

Traditionally, models like those developed by Pástor et al. (2021) have not incorporated the relationship between an agent's wealth and ESG preferences. Specifically, in these models, the nonpecuniary benefit term (b_i) is independent of the agent's wealth and unaffected by ESG-related risks. The independence means that the utility derived from ESG preferences remains constant regardless of changes in wealth or the risk profile of ESG investments, thereby not fully capturing the dynamic interaction between financial outcomes and ESG motivations in investment decisions.

The absence of this consideration may overlook critical aspects of investor behavior and market dynamics. Duchêne et al. (2022) demonstrate that investors are willing to accept lower returns for positive environmental impacts, though their tolerance for risk declines in scenarios of

increased market risk. This behaviour follows the findings of Bansal et al. (2022), who show that the demand for socially responsible investments (SRI) depends on the investors' economic circumstances. It further indicates that during economic downturns or periods of increased market volatility, the preference for SRIs fades. Given that wealth depends on the state of the economy, wealth levels influence the degree to which investors prioritize ESG investments and moderate the non-pecuniary benefits derived from such investments. This wealth-dependent moderation of ESG preferences presents a compelling case for integrating a direct relationship between wealth levels and ESG preferences into the utility function of investors within asset pricing models.

A second factor that could be reconsidered is the risk aversion of agents. Pástor et al. (2021) assume a constant level of risk aversion and do not create a connection between risk aversion and holding green or brown assets. On the other hand, Holt and Laury (2002) have shown that individuals' risk aversion significantly increases with higher monetary stakes. This finding challenges the traditional economic assumption of constant relative risk aversion and hints towards different levels of risk aversion in various domains. Ioannou and Sadeh (2016) build on that and investigate the differences in risk aversion across monetary and environmental domains. They assess how individuals' time preferences and risk aversion vary between these two domains. While their findings indicate that time preferences remain consistent, they reveal a significant increase in risk aversion in the environmental domain compared to the monetary domain. Ioannou and Sadeh also confirm that women are generally more risk-averse than men in both domains. Their study underscores the need to consider and incorporate domain-specific risk aversion when modelling agents' behaviour, especially in an environmental context. Escobar-Anel (2022b) took up that challenge and implemented a multivariate risk aversion in an ESG investment model. The study proposes the concept of multi-attributive utility, which allows investors to apply different risk aversion levels to various asset classes, thereby aligning investment strategies with their ESG preferences. He showed that incorporating risk aversion levels for green and brown stocks can significantly increase green investments. Specifically, the numerical analysis indicates up to a 33% rise in green stock allocations when investors recognize different risk profiles for ESG-related assets.

To address these gaps, relative ESG risk aversion is employed to incorporate the effect of wealth levels on the non-pecuniary benefits of holding green or brown assets. This approach also accounts for absolute risk aversion but focuses on "greenness risk aversion" rather than financial loss. ESG risk aversion in the context of this thesis refers to the risk aversion towards companies not having positive ESG impacts, reflecting concerns about the ESG impact of investments. The according hypothesis is:

H2. The direct relationship between an agent's relative ESG risk aversion and its ESG preference, incorporated in the agent's utility function, has an effect on the prices of green and brown assets.

By incorporating relative ESG risk aversion to reflect the varying sensitivity of investors to ESG risks, the expectation is that this adjustment will better capture the interplay between financial outcomes and ESG motivations. The anticipated effect is that higher relative ESG risk aversion towards ESG risks will decrease the equity premium of positive ESG investments, reflecting the acceptance of lower compensation for decreased perceived ESG risks. This decrease in equity premium is expected to influence the pricing of green and brown assets based on the impact of their ESG characteristics (ESG score).

For green assets with higher ESG scores, the anticipated decrease in equity premium means that these assets might increase in price. Investors accepting lower returns for green assets will take higher prices. However, the equity premium would increase for brown assets with lower ESG scores and lead to relatively lower prices. As these assets are perceived to have more ESG-related risks, the lower equity premium requirement will be less pronounced, making them more attractive to investors seeking higher returns with additional ESG risks.

4.3 Third Hypothesis

A third aspect of investor ESG preferences that remains unexplored is the possibility of negative ESG tastes. To avoid any uncertainty regarding this concept, 'ESG aversion' or 'negative ESG tastes' will be used. ESG aversion, in short, refers to the preference for holding stocks with a negative ESG impact.

The ESG preference proposed by Pástor et al. (2021) is based on a variable (b_i) that provides the non-pecuniary benefits of holding the stock. That benefit factor has an agent-specific (d_i) and firm-specific (g_n) component.

$$b_i = d_i g_n \quad (2)$$

The agent-specific component (d_i) is the degree of an agent's ESG taste and is equal to or larger than zero ($d_i \geq 0$). However, ESG tastes can fluctuate based on economic conditions and personal wealth levels (Bansal et al., 2022; Duchêne et al., 2022). Building upon this argument suggests that there may be instances where economic conditions appear bleak, and individuals have limited wealth, leading to a desire for greater returns and favouring potential negative ESG impacts. Sin stocks, for instance, have been shown to have lower ESG scores than companies in less harmful industries (Paradis & Schiehl, 2021). Sin stocks in portfolios suggest that some investors actively seek out investments with harmful ESG impacts in anticipation of higher returns, challenging traditional models that primarily account for positive ESG preferences. To incorporate this ESG aversion into an asset pricing model, it is necessary to reassess the utility function proposed, building upon the model of Pástor et al. (2021). By extending the range of ESG preference to include negative values, the asset prices of green and brown assets would be affected differently than the original showed. The according hypothesis is:

H3. The impact of an agent's ESG aversion on the asset prices of green and brown assets differs from the effect of an ESG preference.

The expectation is that incorporating ESG aversion into the utility function will reveal that some investors prioritize negative ESG impacts over positive impacts, thereby favouring brown assets. This adjustment is anticipated to result in lower prices for green assets and higher prices for brown assets, reflecting investors' negative preferences towards ESG characteristics. The increased demand for brown assets is expected to drive their prices up, while green assets with positive ESG scores will experience a decline in prices due to reduced demand.

5 Results

This Chapter delves into the initial asset pricing model proposed by Pástor et al. (2021) and the three hypotheses. The hypotheses incorporate various modifications to understand their influence on asset prices, mainly focusing on ESG preferences. The functions within each model are numbered, restarting at (1) for each new model.

The chapter presents the original model as the foundation for the hypotheses (paragraph 5.1). The first hypothesis examines the impact of disaggregating ESG preferences into distinct E, S and G components within an agent's utility function (paragraph 5.2). The second hypothesis explores the incorporation of relative ESG risk aversion into the utility function (paragraph 5.3). The third hypothesis addresses ESG aversion by extending the range of ESG preferences to include negative values (paragraph 5.4). To illustrate the implications of these hypotheses and a more intuitive understanding of the effects, plots of various functions are presented (paragraph 5.5).

5.1 The Original Model

To examine the three hypotheses, it is essential to understand the initial model first. Therefore, this paragraph will provide the initial model of Pástor et al. (2021).

5.1.1 Utility Function

The model considers a single time period from time 0 to time 1. The model has N firms, $n = 1, \dots, N$. The return of a firm n 's shares above the riskless rate (r_f) is denoted by \tilde{r}_n . \tilde{r} is the $N \times 1$ vector of which the n th element is \tilde{r}_n . The model assumes \tilde{r} is normally distributed with:

$$\tilde{r} = \mu + \tilde{\epsilon} \quad (1)$$

The μ denotes the equilibrium expected excess returns, and the error term is normally distributed $\tilde{\epsilon} \sim N(0, \sigma)$. The expected return on a stock is denoted by μ , and the variance by σ .

Next to financial returns, firms also have a non-financial impact in the form of "ESG characteristics". The ESG characteristic of each firm, denoted by g_n , can be positive or negative, representing the firm's ESG impact on the world. A positive ESG impact indicates that the firm contributes positively to environmental, social, and governance criteria, such as reducing carbon emissions. In contrast, a negative ESG impact suggests that the firm has adverse effects on these

criteria, like contributing to pollution. However, it is essential to note that there is no clear definition of ESG and its impacts, which can vary significantly across different contexts and evaluations.

Agents trade firms' shares and risk-free assets. The risk-free asset maintains a zero net supply, while each firm's stock has a positive net supply.

X_i is a $N \times 1$ vector whose n th element is the fraction of the agent i 's wealth invested in stock n . The agents' wealth at time 0 is denoted by W_{0i} and the wealth at time 1 by $\tilde{W}_{1i} = W_{0i}(1 + r_f + X_i' \tilde{r})$. Agents gain utility through wealth and holding green stocks ($g > 0$) depending on their ESG preference. The ESG preference of agent i is denoted by d_i . Agents with higher values of d_i have more pungent ESG tastes. The preference interacts with the ESG characteristic of a firm (g) and provides the nonpecuniary benefit of holding the firm's stock with:

$$b_i = g d_i \quad (2)$$

g is an $N \times 1$ vector whose n th element is g_n . Each agent then gains utility based on the following:

$$V(\tilde{W}_{1i}, X_i) = -e^{-A_i \tilde{W}_{1i} - b_i X_i}. \quad (3)$$

The A_i denotes the agent's absolute risk aversion.

5.1.2 Expected Returns

Given the small size of their holdings (infinitesimal), agents consider asset prices and returns as fixed when determining their portfolio distribution at time 0. Agents are assumed to be rational and seek to maximize their utility when making these portfolio decisions. To achieve utility maximization, the First Order Condition of formula (3) is derived for X_i . This process first involves rewriting the utility function based on the agent's expected utility.

$$\begin{aligned} E[V(\tilde{W}_{1i}, X_i)] &= E[-e^{-A_i \tilde{W}_{1i} - b_i X_i}] \\ &= E[-e^{-A_i W_{0i}(1+r_f+X_i' \tilde{r}) - b_i X_i}]. \end{aligned}$$

The $a_i = A_i W_{0i}$ is the agent i 's relative risk aversion. It is assumed that $a_i = a$ for all agents. Although risk aversion varies among individuals, this simplification is made for three reasons. First, it enhances analytical tractability, allowing more precise and interpretable results. Second, it facilitates comparative analysis by isolating the effects of other variables on portfolio distribution and asset prices. Third, it enables the examination of financial components of the entire market and the interactions between the agent and the market, such as the agent's

portfolio investment weight based on the market portfolio's components and the greenness of the ESG portfolio in the market.

$$= -e^{-a(1+r_f)} E[e^{-aX_i(\tilde{r}+1/ab_i)}]$$

Given the lognormality of \tilde{r} , the property of the expectation of an exponential function is used for a normally distributed variable, leading to the simplification:

$$= -e^{-a(1+r_f)} e^{-aX_i(E[\tilde{r}]+1/ab_i)+1/2a^2X_i^2Var[\tilde{r}]}$$

$$E[V(\tilde{W}_{1i}, X_i)] = -e^{-a(1+r_f)} e^{-aX_i(\mu+1/ab_i)+1/2a^2X_i^2\sigma}$$

Maximizing this function for X_i gives:

$$-a(\mu + 1/a b_i) + a^2 X_i \sigma = 0$$

$$X_i = 1/a \sigma^{-1} (\mu + 1/a b_i). \quad (4)$$

The function represents the optimal asset allocation for an agent seeking to maximize utility. If the relative risk aversion a increases, the fraction of wealth invested in stocks X_i decreases, reflecting a more conservative investment approach. An increase in the expected excess return μ leads to a higher allocation to stocks, as the potential for greater returns makes these investments more attractive. Higher stock volatility σ reduces X_i , demonstrating the agent's aversion to riskier assets. Additionally, an increase in the nonpecuniary benefit b_i boosts the stock allocation, as agents derive additional utility from holding stocks with desirable ESG characteristics.

The ratio of the agent i 's initial wealth to the total initial wealth of all agents is defined by $\omega_i = W_{0i}/W_0$ and $W_0 = \int_i W_{0i} di$. The vector of weights in the market portfolio is a $N \times 1$ vector defined by w_m and due to the assumption that the riskless asset is in net zero supply, w_m must satisfy:

$$w_m = \int_i \omega_i X_i di$$

$$w_m = a^{-1} \sigma^{-1} \mu + a^{-2} \sigma^{-1} \bar{d} g. \quad (5)$$

Where \bar{d}_i is the wealth-weighted mean of the ESG preference of all agents: $\bar{d} = \int_i \omega_i d_i di$. $\iota' w_m = 1$, with ι denoting an $N \times 1$ vector of ones. If the average ESG preferences in the market (\bar{d}) and the ESG score of the company (g) increases, the allocation to these assets in the market portfolio rises. Solving equation (5) for μ gives:

$$\mu = a \sigma w_m - a^{-1} \bar{d} g. \quad (6)$$

Contrary to the weights in the market portfolio (w_m), the expected returns decrease if the average ESG preferences in the market (\bar{d}) and the ESG score of the company (g) increases.

Premultiplying this equity premium with $\mu_m = w'_m \mu$ gives the market equity premium:

$$\mu_m = a\sigma_m^2 - a^{-1}\bar{d}g w'_m \quad (7)$$

$\sigma_m^2 = w'_m \sigma w_m$ is the market variance. The equity premium depends on the level of relative risk aversion, the variance of the market and the average ESG taste through $g w'_m$, which are the overall ESG scores of the market portfolio. Suppose the market portfolio has net positive ESG scores. In that case, stronger ESG tastes reduce the equity premium and vice versa if the market portfolio has net negative scores. It is assumed that the market portfolio is ESG-neutral for simplicity. ESG-neutral means that the negative scores of bad-performing firms balance out the positive scores of good-performing firms.

$$w'_m g = 0 \quad (8)$$

This would imply that the equity premium of equation (7) is independent of the agent's ESG tastes. ESG could also be defined as increasing agents' utility because these companies score higher than the market. Using this insight and combining equations (7) and (8) implies that $a = \mu_m / \sigma_m^2$. With the addition of equation (6) and noting that the vector of market betas is $\beta_m = (1/\sigma_m^2)\sigma w_m$, the equity premium is defined by:

$$\mu = \mu_m \beta_m - a^{-1}\bar{d}g. \quad (9)$$

Equation (9) shows that the excess returns differ from traditional CAPM values. Now, the average ESG tastes affect the excess returns. If \bar{d} is above 0, the expected return on stock n decreases in g . If the average taste (\bar{d}) is positive, then the expected returns are decreasing in ESG characteristics. In that case, agents are willing to pay more for firms with higher ESG scores, which lowers the firm's expected returns. The CAPM alpha is given by $\alpha = \mu - \mu_m \beta_m$. Using equation (9), we receive the alpha of this adjusted CAPM model:

$$\alpha_n = -a^{-1}\bar{d}g_n. \quad (10)$$

The alpha decreases if the average ESG preference and the company's ESG score are positive. The negative relationship between α_n and g_n is stronger when the relative risk aversion is lower and when \bar{d} is higher.

The mean of the excess return on agent i 's portfolio is defined by:

$$E[\tilde{r}_i] = \mu X_i.$$

We find X_i by combining equation (4) and (5):

$$E[\tilde{r}_i] = [w_m + a^{-2}\sigma^{-1}g(d_i - \bar{d})][\mu_m\beta_m - a^{-1}\bar{d}g_n].$$

This formula is rewritten by defining $\delta_i = d_i - \bar{d}$, which is the difference between the agent i 's taste and the average ESG market preference. Combining this with the assumption under equation (8) provides:

$$E[\tilde{r}_i] = \mu_m - \delta_i(a^{-3}\sigma^{-1}\bar{d}g'g). \quad (11)$$

The variance of the excess return on agent i 's portfolio is given by:

$$\begin{aligned} \text{Var}(\tilde{r}_i) &= X_i^2 \sigma \\ \text{Var}(\tilde{r}_i) &= \sigma(w_m + a^{-2}\sigma^{-1}(\delta_i g))(w_m + a^{-2}\sigma^{-1}(\delta_i g)) \\ \text{Var}(\tilde{r}_i) &= \sigma_m^2 + \delta_i^2(a^{-4}\sigma^{-1}g'g). \end{aligned} \quad (12)$$

Here, we see that the variance of the portfolio depends not only on the market variance but also on the difference between the agent's preferences and the average market preferences. Relative risk aversion significantly impacts the variance added to the agent's portfolio. As long as the ESG scores are above zero, agents who have stronger (weaker) tastes than the market (δ_i) for holding green assets accept lower (higher) returns and higher (lower) volatility on their portfolio. The lower expected returns do not make the agents unhappy.

If the preferences of an agent are equal to the market average preferences, δ_i is 0, and the utility function is:

$$\tilde{V} = -e^{-a(1+r_f)}e^{-a(\mu_m - 1/2a\sigma_m^2)}.$$

The expected utility in equilibrium can then be derived in the following manner:

$$\begin{aligned} E[V] &= -e^{-a(1+r_f)}e^{-aX_i(\mu + a^{-1}d_i g_n) + 1/2a^2X_i^2\sigma} \\ E[V] &= -e^{-a(1+r_f)}e^{-a(\mu_m - 1/2a\sigma_m^2)}e^{-\frac{1}{2}a^{-2}\sigma^{-1}\delta_i^2g'g} \\ E[V] &= \tilde{V}e^{-\frac{1}{2}a^{-2}\sigma^{-1}\delta_i^2g'g}. \end{aligned} \quad (13)$$

5.1.3 Portfolio Tilt and the ESG Portfolio

Equation (9) is substituted with equation (4) to obtain the portfolio weights of an agent in equilibrium.

$$X_i = w_m + a^{-2}\sigma^{-1}\delta_i g \quad (14)$$

Each portfolio is implemented with three possible assets: the riskless asset, the market portfolio and an 'ESG portfolio'. The weights of the ESG portfolio are proportional to $\sigma^{-1}g$. The fraction of the agent's wealth in the riskless asset is $1 - l'X_i = -a^{-2}\sigma^{-1}l'\delta_i g$. This fraction can be positive or negative; the remaining wealth is invested in stocks. Agents allocate a fraction ϕ_i of the remaining wealth to the ESG portfolio and a fraction of $1 - \phi_i$ to the market portfolio. The weights within agent i 's stock portfolio are defined by w_i , a $N \times 1$ vector:

$$w_i = \frac{1}{\nu(w_m + a^{-2}\sigma^{-1}\delta_i g)}(w_m + a^{-2}\sigma^{-1}\delta_i g)$$

$$w_i = (1 - \phi_i)w_m + \phi_i w_g. \quad (15)$$

The fraction of the agent i 's stock portfolio invested in the ESG portfolio (ϕ_i) lies between 0 and 1, and it is given by:

$$\phi_i = \frac{a^{-2}\sigma^{-1}\nu(\delta_i g)}{1 + a^{-2}\sigma^{-1}\nu(\delta_i g)} \quad (16)$$

and the $N \times 1$ vector of weights in the ESG portfolio is given by:

$$w_g = \frac{1}{\sigma^{-1}\nu g} \sigma^{-1}g. \quad (17)$$

In this formula, σ^{-1} is the inverse variance matrix of asset returns, and g is the vector of ESG characteristics of the assets. The term $l'g$ is a scalar resulting from the dot product of the row vector of ones (l') and the ESG characteristics vector (g). This scalar normalizes the adjusted weights in w_g . By multiplying σ^{-1} by g , the vector of ESG-adjusted weights is obtained, which is then scaled by the factor $\frac{1}{\sigma^{-1}\nu g}$ to ensure normalization.

If the range of ϕ_i lies between 0 and 1, w_g represents the actual allocation of weights to the ESG portfolio, ensuring that the portfolio reflects the desired ESG impact adjusted for risk.

When $\sigma^{-1}l'g = 0$, the fraction of the agent's wealth allocated to the riskless asset, given by $1 - l'X_i = -a^{-2}\sigma^{-1}l'\delta_i g$, becomes zero. This equation indicates that the agent holds no wealth in the riskless asset. Consequently, the ESG portfolio weights are simplified to $w_g = \sigma^{-1}g$, as the normalization factor $\frac{1}{\sigma^{-1}\nu g}$ is zero. This results in the ESG portfolio being at a zero-cost position:

$$w_{g0} = \sigma^{-1}g \quad (18)$$

and $w_i = X_i$, so that:

$$w_{i0} = w_m + \phi_{i0}w_{g0}. \quad (19)$$

ϕ_{i0} is then defined as:

$$\phi_{i0} = a^{-2}\delta_i. \quad (20)$$

The greenness of the ESG portfolio is denoted by:

$$g_g = w_g g \quad (21)$$

The weights in the ESG portfolio are provided by $w_g = \frac{1}{\sigma^{-1}\nu g} \sigma^{-1}g$, the greenness of the ESG portfolio will be positive ($g_g > 0$) as long as g is positive. g_g is negative if $\sigma^{-1}l'g$ is below zero and positive otherwise.

The fraction of an agent's stock portfolio invested in the ESG portfolio (ϕ_i) is determined by the expression: $\phi_i = \frac{a^{-2}\sigma^{-1}\nu(\delta_i g)}{1+a^{-2}\sigma^{-1}\nu(\delta_i g)}$. The numerator, $a^{-2}\sigma^{-1}l'(\delta_i g)$, is influenced by the agent's difference in ESG preference (δ_i) and the ESG score (g). The denominator remains positive if the agent invests a positive fraction of their wealth in stocks ($l'X_i > 0$). This ensures that the denominator does not alter the sign of ϕ_i .

The greenness of the ESG portfolio (g_g) is given by: $\frac{1}{\sigma^{-1}\nu g} \sigma^{-1}g'g$. This expression indicates that g_g is positive if g and σ^{-1} align positively.

Given these relationships, ϕ_i has the same sign as the product of g_g and δ_i . Specifically, if δ_i and g_g are both positive, ϕ_i will be positive, meaning the agent allocates a positive fraction of their wealth to the ESG portfolio. However, if δ_i and g_g are both negative, ϕ_i will also be positive, reflecting a positive allocation to ESG investments due to the alignment of preferences and portfolio greenness. If δ_i and g_g have opposite signs, ϕ_i will be negative, which is minimized at 0 in this model. Thus, the sign of ϕ_i directly reflects the alignment of the agent's ESG preferences with the greenness of the portfolio, provided the denominator is positive.

This agent tilts away from the market portfolio in the direction of greenness by tilting towards the ESG portfolio (ϕ_i) when its ESG scores are positive ($g > 0$) and away from it when these scores are negative ($g < 0$). Agents with a negative difference in ESG preferences ($\delta_i < 0$), however, tilt away from the ESG portfolio when its ESG scores are positive and towards it when its scores are negative. From equation (10), the ESG portfolio's CAPM alpha is

$$\alpha_g = -a^{-1}g_g \bar{d}. \quad (22)$$

The sign is the opposite of g_g . Therefore, the agents described above hold portfolios that produce negative (positive) alphas.

The ESG tilt is zero for agents with average ESG preferences. Those agents hold the market portfolio. Agents who are ESG-neutral tilt away from the market portfolio. These agents optimize their portfolio by tilting away from the market portfolio now that it consists of agents with average ESG preferences.

If all agents have equal preferences, then equations (16) and (20) imply a zero ESG tilt for each agent and all agents hold the market portfolio. All agents hold the market portfolio when none of the agents care about ESG or when they all have very strong ESG tastes. Stock prices adjust to these equal tastes and, in that way, make the market the optimal choice for everybody. For an ESG investment industry to exist, there has to be a dispersion in ESG tastes.

5.1.4 Two-factor Pricing with the ESG Portfolio

The excess return on the ESG portfolio is $\tilde{r}_g = w'_g \tilde{r}$. By combining equation (8), (17), and the market beta equation $\beta_m = \frac{1}{\sigma_m^2} \sigma w_m$, it can be shown that the ESG portfolio's market beta is zero. This result, $\beta_g = w'_g \beta_m$, simplifies to:

$$\beta_g = \left(\frac{1}{\sigma^{-1} l'_g} \sigma^{-1} g \right)' \left(\frac{1}{\sigma_m^2} \sigma w_m \right).$$

Given that $w'_m g = 0$ from equation (8), $w'_g \beta_m = 0$, which indicates that the ESG portfolio does not correlate with the market portfolio. $w'_g \beta_m = 0$ confirms that the market portfolio is ESG-neutral, as the greenness of the market portfolio does not affect its returns.

The expected excess return on the ESG portfolio can be derived by premultiplying equation (9) with w'_g :

$$\mu_g = -a^{-1} g_g \bar{d} \quad (23)$$

which equals the alpha of equation (22). The variance of the ESG portfolio is determined by:

$$\sigma_g^2 = \left(\frac{1}{l'_g \sigma^{-1} g} \right)^2 g'_g g \sigma^{-1} = \left(\frac{1}{l'_g \sigma^{-1} g} \right) g_g. \quad (24)$$

The covariance of the returns with N assets is

$$\text{Cov}(\tilde{r}, \tilde{r}_g) = \left(\frac{1}{l'_g \sigma^{-1} g} \right) g. \quad (25)$$

The betas for \tilde{r}_g are defined by $\beta_g = (1/\sigma_g^2)Cov(\tilde{r}, \tilde{r}_g)$. This β_g represents how sensitive the returns of each asset in the market are to the returns of the ESG portfolio. It shows the relationship between the returns of the ESG portfolio and the returns of individual assets. The value of β_g is not zero because it represents the sensitivity of individual asset returns to the ESG portfolio, reflecting the relationship between these assets and the ESG factor. However, $w'_g \beta_m = 0$ because the ESG portfolio does not move in tandem with the market portfolio, meaning their returns are independent.

From equation (24) and (25) we then get:

$$\beta_g = \frac{1}{g_g} g. \quad (26)$$

To find the expected returns of the market and the ESG portfolio concerning their betas, equations (9), (23), and (26) are combined:

$$\mu = \mu_m \beta_m + \mu_g \beta_g. \quad (27)$$

As noted earlier, by combining equation (8), (17) and $\beta_m = (\frac{1}{\sigma_m^2})\sigma w_m$, the ESG portfolio has a zero-beta. Based on that, the covariance between the returns of the ESG portfolio and the market is also 0. β_m and β_g are also the slope coefficients of the regression of \tilde{r} on \tilde{r}_m and \tilde{r}_g . Using equation (27), we have the following two-factor asset pricing model:

$$\tilde{r} = \beta_m \tilde{r}_m + \beta_g \tilde{r}_g + \tilde{v}. \quad (28)$$

This regression model can estimate excess returns. The expected value of the standard error (\tilde{v}) is 0 ($E(\tilde{v} | \tilde{r}_m, \tilde{r}_g, \beta_m, \beta_g) = 0$). All assets have zero alphas in the two-factor world, equivalent to zero intercepts in the regression. From equation (9), (10) and (27), the vector of CAPM alphas is given by:

$$\alpha = \beta_g \mu_g \quad (29)$$

$$\alpha = -a^{-1} \bar{d} g. \quad (30)$$

Equations (29) and (30) provide the opportunity to interpret the α in separate ways. Equation (29) provides a risk-based interpretation. β_g shows the exposure of the returns \tilde{r}_g and μ_g is the expected return that is tied to a unit of that risk. The asset's nonzero CAPM alphas can be attributed to that omitted-priced risk factor. However, the only reason that investors expose themselves to the risk in \tilde{r}_g is that they have non-average preferences for ESG factors. Equation

(30) also shows that the sources of α are preferences for known characteristics (ESG) and not aversion to an additional fundamental risk.

5.2 Divergent ESG Preferences

Hypothesis 1 states that the divergence of an agent’s ESG preference into E, S and G preferences, incorporated in the agent’s utility function, has an effect on the prices of green and brown assets. Pástor et al. (2021) integrated ESG preferences into asset pricing models without distinguishing the individual components of ESG. However, stakeholder theory (see Appendix 9.3.2.1) suggests that stakeholders prioritize E, S, and G factors differently, which can significantly impact their investment decisions. Empirical evidence supports this differentiation and highlights the practical reality of diverse ESG preferences among investors (see paragraph 4.2).

This paragraph aims to reflect these complexities by separating the non-pecuniary benefits into the utility function's distinct Environmental, Social, and Governance components. To test the first hypothesis, the original model of Pástor et al. (2021) will be reused, provided in the previous section. The adjusted formulas are presented, highlighting the differences from the original model. Detailed explanations of each component and use of each formula will not be reiterated here, as they have already been covered.

5.2.1 Utility Function

The return of a firm n 's shares above the riskless rate (r_f) is denoted by \tilde{r}_n . \tilde{r} is the $N \times 1$ vector of which the n th element is \tilde{r}_n . \tilde{r} is assumed as normally distributed with:

$$\tilde{r} = \mu + \tilde{\epsilon}. \quad (1)$$

Next to financial returns, firms also have a non-financial impact in the form of “ESG characteristics”. Other than the Pástor et al. (2021) model, the ESG characteristics of each firm are denoted by E , S and G respectively. Each characteristic can be positive or negative (depending on the firm’s environmental and social impacts or the strength of its governance).

Agents gain utility through their wealth and holding positive E, S, and G stocks, depending on their E, S, or G preferences. The ESG preferences are divided into an E preference (T_{Ei}), an S preference (T_{Si}) and a G preference (T_{Gi}). Agents with higher values of T_{Ei} , T_{Si} and T_{Gi} have stronger ESG tastes. The preferences interact with a firm's E, S and G characteristics and provide

the nonpecuniary benefits of holding the firm's stock. Each agent gains utility based on the following:

$$V(\tilde{W}_{1i}, X_i) = -e^{-A_i \tilde{W}_{1i} - (T_{Ei}E + T_{Si}S + T_{Gi}G)X_i}. \quad (2)$$

5.2.2 Expected Returns

Agents consider asset prices and returns as fixed when determining their portfolio distribution to maximise their utility. The utility function is first computed based on the agent's expected utility.

$$\begin{aligned} E[V(\tilde{W}_{1i}, X_i)] &= E[-e^{-A_i \tilde{W}_{1i} - (T_{Ei}E + T_{Si}S + T_{Gi}G)X_i}] \\ &= E[-e^{-A_i W_{0i}(1+r_f + X_i \bar{r}) - (T_{Ei}E + T_{Si}S + T_{Gi}G)X_i}]. \end{aligned}$$

The $a_i = A_i W_{0i}$ is the agent i 's relative risk aversion. It is assumed that $a_i = a$ for all agents. Although risk aversion varies among individuals, this simplification is made for the same reasons as the original model. First, simplifying the models enhances analytical tractability, allowing more precise and interpretable results. Second, it facilitates comparative analysis by isolating the effects of other variables on portfolio distribution and asset prices. Third, it enables the examination of financial components of the entire market and the interactions between the agent and the market, such as the agent's portfolio investment weight based on the market portfolio's components and the greenness of the ESG portfolio in the market.

$$\begin{aligned} &= -e^{-a(1+r_f)} E[e^{-aX_i(\bar{r} + 1/a T_{Ei}E + 1/a T_{Si}S + 1/a T_{Gi}G)}] \\ &= -e^{-a(1+r_f)} e^{-aX_i(E[\bar{r}] + 1/a T_{Ei}E + 1/a T_{Si}S + 1/a T_{Gi}G) + 1/2 a^2 X_i^2 \text{Var}[\bar{r}]} \end{aligned}$$

The expected return on a stock is denoted by μ , and the variance by σ .

$$E[V(\tilde{W}_{1i}, X_i)] = -e^{-a(1+r_f)} e^{-aX_i(\mu + 1/a T_{Ei}E + 1/a T_{Si}S + 1/a T_{Gi}G) + 1/2 a^2 X_i^2 \sigma}$$

Maximizing this function for X_i gives:

$$\begin{aligned} -a(\mu + 1/a T_{Ei}E + 1/a T_{Si}S + 1/a T_{Gi}G) + a^2 X_i \sigma &= 0 \\ X_i &= 1/a \sigma^{-1}(\mu + 1/a T_{Ei}E + 1/a T_{Si}S + 1/a T_{Gi}G). \end{aligned} \quad (3)$$

The function models the fraction of wealth allocated to stocks for an individual agent. In this context, the agent's preferences for environmental, social, and governance (ESG) factors are represented by T_{Ei} , T_{Si} and T_{Gi} respectively.

A higher relative risk aversion (a) results in a lower fraction of wealth allocated to stocks, as more risk-averse agents prefer to allocate less wealth to risky assets. Similarly, an increase in stock

volatility (σ) also decreases X_i as higher volatility implies more significant risk. However, an increase in expected returns (μ) raises X_i , making stocks more attractive to the agent.

The preferences for ESG factors (T_{Ei} , T_{Si} and T_{Gi}) and the corresponding scores (E, S and G) also play significant roles. Higher values of these preferences or scores increase X_i , indicating that agents with stronger preferences for ESG factors or higher ESG scores of investments allocate a larger fraction of their wealth to stocks.

With regards to the market portfolio, the vector of weights in it, w_m must satisfy:

$$w_m = \int_i \omega_i X_i di$$

$$w_m = a^{-1}\sigma^{-1}\mu + a^{-2}\sigma^{-1}\bar{T}_E E + a^{-2}\sigma^{-1}\bar{T}_S S + a^{-2}\sigma^{-1}\bar{T}_G G. \quad (4)$$

Where \bar{T}_E , \bar{T}_S and \bar{T}_G are the wealth-weighted mean of all agents' E, S and G tastes. Solving equation (4) for μ gives:

$$\mu = a\sigma w_m - a^{-1}\bar{T}_E E - a^{-1}\bar{T}_S S - a^{-1}\bar{T}_G G. \quad (5)$$

Premultiplying this equity premium with $\mu_m = w'_m \mu$ gives the market equity premium:

$$\mu_m = a\sigma_m^2 - a^{-1}\bar{T}_E E w'_m - a^{-1}\bar{T}_S S w'_m - a^{-1}\bar{T}_G G w'_m. \quad (6)$$

The equity premium depends on the level of relative risk aversion, the variance of the market and the average E, S and G tastes through $E w'_m$, $S w'_m$ and $G w'_m$, which are the market portfolio's overall environmental, social and governance scores. Suppose the market portfolio has net positive environmental, social or governance scores. In that case, more substantial E, S or G tastes reduce the equity premium and vice versa if the market portfolio has net negative scores.

It is assumed that the market portfolio is E-, S- and G-neutral for simplicity:

$$w'_m E = 0, w'_m S = 0 \text{ and } w'_m G = 0. \quad (7)$$

Defining E, S and G as increasing the utility of agents due to the higher ESG scores than the market average and combining equations (6) and (7) implies that the equity premium is defined by:

$$\mu = \mu_m \beta_m - a^{-1}(\bar{T}_E E + \bar{T}_S S + \bar{T}_G G). \quad (8)$$

Equation (8) shows that the excess returns differ from traditional CAPM values, now influenced by the average E, S, and G tastes. If \bar{T}_E , \bar{T}_S and \bar{T}_G are positive, expected returns are decreasing in E, S and G . Unlike the original model, a single negative average taste or company score does not directly result in lower returns. The decrease in returns depends on the E, S, and G interactions

as a whole, based on the (potentially diverging) tastes of the agent and the (potentially diverging) scores of companies. For instance, while the average interest in a positive environmental impact might increase, the average interest in a positive governance impact could be indifferent.

If all average tastes (\bar{T}_E , \bar{T}_S and \bar{T}_G) are positive, and expected returns are decreasing in ESG characteristics, agents are willing to pay more for firms with higher E, S, and G scores. The increased price lowers the firm's expected returns. The alpha of this adjusted CAPM model is:

$$\alpha_n = -a^{-1}(\bar{T}_E E + \bar{T}_S S + \bar{T}_G G). \quad (9)$$

The alpha decreases as long as the average taste in E, S, and G is positive and the company's E, S and G score is positive. The negative relationship between α_n and E_n , S_n and G_n is stronger when the relative risk aversion is lower and when the average E, S and G taste is higher.

The mean of the excess return on agent i 's portfolio is defined by:

$$E[\tilde{r}_i] = \mu X_i.$$

Introducing $\delta_{Ei} = T_{Ei} - \bar{T}_E$, $\delta_{Si} = T_{Si} - \bar{T}_S$ and $\delta_{Gi} = T_{Gi} - \bar{T}_G$ provides:

$$E[\tilde{r}_i] = \mu_m - a^{-3} \sigma^{-1} (\delta_{Ei} \bar{T}_E E' E + \delta_{Si} \bar{T}_S S' S + \delta_{Gi} \bar{T}_G G' G + \delta_{Ei} \bar{T}_S E' S + \delta_{Ei} \bar{T}_G E' G + \delta_{Si} \bar{T}_E S' E + \delta_{Si} \bar{T}_G S' G + \delta_{Gi} \bar{T}_E G' E + \delta_{Gi} \bar{T}_S G' S). \quad (10)$$

The variance of the excess return on agent i 's portfolio is given by:

$$\begin{aligned} Var(\tilde{r}_i) &= X_i^2 \sigma \\ Var(\tilde{r}_i) &= \sigma (w_m + a^{-2} \sigma^{-1} (\delta_{Ei} E + \delta_{Si} S + \delta_{Gi} G)) (w'_m + a^{-2} \sigma^{-1} (\delta_{Ei} E' + \delta_{Si} S' + \delta_{Gi} G')) \\ Var(\tilde{r}_i) &= \sigma_m^2 + a^{-4} \sigma^{-1} (\delta_{Ei}^2 E' E + \delta_{Si}^2 S' S + \delta_{Gi}^2 G' G + \delta_{Ei} \delta_{Si} E' S + \delta_{Ei} \delta_{Gi} E' G + \delta_{Si} \delta_{Gi} S' G + \\ &\delta_{Ei} \delta_{Si} E S' + \delta_{Ei} \delta_{Gi} E G' + \delta_{Si} \delta_{Gi} S G'). \end{aligned} \quad (11)$$

Here, we see that the variance of the portfolio depends not only on the market variance but also on the difference between the agent's preferences and the average market preferences. Interestingly, the differences in tastes for E, S, and G interact with each other and further increase the variance of the portfolio. As long as the E, S and G scores are above zero, agents who have stronger (weaker) tastes than the market (δ_i) for holding E, S or G assets accept lower (higher) returns and higher (lower) volatility on their portfolio.

If the preferences of an agent are equal to the market average preferences, δ_{Ei} , δ_{Si} and δ_{Gi} are 0, and the utility function is:

$$\tilde{V} = -e^{-a(1+r_f)} e^{-a(\mu_m - 1/2 a \sigma_m^2)}.$$

The expected utility in equilibrium can then be derived in the following manner:

$$E[V] = -e^{-a(1+r_f)} e^{-aX_i(\mu + a^{-1}T_{Ei}E_n + a^{-1}T_{Si}S_n + a^{-1}T_{Gi}G_n) + 1/2 a^2 X_i^2 \sigma}$$

$$E[V] = \tilde{V} e^{-a^{-1} \sigma^{-1} \mu (\delta_{Ei}E + \delta_{Si}S + \delta_{Gi}G)}$$

$$e^{\frac{1}{2} a^{-2} (\delta_{Ei}^2 E' E + \delta_{Si}^2 S' S + \delta_{Gi}^2 G' G + \delta_{Ei} \delta_{Si} E' S + \delta_{Ei} \delta_{Gi} E' G + \delta_{Si} \delta_{Gi} S' G + \delta_{Ei} \delta_{Si} E S' + \delta_{Ei} \delta_{Gi} E G' + \delta_{Si} \delta_{Gi} S G')}$$
 (12)

5.2.3 Portfolio Tilt and the ESG Portfolio

We substitute equation (8) with equation (3) to obtain the portfolio weights.

$$X_i = w_m + a^{-2} \sigma^{-1} (\delta_{Ei}E + \delta_{Si}S + \delta_{Gi}G) \quad (13)$$

Agents allocate a fraction ϕ_i of their wealth to the ESG portfolio and $1 - \phi_i$ to the market portfolio. The weights in the ESG portfolio are proportional to $\sigma^{-1}E$, $\sigma^{-1}S$ and $\sigma^{-1}G$. The weights within the agent i 's stock portfolio are defined by w_i :

$$w_i = \frac{1}{\nu(w_m + a^{-2} \sigma^{-1} (\delta_{Ei}E + \delta_{Si}S + \delta_{Gi}G))} (w_m + a^{-2} \sigma^{-1} (\delta_{Ei}E + \delta_{Si}S + \delta_{Gi}G))$$

$$w_i = (1 - \phi_i)w_m + \phi_i w_g. \quad (14)$$

The fraction of agent i 's stock portfolio invested in the ESG portfolio is given by:

$$\phi_i = \frac{a^{-2} \sigma^{-1} \nu (\delta_{Ei}E + \delta_{Si}S + \delta_{Gi}G)}{1 + a^{-2} \sigma^{-1} \nu (\delta_{Ei}E + \delta_{Si}S + \delta_{Gi}G)}. \quad (15)$$

and the $N \times 1$ vector of weights in the ESG portfolio is given by:

$$w_g = \frac{1}{\sigma^{-1} \nu (E + S + G)} \sigma^{-1} (E + S + G). \quad (16)$$

The greenness of the ESG portfolio is denoted by:

$$g_g = w_g (E + S + G) \quad (17)$$

g_g is nonzero as long as E , S and G are nonzero. g_g is negative if $\sigma^{-1} \nu (E + S + G)$ is below zero and positive otherwise. ϕ_i has the same sign as the product of g_g and δ_{Ei} , δ_{Si} and δ_{Gi} , as long as the denominator of ϕ_i is positive in equation (15). From equation (13), the denominator of ϕ_i is positive if agent i invests a positive fraction of his wealth in stocks ($i'X_i > 0$). Therefore, an agent with positive wealth in stocks and a positive difference in E , S and G tastes compared to the market (δ_{Ei} , δ_{Si} and $\delta_{Gi} > 0$), ϕ_i is positive if g_g is positive and vice versa. This agent tilts away from the market portfolio in the direction of greenness by tilting towards the ESG portfolio when the E , S and G scores are positive and away from it when these scores are negative.

Agents with a negative difference in E, S and G tastes (δ_{Ei}, δ_{Si} and $\delta_{Gi} < 0$) have a lower ESG taste than the market average. These agents tilt away from the ESG portfolio when the E, S, and G scores are positive and towards the ESG portfolio when the scores are negative.

The alterations made by diverging E, S and G reveal that the greenness of the portfolio stems from a more complex interaction of each component, just like the fraction invested in the ESG portfolio (ϕ_i).

From equation (9), the ESG portfolio's CAPM alpha is

$$\alpha_g = -a^{-1}w_g(\bar{T}_E + \bar{T}_S + \bar{T}_G)(E + S + G). \quad (18)$$

The sign is the opposite of g_g . Therefore, the agents described above hold portfolios that produce negative (positive) alphas.

If all agents have equal preferences, then equation (15) implies a zero ESG tilt for each agent and all agents hold the market portfolio. All agents hold the market portfolio when none of the agents cares about E, S, and G, or they have equally strong E, S, and G tastes. For an ESG investment industry to exist, there has to be dispersion in E, S and G tastes. The ESG divergence increases the possibilities of dispersion in ESG interests, and, in that sense, the ESG divergence increases the possibilities for the ESG investment industry.

5.2.4 Two-factor Pricing with the ESG Portfolio

The excess return on the ESG portfolio is $\tilde{r}_g = w'_g \tilde{r}$. By combining equation (7), (16) and $\beta_m = (\frac{1}{\sigma_m^2})\sigma w_m$. The ESG portfolio's market beta is zero ($w'_g \beta_m = 0$). The expected excess return on the ESG portfolio can be derived by premultiplying equation (8) with w'_g :

$$\mu_g = -a^{-1}g_g(\bar{T}_E + \bar{T}_S + \bar{T}_G). \quad (19)$$

which equals the alpha of equation (18). The variance of the ESG portfolio is determined by:

$$\sigma_g^2 = (\frac{1}{l'\sigma^{-1}(E+S+G)})^2(E' + S' + G')(E + S + G)\sigma^{-1} = (\frac{1}{l'\sigma^{-1}(E+S+G)})g_g. \quad (20)$$

The covariance of the returns with N assets is:

$$Cov(\tilde{r}, \tilde{r}_g) = (\frac{1}{l'\sigma^{-1}(E+S+G)})(E + S + G). \quad (21)$$

The betas for \tilde{r}_g are defined by $\beta_g = (1/\sigma_g^2)Cov(\tilde{r}, \tilde{r}_g)$. From equation (20) and (21) we then get:

$$\beta_g = \frac{1}{g_g}(E + S + G). \quad (22)$$

The expected returns of the market and the ESG portfolio with regard to their betas are:

$$\mu = \mu_m \beta_m + \mu_g \beta_g. \quad (23)$$

As noted earlier, by combining equation (7), (16) and $\beta_m = (\frac{1}{\sigma_m^2})\sigma w_m$, the ESG portfolio has a zero-beta. Based on that, the covariance between the returns of the ESG portfolio and the market is also 0. β_m and β_g are also the slope coefficients of the regression of \tilde{r} on \tilde{r}_m and \tilde{r}_g . Using equation (26), we have the following two-factor asset pricing model:

$$\tilde{r} = \beta_m \tilde{r}_m + \beta_g \tilde{r}_g + \tilde{v}. \quad (24)$$

This regression model can estimate excess returns. From equation (8), (9) and (23), the vector of CAPM alphas is given by:

$$\alpha = \beta_g \mu_g \quad (25)$$

$$\alpha = -a^{-1}(\bar{T}_E E + \bar{T}_S S + \bar{T}_G G). \quad (26)$$

Similar to the Pástor et al. (2021) model, these equations provide the opportunity to interpret the α separately. Equation (25) provides a risk-based interpretation, and equation (26) shows that the sources of α are preferences for known characteristics (E, S and G) and not aversion to an additional fundamental risk. The sources of this α diverge into E, S and G preferences and scores. This divergence in both preferences and scores creates more dynamics of the α . If the average preferences and scores are equally (strongly) positive or negative, the α will be determined in an equal manner to the original model. When the market is indifferent to E, S or G (\bar{T}_E, \bar{T}_S or $\bar{T}_G = 0$), whilst the other preferences are not (\bar{T}_E, \bar{T}_S or $\bar{T}_G \neq 0$) the α will differ from the original model. Similarly, if companies' E, S, or G scores diverge on average, the alpha will deviate from the original model. This divergence introduces additional complexity and variability in the expected returns.

Hypothesis 1 suggests that incorporating distinct E, S and G preferences into an agent's utility function affects the prices of green and brown assets. By disaggregating these preferences, the model recognizes the nuanced investment behaviours of agents who prioritize different aspects of ESG. When these preferences are accounted for, assets with high E, S, and G scores may see increased demand, driving their prices and resulting in lower expected returns. Investors with

strong ESG preferences are willing to accept lower financial returns in exchange for higher non-pecuniary benefits associated with these assets. Thus, green assets with positive ESG scores are likely to be priced higher due to this premium on their non-pecuniary benefits.

On the other hand, brown assets with lower or negative ESG scores offer higher expected returns as compensation for their lack of non-pecuniary benefits. Investors less concerned with ESG factors or prioritising financial returns may find these assets more attractive, leading to lower prices. This price differentiation based on ESG preferences highlights the complex interactions between investor preferences and asset characteristics. The model shows that separating ESG preferences into E, S, and G components creates a more detailed and precise reflection of how these preferences influence asset prices. This divergence leads to a differentiated market where green and brown assets are distinctly priced according to specific ESG components rather than a single aggregated score.

5.3 Interaction between ESG Preferences and Relative ESG Risk Aversions

The second hypothesis states that the divergence of an agent's ESG preferences into E, S and G components, linked to separate relative risk aversions within the agent's utility function, affects the prices of green and brown assets. Pástor et al. (2021) did not incorporate this relationship or consider domain-specific risk aversion. The absence of these considerations may overlook critical aspects of investor behavior and market dynamics.

To address the potential gap, relative risk aversion is employed to incorporate the effect of wealth levels on the non-pecuniary benefits of holding green or brown assets.

The model in this paragraph incorporates additional risk aversions by building upon the original model from paragraph 5.1. This paragraph will present the adjusted model, demonstrating the incorporation of wealth levels and ESG domain-specific risk aversions into the utility function and highlighting the differences from the original model.

5.3.1 Utility Function

The utility function used in the original model is:

$$V(\tilde{W}_{1i}, X_i) = -e^{-A_i \tilde{W}_{1i} - b_i X_i}.$$

The return of a firm's shares (\tilde{r}) above the riskless rate (r_f) is denoted by:

$$\tilde{r} = \mu + \tilde{\epsilon}. \quad (1)$$

Agents gain utility through their wealth and holding positive ESG stocks, depending on their ESG preferences. The absolute risk aversion is taken from the Pástor et al. (2021) model (A_{Fi}). This risk aversion is the aversion of agents towards financial losses. An increase in absolute risk aversion means that the agent becomes more reluctant to engage in investments that could result in unfavourable returns, demonstrating an increased sensitivity to potential financial losses.

The utility function in this model will also include three separate risk aversion factors (A_{Ei} , A_{Si} and A_{Gi}) that correspond to an agent's risk aversion towards holding stocks with a negative E, S or G impact. An ESG risk aversion refers to an individual's resistance level to risks associated with E, S or G factors. An increase in ESG risk aversion indicates that the agent becomes more reluctant to engage in investments that could negatively impact the environment, society, or corporate governance. For example, negative environmental impacts might include significant carbon emissions, negative social impacts could encompass labour rights violations, and poor governance impacts might involve inadequate corporate transparency or ethical breaches.

The ESG preference of an agent is divided in the same manner as in the previous hypothesis (into T_{Ei} , T_{Si} and T_{Gi}). The preferences interact with the E, S and G characteristics of a firm (E , S and G) and provide the nonpecuniary benefits of holding the firm's stock:

$$\begin{aligned} b_{Ei} &= T_{Ei}E \\ b_{Si} &= T_{Si}S \\ b_{Gi} &= T_{Gi}G. \end{aligned} \quad (2)$$

Each agent gains utility based on the following:

$$V(\tilde{W}_{1i}, X_i) = -e^{-A_{Fi}\tilde{W}_{1i} - (A_{Ei}W_{0i}b_{Ei} + A_{Si}W_{0i}b_{Si} + A_{Gi}W_{0i}b_{Gi})X_i} \quad (3)$$

A_{Ei} , A_{Si} and A_{Gi} are multiplied by the wealth level of the agent at time 0 and provide the relative ESG risk aversions of the agent ($a_{Fi} = A_{Fi}W_{0i}$, $a_{Ei} = A_{Ei}W_{0i}$, $a_{Si} = A_{Si}W_{0i}$ and $a_{Gi} = A_{Gi}W_{0i}$). Relative ESG risk aversion refers to an agent's aversion to risks associated with E, S or G factors, particularly concerning their wealth level. Implementing the relative risk aversions creates:

$$V(\tilde{W}_{1i}, X_i) = -e^{-a_{Fi}(1+r_f+X_i\tilde{r}) - (a_{Ei}b_{Ei} + a_{Si}b_{Si} + a_{Gi}b_{Gi})X_i}$$

It is assumed that $a_{Fi} = a_F$, $a_{Ei} = a_E$, $a_{Si} = a_S$ and $a_{Gi} = a_G$ for all agents. Including a_E , a_S and a_G the utility function reflects how financial and ESG considerations influence the agent's

utility. In this formulation, the agent's sensitivity to ESG impacts is directly incorporated into the utility function through the multiplication of nonpecuniary benefits (b_{Ei} , b_{Si} and b_{Gi}) by their respective ESG risk aversions (a_E , a_S and a_G). This implies that as the agent's aversion to ESG risks increases, the importance of the nonpecuniary benefits in the utility calculation also increases, provided these benefits are positive. Positive nonpecuniary benefits significantly affect the agent's utility if the ESG risk aversions increase.

5.3.2 Expected Returns

Agents consider asset prices and returns fixed when determining their portfolio distribution to maximise utility. The utility function is first computed based on the agent's expected utility.

$$E[V(\tilde{W}_{1i}, X_i)] = E[-e^{-a_F(1+r_f+X_i\tilde{r})-(a_E b_{Ei}+a_S b_{Si}+a_G b_{Gi})X_i}],$$

$$E[V(\tilde{W}_{1i}, X_i)] = -e^{-a_F(1+r_f)} e^{-a_F X_i (E[\tilde{r}] + a_F^{-1} a_E b_{Ei} + a_F^{-1} a_S b_{Si} + a_F^{-1} a_G b_{Gi}) + 1/2 a_F^2 X_i^2 \text{Var}[\tilde{r}]}$$

$$E[V(\tilde{W}_{1i}, X_i)] = -e^{-a_F(1+r_f)} e^{-a_F X_i (\mu + a_F^{-1} a_E b_{Ei} + a_F^{-1} a_S b_{Si} + a_F^{-1} a_G b_{Gi}) + 1/2 a_F^2 X_i^2 \sigma}$$

Maximizing this function for X_i gives:

$$-a_F (\mu + a_F^{-1} a_E b_{Ei} + a_F^{-1} a_S b_{Si} + a_F^{-1} a_G b_{Gi}) + a_F^2 X_i \sigma = 0$$

$$X_i = a_F^{-1} \sigma^{-1} (\mu + a_F^{-1} a_E b_{Ei} + a_F^{-1} a_S b_{Si} + a_F^{-1} a_G b_{Gi}).$$

An increase in the expected return (μ) or the nonpecuniary benefits (b_{Ei} , b_{Si} and b_{Gi}) leads to a higher allocation to stocks, as these factors enhance the overall attractiveness of the investment. However, an increase in the variance of the stock (σ) or the relative risk aversion towards financial losses (a_F) reduces the stock allocation, reflecting a more cautious investment approach in the face of higher risk or greater sensitivity to financial losses.

The increase in ESG risk aversion (a_E , a_S and a_G) indicates that the agent is more reluctant to invest in assets with potential negative ESG impacts. This formula logically suggests that the stock allocation increases if the agent possesses a higher ESG risk aversion combined with a higher ESG score. This increase aligns with the notion that agents with heightened sensitivity to ESG risks prefer investments with favourable ESG characteristics, thereby justifying a higher allocation to such stocks despite the increased aversion.

The vector of weights in the market portfolio (w_m) is defined by:

$$w_m = \int_i \omega_i X_i di$$

$$w_m = a_F^{-1} \sigma^{-1} \mu + a_F^{-2} a_E \sigma^{-1} \bar{T}_E E + a_F^{-2} a_S \sigma^{-1} \bar{T}_S S + a_F^{-2} a_G \sigma^{-1} \bar{T}_G G. \quad (5)$$

Solving equation (5) for μ gives:

$$\mu = a_F \sigma w_m - a_F^{-1} a_E \bar{T}_E E - a_F^{-1} a_S \bar{T}_S S - a_F^{-1} a_G \bar{T}_G G. \quad (6)$$

Premultiplying this equity premium with $\mu_m = w'_m \mu$ gives the market equity premium:

$$\mu_m = a_F \sigma_m^2 - a_F^{-1} a_E \bar{T}_E E w'_m - a_F^{-1} a_S \bar{T}_S S w'_m - a_F^{-1} a_G \bar{T}_G G w'_m. \quad (7)$$

A new component in the equity premium is the dependence on the relative ESG risk aversions. Unlike the effect of the relative financial risk aversion (a_F), ESG risk aversions have a negative relationship with the equity premium. The higher the a_E , a_S and a_G , the higher the reduction of the equity premium through the average E, S and G preferences (\bar{T}_E , \bar{T}_S and \bar{T}_G). The market portfolio is assumed to be E-, S- and G-neutral.

$$w'_m E = 0, w'_m S = 0 \text{ and } w'_m G = 0 \quad (8)$$

Defining E, S and G in equation (7) as increasing utility of agents because these companies score higher than the market on these aspects, the equity premium is defined by:

$$\mu = \mu_m \beta_m - a_F^{-1} (a_E \bar{T}_E E + a_S \bar{T}_S S + a_G \bar{T}_G G). \quad (9)$$

Equation (9) differs from the previous models now that the relative ESG risk aversions affect the excess returns. A higher relative ESG risk aversion of the agent (a_E , a_S and a_G) decreases the equity premium because higher relative risk aversion implies a greater sensitivity to the risks associated with ESG factors. When the agent is more risk-averse towards these ESG factors, they require different compensation levels in the form of an equity premium.

A reduced equity premium stems from the agent's valuation of higher ESG scores. Agents with high ESG risk aversion perceive companies with strong ESG performance as less risky and more attractive investments. Consequently, these agents are willing to accept a lower equity premium as the higher ESG scores of the companies in the market effectively reward them. The attractiveness of high ESG scores compensates for their aversion to ESG-related risks, leading to a lower required equity premium.

However, if the ESG scores of companies in the market decrease, the scenario changes. For agents with high ESG risk aversion, a decline in ESG performance represents a substantial increase in perceived risk. These agents demand a higher equity premium to compensate for this increased risk. This demand for higher compensation is more pronounced than that of agents who do not

factor ESG risk aversion into their investment decisions. Thus, the equity premium increases more strongly for ESG risk-averse agents in response to lower ESG scores, reflecting their greater sensitivity to ESG-related risks.

The alpha of this adjusted CAPM model is:

$$\alpha_n = -a_F^{-1}(a_E \bar{T}_E E + a_S \bar{T}_S S + a_G \bar{T}_G G). \quad (10)$$

The alpha decreases if the average ESG taste and the company's ESG scores are positive. The ESG risk aversions of agents strengthen these decreasing factors. As the ESG risk aversions increase, the alpha decreases with positive average market ESG preferences and ESG scores.

The mean of the excess return on agent i 's portfolio is defined by:

$$E[\tilde{r}_i] = \mu X_i.$$

Introducing $\delta_{Ei} = T_{Ei} - \bar{T}_E$, $\delta_{Si} = T_{Si} - \bar{T}_S$ and $\delta_{Gi} = T_{Gi} - \bar{T}_G$ provides:

$$E[\tilde{r}_i] = \mu_m - a_F^{-3} \sigma^{-1} (a_E^2 \delta_{Ei} \bar{T}_E E' E + a_S^2 \delta_{Si} \bar{T}_S S' S + a_G^2 \delta_{Gi} \bar{T}_G G' G + a_E a_S \delta_{Ei} \bar{T}_S E' S + a_E a_G \delta_{Ei} \bar{T}_G E' G + a_S a_E \delta_{Si} \bar{T}_E S' E + a_S a_G \delta_{Si} \bar{T}_G S' G + a_G a_E \delta_{Gi} \bar{T}_E G' E + a_G a_S \delta_{Gi} \bar{T}_S G' S). \quad (11)$$

The variance of the excess return on agent i 's portfolio is given by:

$$Var(\tilde{r}_i) = X_i^2 \sigma$$

$$Var(\tilde{r}_i) = \sigma_m^2 + a_F^{-4} \sigma^{-1} (a_E^2 \delta_{Ei}^2 E' E + a_S^2 \delta_{Si}^2 S' S + a_G^2 \delta_{Gi}^2 G' G + a_E a_S \delta_{Ei} \delta_{Si} E' S + a_E a_G \delta_{Ei} \delta_{Gi} E' G + a_S a_E \delta_{Si} \delta_{Ei} S' E + a_S a_G \delta_{Si} \delta_{Gi} S' G + a_G a_E \delta_{Gi} \delta_{Ei} G' E + a_G a_S \delta_{Gi} \delta_{Si} G' S). \quad (12)$$

Comparing equations (11) and (12) to previous models shows the addition of relative ESG risk aversions and their interactions with each other. If a_E , a_S or a_G increase, agents who have stronger (weaker) tastes than the market ($\delta_i > 0$) for holding E, S or G assets accept lower (higher) returns and higher (lower) volatility on their portfolio.

If the preferences of an agent are equal to the market average preferences, δ_{Ei} , δ_{Si} and δ_{Gi} are 0, and the utility function is:

$$\tilde{V} = -e^{-a_F(1+r_f)} e^{-a_F(\mu_m^{-1}/2 a_F \sigma_m^2)}.$$

The expected utility in equilibrium can then be derived in the following manner:

$$E[V] = -e^{-a_F(1+r_f)} e^{-a_F X_i (\mu + a_F^{-1} a_E b_{Ei} + a_F^{-1} a_S b_{Si} + a_F^{-1} a_G b_{Gi}) + \frac{1}{2} a_F^2 X_i^2 \sigma}$$

$$E[V] = \tilde{V} e^{-a_F^{-1} \sigma^{-1} \mu(a_E \delta_{Ei} E + a_S \delta_{Si} S + a_G \delta_{Gi} G)} \quad (13)$$

$$e^{-a_F^{-2} \sigma^{-1} (a_E b_{Ei} + a_S b_{Si} + a_G b_{Gi}) (a_E \delta_{Ei} E + a_S \delta_{Si} S + a_G \delta_{Gi} G)}$$

$$e^{\frac{1}{2} a_F^{-2} (a_E^2 \delta_{Ei}^2 E' E + a_S^2 \delta_{Si}^2 S' S + a_G^2 \delta_{Gi}^2 G' G + a_E a_S \delta_{Ei} \delta_{Si} E' S + a_E a_G \delta_{Ei} \delta_{Gi} E' G + a_S a_E \delta_{Si} \delta_{Ei} S' E + a_S a_G \delta_{Si} \delta_{Gi} S' G + a_G a_E \delta_{Gi} \delta_{Ei} G' E + a_G a_S \delta_{Gi} \delta_{Si} G' S)}$$

5.3.3 Portfolio Tilt and the ESG Portfolio

We substitute equation (9) with equation (4) to obtain the portfolio weights.

$$X_i = w_m + a_F^{-2} \sigma^{-1} (a_E \delta_{Ei} E + a_S \delta_{Si} S + a_G \delta_{Gi} G) \quad (14)$$

The weights within agent i 's stock portfolio are defined by w_i :

$$w_i = \frac{1}{\nu(w_m + a_F^{-2} \sigma^{-1} (a_E \delta_{Ei} E + a_S \delta_{Si} S + a_G \delta_{Gi} G))} (w_m + a_F^{-2} \sigma^{-1} (a_E \delta_{Ei} E + a_S \delta_{Si} S + a_G \delta_{Gi} G))$$

$$w_i = (1 - \phi_i) w_m + \phi_i w_g. \quad (15)$$

A fraction ϕ_i is invested in the ESG portfolio and $1 - \phi_i$ to the market portfolio. ϕ_i is given by:

$$\phi_i = \frac{a_F^{-2} \sigma^{-1} \nu(a_E \delta_{Ei} E + a_S \delta_{Si} S + a_G \delta_{Gi} G)}{1 + a_F^{-2} \sigma^{-1} \nu(a_E \delta_{Ei} E + a_S \delta_{Si} S + a_G \delta_{Gi} G)}. \quad (16)$$

and the weights within this ESG portfolio are found through:

$$w_g = \frac{1}{\sigma^{-1} \nu(E + S + G)} \sigma^{-1} (E + S + G). \quad (17)$$

The greenness of the ESG portfolio is denoted by:

$$g_g = w_g (E + S + G) \quad (18)$$

The parameter g_g remains consistent across previous models, as does the interaction between ϕ_i and g_g . Specifically, if one of these variables is positive, the other is also positive.

The proportion of investment allocated to the ESG portfolio (ϕ_i) is influenced by aversion to ESG risks. At first glance, incorporating the ESG risk aversions into the numerator and denominator of equation (15) might seem to offset each other, suggesting the fraction should remain unchanged. However, the inclusion of an additional term in the denominator results in an increase in this fraction as long as the ESG scores (E , S and G) and the difference in ESG preference (δ_{Ei} , δ_{Si} and δ_{Gi}) are positive.

For illustration, consider an agent with a 33% investment in the ESG portfolio according to an equation that does not account for ESG risk aversions. Here, the numerator is 0.5 and the denominator is 1.5. Upon incorporating ESG risk aversions, which average out to 2.5 (a_E , a_S and

a_G), the numerator adjusts to 1.25 and the denominator to 3.75. The fraction invested in the ESG portfolio increases to 55.56%.

Therefore, ϕ_i increases with an increase in ESG risk aversions. This indicates that an agent with higher relative ESG risk aversions exhibits greater reluctance towards negative impacts in ESG areas and subsequently increases their investment in an ESG portfolio.

When the agents' preferences do not deviate from market preferences (i.e., δ_{Ei} , δ_{Si} and δ_{Gi} are all 0), only the market portfolio is held. However, δ_{Ei} , δ_{Si} and δ_{Gi} continue to drive the ESG investment industry. Additionally, the relative ESG risk aversion speeds up the growth of the ESG investment industry.

The ESG portfolio's CAPM alpha is:

$$\alpha_g = -a_F^{-1} w_g (a_E \bar{T}_E + a_S \bar{T}_S + a_G \bar{T}_G) (E + S + G). \quad (19)$$

The CAPM alpha decreases if the ESG risk aversions increase, showing that the ESG risk-averse agent accepts a lower financial compensation for holding the ESG portfolio.

5.3.4 Two-factor Pricing with the ESG Portfolio

The excess return on the ESG portfolio is $\tilde{r}_g = w'_g \tilde{r}$. The ESG portfolio's market beta is zero ($w'_g \beta_m = 0$). The expected excess return on the ESG portfolio is:

$$\mu_g = -a_F^{-1} g_g (a_E \bar{T}_E + a_S \bar{T}_S + a_G \bar{T}_G). \quad (20)$$

which equals the alpha of equation (19). The expected returns of the market and ESG portfolio in equilibrium are determined by:

$$\mu = \mu_m \beta_m + \mu_g \beta_g. \quad (21)$$

This regression model can estimate excess returns. The vector of CAPM alphas is given by:

$$\alpha = \beta_g \mu_g \quad (22)$$

$$\alpha = -a_F^{-1} (a_E \bar{T}_E E + a_S \bar{T}_S S + a_G \bar{T}_G G). \quad (23)$$

Equation (22) provides the same risk-based interpretation. β_g shows the exposure of the returns \tilde{r}_g and μ_g is the expected return that is tied to a unit of that risk.

Equation (23) tells a different story than Pástor et al.'s original model. In the original CAPM model proposed by Pástor et al. (2021), the alpha (α) is expressed as: $\alpha = -a^{-1} \bar{d}g$. Pástor elaborated on this by stating:

"While the popular risk-based interpretation of factor pricing models is mechanically valid, we see here an example of how that interpretation can miss the underlying economics. [...] (The original alpha equation) reveals that the sources of α are tastes for known characteristics, g , not aversion to an additional fundamental risk."

The alteration to the CAPM model represents a significant shift in how alpha is interpreted and calculated. While Pástor's model highlighted the role of investor preferences for known characteristics without necessarily considering risk aversion, the new model explicitly integrates aversion to ESG risks. ESG risk aversions decrease the alpha with positive average market ESG preferences and positive ESG scores.

By integrating relative risk aversions towards ESG impacts, the model reflects investors' varying attitudes to risks associated with ESG factors. Incorporating ESG risk aversions influences asset allocation decisions and asset prices. Higher ESG risk aversion typically increases the wealth allocated to ESG portfolios, as investors require less compensation for bearing fewer ESG-related risks. This results in lower expected returns for green assets, as investors accept a lower premium for holding assets with a higher ESG score. The prices for these green assets might be higher than scenarios without ESG risk aversions.

Brown assets are also affected by ESG risk aversions. Higher ESG risk aversions would lead to decreased demand from investors for brown assets seeking to avoid ESG risks. The decrease in demand decreases brown asset prices and increases the expected returns as compensation for their negative ESG impacts. Including ESG risk aversions adds a layer of complexity to asset prices, where both the non-pecuniary benefits and the aversions towards ESG risks play significant roles in determining the equilibrium prices and expected returns of green and brown assets. This model suggests that ESG risk aversions can influence investment strategies and market dynamics by altering the perceived attractiveness of green and brown assets based on their associated risks.

5.4 Negative ESG Preference

In this section, the third hypothesis of this thesis is examined. This hypothesis explores the potential ESG aversion, an aspect not addressed in previous sections. Unlike earlier adjustments, this part reinterprets the original model to incorporate ESG aversion.

Pástor et al. (2021) base their model on a variable b_i that quantifies the non-pecuniary benefits of holding a stock, which includes an agent-specific component (d_i) and a firm-specific component (g_n). $d_i \geq 0$ represents indifference or positive ESG tastes. However, ESG preferences are not static and can vary with economic conditions and personal wealth levels. In challenging economic climates, investors may prioritize higher returns over positive ESG impacts, leading to the inclusion of sin stocks, for example.

Building on this premise, the third hypothesis states that the impact of an agent's ESG aversion on the asset prices of green and brown assets will differ from that of positive ESG preferences. The utility function is reassessed to explore this, and the range of ESG preferences is extended to encompass negative values. This reassessment does not alter the structure of the model of Pástor et al. (2021). Instead, it provides a nuanced interpretation considering investor behaviour under varying economic conditions.

5.4.1 Utility Function

In the base model, the ESG preference (d_i) interacts with the ESG characteristic of a firm (g) and provides the nonpecuniary benefit of holding the firm's stock with:

$$b_i = g d_i. \quad (1)$$

The variable g can assume positive or negative values, depending on the company's ESG score. In contrast to the original model, where d_i is exclusively non-negative, the variable is extended to include both positive and negative values. A negative d_i indicates an ESG aversion, signifying that the agent derives disutility from holding stocks with positive ESG scores and prefers investments with negative ESG impacts. Each agent's utility is then:

$$V(\tilde{W}_{1i}, X_i) = -e^{-A_i \tilde{W}_{1i} - g d_i X_i}. \quad (2)$$

A company with a positive g and an agent with a negative ESG preference (d_i) will decrease the agent's utility through its holdings (X_i). However, the agent's utility increases if the company's ESG impact is negative.

5.4.2 Expected Returns

Maximizing utility for the agents and finding the associated asset allocation (X_i) provides us:

$$\begin{aligned} E[V(\tilde{W}_{1i}, X_i)] &= E[-e^{-A_i \tilde{W}_{1i} - b_i X_i}] \\ X_i &= a^{-1} \sigma^{-1} (\mu + a^{-1} g d_i) \end{aligned} \quad (3)$$

An agent with negative values for d_i will hold fewer stocks (X_i) if the company's ESG impact is positive ($g > 0$). On the other hand, the ESG-averse agent will increase its stock holdings if the company's ESG impact is negative ($g < 0$).

The market portfolio weights (w_m) are defined as:

$$w_m = a^{-1} \sigma^{-1} \mu + a^{-2} \sigma^{-1} \bar{d} g. \quad (4)$$

ESG aversion creates a negative average of the ESG preferences (\bar{d}) and, due to the interaction with g , correctly adjust the market portfolio (w_m) to increase w_m when g is negative and vice versa.

The market equity premium (μ_m) is:

$$\mu_m = a \sigma_m^2 - a^{-1} \bar{d} g w'_m \quad (5)$$

and the ESG aversion adjusts the equity premium through the average ESG preference (\bar{d}). An ESG aversion combined with negative overall ESG scores of the market portfolio ($g w'_m$), decreases the market equity premium. Agents are then (already) rewarded through their increased utility of holding stocks with negative ESG impacts.

From this point, the model assumes that the market portfolio is ESG-neutral:

$$w'_m g_n = 0. \quad (6)$$

The equity premium is thus independent of the agent's ESG tastes, redefining ESG as increasing agents' utility when companies score higher than the market on these aspects or, in the case of ESG aversion, when companies score lower than the market on these aspects. The expected excess return is then:

$$\mu = \mu_m \beta_m - a^{-1} \bar{d} g. \quad (7)$$

Again, if the average taste (\bar{d}) is negative, then the expected returns decrease in positive ESG characteristics. Agents are willing to pay less for firms with higher ESG scores, which increases the firm's expected returns. The alpha of this CAPM model is:

$$\alpha_n = -a^{-1}\bar{d}g_n. \quad (8)$$

If the average ESG preference is negative and the ESG score of the company is negative as well, the alpha decreases. The negative relationship between α_n and g_n is stronger when the relative risk aversion is lower and when \bar{d} is increasingly negative.

The difference between the agent i 's ESG preference or aversions and the average ESG market preference is $\delta_i = d_i - \bar{d}$. If both d_i and \bar{d} are negative, δ_i is not altered. The minus sign between d_i and \bar{d} still functions to find the difference between the preference of agent i and the average preference of the market. The only difference is that δ_i can now take on larger values. An ESG-averse agent with a strong market-positive ESG preference will have a more significant difference in preference than in the original model, where the agent could only be indifferent ($d_i = 0$).

The mean of the excess return is defined by:

$$\begin{aligned} E[\tilde{r}_i] &= \mu X_i \\ E[\tilde{r}_i] &= \mu_m - \delta_i(a^{-3}\sigma^{-1}\bar{d}g'g). \end{aligned} \quad (9)$$

The new interpretation of δ_i only affects the mean returns by being able to take up more extreme values. The mean returns decrease or increase more heavily depending on the $(a^{-3}\sigma^{-1}\bar{d}g'g)$. The interaction between the market preference and the company scores ($\bar{d}g'g$) becomes interesting. A negative ESG score (g) becomes positive by multiplication with itself and then negative again with the multiplication with the market ESG aversion (\bar{d}). The expected mean excess returns of an agent ($E[\tilde{r}_i]$) then increase when the difference between the market preference and the preference of the agent is positive (δ_i). A positive difference with a negative market preference will occur when the agent has a weaker ESG aversion (or a positive ESG preference) than the market average.

The variance of the excess return on agent i 's portfolio is:

$$\begin{aligned} Var(\tilde{r}_i) &= X_i^2 \sigma \\ Var(\tilde{r}_i) &= \sigma_m^2 + \delta_i^2(a^{-4}\sigma^{-1}g'g). \end{aligned} \quad (10)$$

The changes in ESG aversion affect the portfolio variance. A negative company score (g) becomes positive when squared and increases the variance depending on δ_i^2 . Agents with more extreme ESG tastes than the market will thus accept higher volatility. A difference in ESG preference of the agent compared to the market will either way create a positive value that could increase the portfolio variance, depending on $(a^{-4}\sigma^{-1}g'g)$.

The expected utility in equilibrium is defined as:

$$E[V] = \tilde{V} e^{-\frac{1}{2}a^{-2}\sigma^{-1}\delta_i^2g'g}. \quad (11)$$

The difference in ESG tastes (δ_i^2) can take on larger values in this model and increase the slope of the agent's utility. Agents with a higher δ_i^2 will then see a faster change in their utility than agents who cannot be ESG averse.

5.4.3 Portfolio Tilt and the ESG Portfolio

The portfolio weights of stocks are determined by:

$$X_i = w_m + a^{-2}\sigma^{-1}\delta_i g. \quad (12)$$

Agents with a more significant difference from the market average ESG taste (larger δ_i) will change their stock holdings more drastically, depending on the agent's ESG scores, stock variance, and relative risk aversion.

The fraction of the agent's wealth in the riskless asset is $1 - l'X_i = -a^{-2}\sigma^{-1}l'\delta_i g$. Agents allocate a fraction ϕ_i of the remaining wealth to the ESG portfolio and a fraction of $1 - \phi_i$ to the market portfolio:

$$\phi_i = \frac{a^{-2}\sigma^{-1}l'(\delta_i g)}{1 + a^{-2}\sigma^{-1}l'(\delta_i g)}. \quad (13)$$

Here, a larger δ_i combined with positive company ESG scores (g) increases the fraction of the agent's stock portfolio invested in the ESG portfolio. If δ_i is positive and becomes larger, the fraction in the ESG portfolio increases. The agent tilts away from the market portfolio in the direction of greenness. Similarly, if δ_i is negative and becomes larger (more negative), and the company's ESG score (g) is also negative, the fraction in the ESG portfolio also increases.

However, if δ_i and g have opposite signs (one is positive and the other negative), the numerator becomes larger in magnitude but negative. In contrast, the denominator becomes smaller (1 plus a negative number). This results in a negative fraction, which is theoretically incorrect as it implies

a negative investment in the ESG portfolio. Therefore, the fraction is minimized at 0, which aligns with the practical outcome: an agent with ESG preferences (δ_i) that are opposite to the actual ESG scores of the companies (g) will not invest in the ESG portfolio. Such agents prefer investments that align with their tastes, which are opposite to the ESG characteristics of the portfolio.

The greenness of the ESG portfolio is denoted by:

$$g_g = w_g g. \quad (14)$$

The ESG portfolio's CAPM alpha is:

$$\alpha_g = -a^{-1} g_g \bar{d}. \quad (15)$$

The equation reveals that the sign of α_g is the opposite of g_g . This means that, similar to the original model, the agents' portfolios can produce either negative or positive alphas depending on the sign of g_g .

However, the introduction of a potential negative average ESG preference in the market (\bar{d}) brings a new dimension to this interpretation. When the average ESG preference (\bar{d}) is negative, it implies that the market has a general aversion to ESG factors. In this scenario, if the ESG portfolio is green ($g_g > 0$), indicating that the companies in the portfolio have positive ESG characteristics, the alpha (α_g) will be positive.

In practice, this means that investors who hold green assets in a market with a negative average ESG preference will see higher excess returns (positive alphas) for those assets. This occurs because the market's aversion to ESG factors decreases the demand for green assets, lowering prices. As a result, these assets offer higher returns to compensate for their lower market valuation.

Thus, green assets become more attractive from a return perspective in a market where ESG preferences are predominantly negative despite lower prices. Brown assets, which have negative ESG characteristics, might see a decrease in excess returns (negative alphas) as they become more sought after, driving up their prices and lowering their yields.

5.4.4 Two-factor Pricing with the ESG Portfolio

The interpretation of the two-factor pricing model remains broadly consistent. The excess return on the ESG portfolio is $\tilde{r}_g = w'_g \tilde{r}$ and the expected excess return on the ESG portfolio is:

$$\mu_g = -a^{-1} g_g \bar{d} \quad (16)$$

which equals the alpha of equation (20). The variance of the ESG portfolio is:

$$\sigma_g^2 = \left(\frac{1}{1'\sigma^{-1}g}\right)^2 g'g\sigma^{-1} = \left(\frac{1}{1'\sigma^{-1}g}\right) g_g \quad (17)$$

The beta of the ESG portfolio is:

$$\beta_g = \frac{1}{g_g} g. \quad (18)$$

The expected returns of the market and the ESG portfolio are then determined by:

$$\mu = \mu_m \beta_m + \mu_g \beta_g. \quad (19)$$

Using equation (19), we have the following two-factor asset pricing model:

$$\tilde{r} = \beta_m \tilde{r}_m + \beta_g \tilde{r}_g + \tilde{v}. \quad (20)$$

This regression model can estimate excess returns. All assets have zero alphas, equivalent to zero intercepts in the regression. The vector of CAPM alphas is:

$$\alpha = \beta_g \mu_g \quad (21)$$

$$\alpha = -a^{-1} \bar{d} g. \quad (22)$$

Equation (21) provides a risk-based interpretation. β_g shows the exposure of the returns \tilde{r}_g , and μ_g is the expected return tied to a unit of that risk.

The sources of α in equation (22) are preferences for known characteristics (ESG) and potential aversion to ESG factors. The presence of an average ESG aversion within the market generates a negative \bar{d} , resulting in a positive α when the ESG characteristics of firms are positive. This scenario reflects a decreased willingness to pay for firms with higher ESG scores, altering the expected returns for these firms. Consequently, the prices of green and brown assets are subject to the agents' possible negative ESG preferences.

Hypothesis 3 explores the impact of negative ESG tastes (ESG aversion) on the prices of green and brown assets. Extending the original model to include negative values for ESG tastes, this hypothesis examines how agents who derive disutility from holding stocks with positive ESG scores behave in the market. In a market where ESG aversion is prevalent, green assets with

positive ESG scores may see reduced demand, leading to lower prices and higher expected returns. Investors with ESG aversion are unwilling to pay a premium for the non-pecuniary benefits associated with positive ESG impacts, resulting in decreased demand and lower prices for green assets.

On the other hand, brown assets, which align with the preferences of ESG-averse investors, may experience higher demand, resulting in higher prices but lower expected returns. This dynamic illustrates the potential for significant shifts in asset prices based on the prevailing ESG tastes in the market. Including ESG aversion adds a new dimension to asset pricing models, reflecting a broader range of investor behaviours. It shows that the demand for green and brown assets can be heavily influenced by agents' negative or positive ESG tastes, leading to more comprehensive and realistic asset prices.

5.5 Quantitative Implications

To illustrate the impacts of the changes made to the original model, four equations are plotted: the utility function of an agent (V), the asset allocation function (the fraction of wealth allocated to stocks (X_i)), the expected excess portfolio returns ($E[\tilde{r}_i]$) and the ESG portfolio fraction (ϕ_i). These equations are plotted using arbitrary values for several variables to demonstrate the effects of the new models.

Parameter	Score or range	Description
Normalized wealth levels	1	Wealth levels are normalized to 1. Thus, \tilde{W}_{1i} and W_{0i} are both set to 1 across all agents. Normalizing wealth levels is common in asset pricing models to facilitate comparisons and model dynamics (Kolari et al., 2023).
ESG scores	-5 to 5	The ESG score of a company (g) is given an arbitrary value between -5 and 5, capturing both positive and negative ESG impacts. This range helps standardize the scores across different scenarios.

Differentiated ESG scores	-5 to 5	In the second hypothesis, the ESG score (g) is split into E, S and G scores (E , S and G). The scores can range between -5 and 5, capturing positive and negative impacts.
Risk aversion parameters	1 to 6	The risk aversion parameters (A_i , A_{Fi} , A_{Ei} , A_{Si} and A_{Gi}) are set on a scale of 1 to 6, where 1 indicates a low-risk aversion, and 6 indicates a risk-averse attitude. The risk aversion parameter is commonly on a scale between 0 and 5 (Díaz & Esparcia, 2019; Mehra & Prescott, 2003). However, the minimum is set to 1 to avoid issues with division by zero when calculating reciprocals.
Fraction invested in stocks	0.3	The fraction of wealth invested in stocks (X_i) is given an arbitrary value. Based on Dutch consumer data from the Central Bureau of Statistics in the Netherlands (Centraal Bureau voor de Statistiek, 2023), an average value for allocating total household wealth to securities has been determined for the Netherlands. The data indicates an average allocation fraction of approximately 30% (see Appendix 9.4). Based on this, the fraction allocated to stocks is set to 0.3 across agents, reflecting a moderate stock allocation.
ESG preference	0 to 5	The ESG preference (d_i) of an agent ranges from 0 to 5, where 0 means indifference to ESG factors and 5 indicates a strong preference for ESG. Regarding plots within the third hypothesis, the preference can also become negative (on a scale of -5 to 5) to reflect possible ESG aversion.

Differentiated ESG preferences	0 to 5	The ESG preference (d_i) is split into E (T_E), S (T_S) and G (T_G) preferences. The scores can range between 0 and 5.
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5.5.1 Utility Function

5.5.1.1 Original Utility Function

The utility function of the original model is:

$$V(\tilde{W}_{1i}, X_i) = -e^{-A_i \tilde{W}_{1i} - g_n d_i X_i}.$$

This equation is plotted below in Figure 1. In this plot, the utility level changes are examined with the company's ESG score (g_n) for different levels of the agent's ESG preference (d_i). The risk aversion parameter (A_i) is set to 2, wealth levels (\tilde{W}_{1i}) are normalized at 1, and stock allocation (X_i) has been set to 0.3.

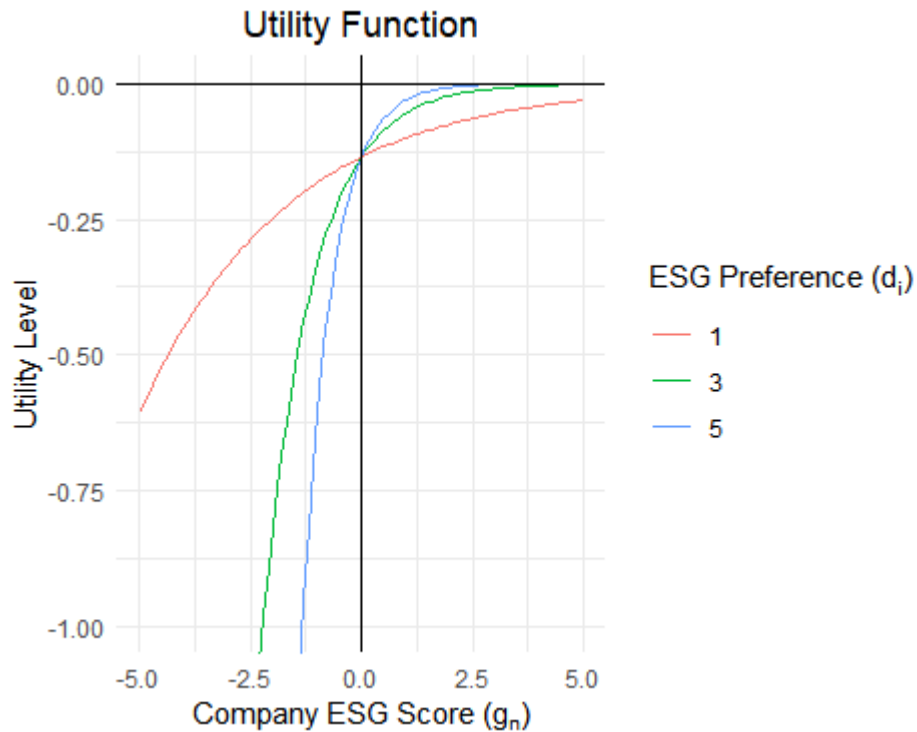


FIGURE 1 - ORIGINAL UTILITY FUNCTION

The plot illustrates that an agent's utility is affected by their ESG preference (d_i). As d_i increases, the sensitivity of the agent's utility to fluctuations in a company's ESG impact (g_n) increases. Specifically, an increase in g_n results in elevated utility for agents with higher ESG

preferences. Crucially, this relationship also shows a downside: a negative ESG score ($g_n < 0$) negatively affects agents' utility with a stronger preference for ESG factors. In such scenarios, an agent with a higher d_i will experience a more substantial reduction in utility compared to an agent with a lower d_i . This dynamic underlines the dual impact of ESG preferences, amplifying both the benefits of positive ESG scores and the losses of negative scores.

5.5.1.2 Utility Function First Hypothesis

The utility function in the model of Hypothesis 1 is:

$$V(\tilde{W}_{1i}, X_i) = -e^{-A_i \tilde{W}_{1i} - (T_{Ei} E_n + T_{Si} S_n + T_{Gi} G_n) X_i}$$

This function is plotted in Figure 2 below. The utility function has been divided into three agents. The first agent has received low environmental and medium social and governance preferences. The second agent has a medium environmental, high social and medium governance preference, and the third has high environmental, medium social and medium governance preferences.

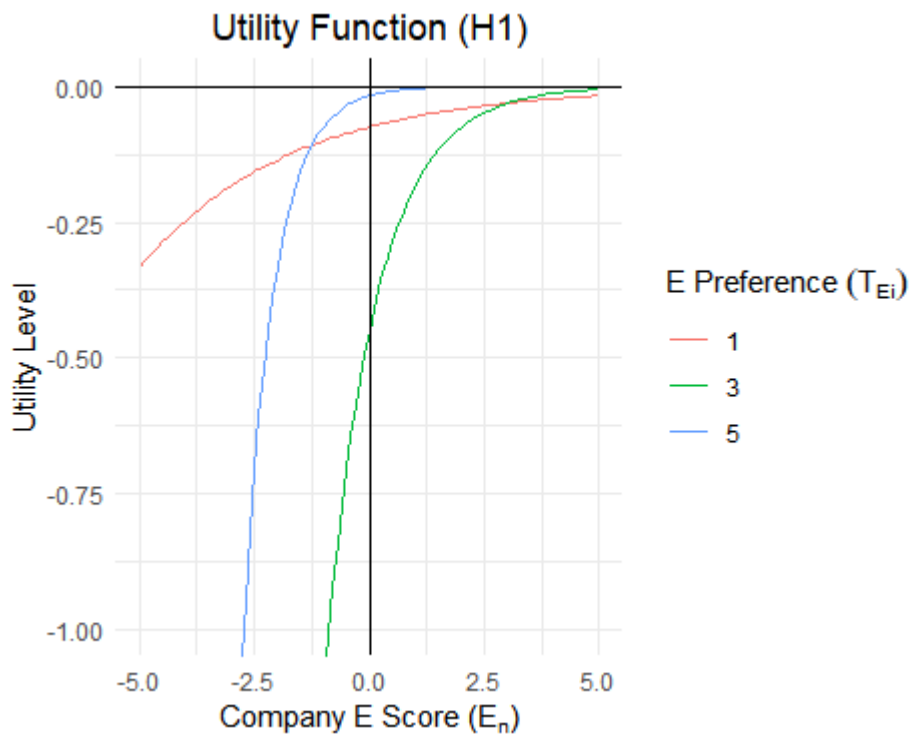


FIGURE 2 – UTILITY FUNCTION HYPOTHESIS 1

AGENT 1 PARAMETERS: $S_n = 2, G_n = 1, T_{Si} = 3, T_{Gi} = 2$

AGENT 2 PARAMETERS: $S_n = -3, G_n = -1, T_{Si} = 4, T_{Gi} = 2$

AGENT 3 PARAMETERS: $S_n = 1, G_n = 2, T_{Si} = 3, T_{Gi} = 2$

Figure 2 – Utility Function Hypothesis 1 illustrates that the agent's utility is influenced by their separate preferences (T_{Ei}, T_{Si} and T_{Gi}). As T_{Ei} increases, so does the sensitivity of utility to changes in the company's E score (E_n). Negative environmental scores lead to sharp declines in utility for agents with high T_{Ei} , while positive environmental scores result in higher utility levels.

This analysis could similarly be conducted by varying the Social (S_n) and Governance (G_n) scores. The current plot shows that splitting the ESG score and ESG preference into separate components for E, S, and G provides a broader spectrum of utility levels to consider. This approach highlights the diverse impacts each ESG component can have on utility.

5.5.1.3 Utility Function Second Hypothesis

The utility function in the model of Hypothesis 2 is:

$$V(\tilde{W}_{1i}, X_i) = -e^{-A_{Ei}\tilde{W}_{1i} - (A_{Ei}W_{0i}b_{Ei} + A_{Si}W_{0i}b_{Si} + A_{Gi}W_{0i}b_{Gi})X_i}$$

The function is plotted in Figure 3.

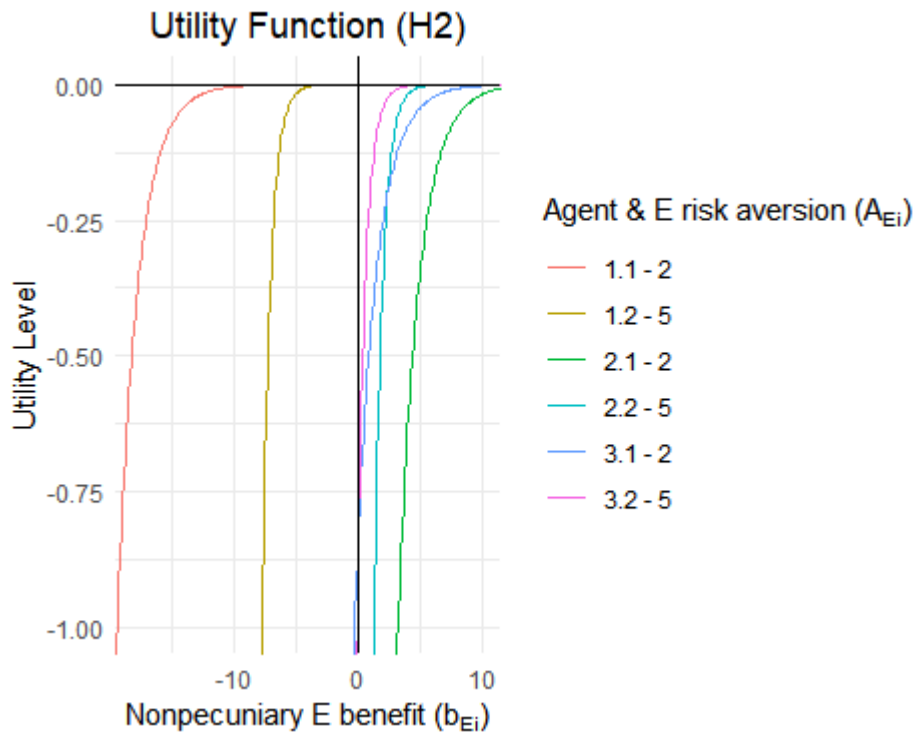


FIGURE 3 - UTILITY FUNCTION HYPOTHESIS 2

AGENT 1 PARAMETERS: $b_{Si} = 4$, $b_{Gi} = 3$, $A_{Si} = 5$ AND $A_{Gi} = 4$

AGENT 2 PARAMETERS: $b_{Si} = -1$, $b_{Gi} = -5$, $A_{Si} = 3$ AND $A_{Gi} = 2$

AGENT 3 PARAMETERS: $b_{Si} = -3$, $b_{Gi} = 6$, $A_{Si} = 4$ AND $A_{Gi} = 1$

Each agent in Figure 3 now has two utility lines. One where the absolute risk aversion for environmental impacts (A_{Ei}) is 2, and the second one, where the risk aversion is 5. The graph demonstrates that incorporating separate risk aversions (A_{Ei} , A_{Si} and A_{Gi}) affects the utility levels derived by the agent. Each group's utility levels vary based on the specific risk aversion parameters, showing how different ESG factors influence utility. Agents with higher environmental risk aversion (A_{Ei}) are more sensitive to changes in nonpecuniary benefits related to environmental factors (b_{Ei}). As the nonpecuniary E benefits increase, the slope of the utility function increases.

5.5.1.4 Utility Function Third Hypothesis

The utility function in the model of Hypothesis 3 is equal to the original:

$$V(\tilde{W}_{1i}, X_i) = -e^{-A_i \tilde{W}_{1i} - g_n d_i X_i}.$$

Now, the negative ESG preferences (d_i) are plotted against increasing ESG scores of companies (g_n).

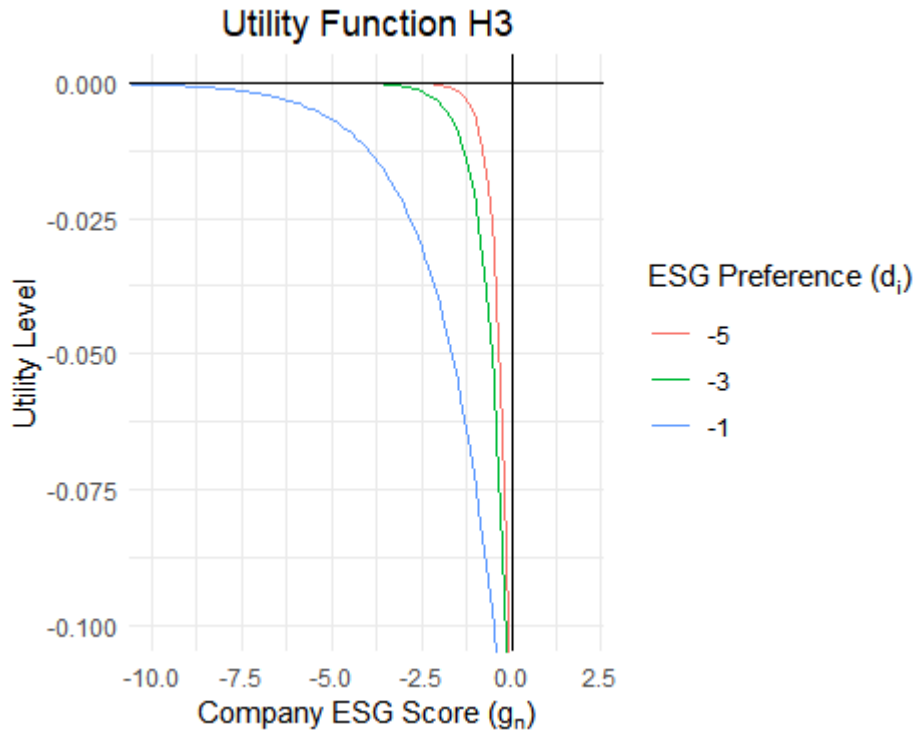


FIGURE 4 - UTILITY FUNCTION HYPOTHESIS 3

Figure 4 shows that extending the range of ESG tastes to include ESG aversion significantly affects the utility levels derived by the agent. The negative ESG taste is inversely related to the ESG score of a company and the utility level derived. In scenarios with negative ESG scores, an agent with a higher negative ESG taste (such as -5) loses the least utility. The strongly ESG-averse agents derive more utility from negative ESG scores than those with lower ESG aversion (such as -1). Consequently, agents with stronger negative ESG tastes gain relatively more utility with negative ESG scores.

5.5.2 Asset Allocation Function

The analysis in this paragraph compares the four asset allocation functions. Each model incorporates variations in critical parameters such as ESG preferences and risk aversion levels. The aim is to illustrate the impact of these variations on investment decisions. Each graph is a plot of the percentage of wealth invested in stocks (X_i) ranging from 0 to 1 (100%).

5.5.2.1 Original Asset Allocation Function

The first plot is the original asset allocation function:

$$X_i = 1/a \sigma^{-1}(\mu + 1/a d_i g).$$

This function determines the proportion of the agent's total wealth allocated to stocks without differentiating based on the ESG score of different stocks. In Figure 5, the original equation is plotted against the ESG preference of the agent.

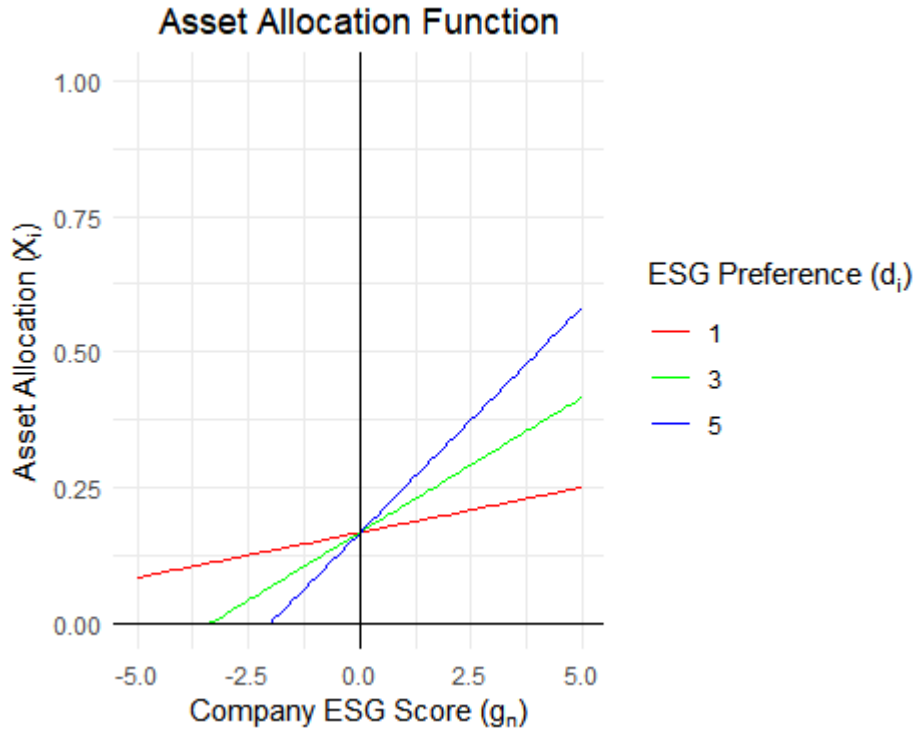


FIGURE 5 – ASSET ALLOCATION FUNCTION

PARAMETERS: $\sigma = 15\%$, $\mu = 5\%$, $A = 2$ AND $W_{0i} = 1$

The plot demonstrates that as an investor's ESG preference increases, their allocation to the stocks with higher ESG scores increases. This linear trend suggests that higher ESG preferences lead to a higher willingness to invest in assets that align with these values, reflecting a direct proportionality between ESG importance and investment decisions.

5.5.2.2 Asset Allocation Function First Hypothesis

The asset allocation function of the first hypothesis is the following:

$$X_i = 1/a \sigma^{-1}(\mu + 1/a T_{Ei} E + 1/a T_{Si} S + 1/a T_{Gi} G).$$

In Figure 6, this equation is plotted for three agents with different parameters against an increasing E score of companies (E). The parameters for the variation ($\sigma = 15\%$), expected return ($\mu = 5\%$), risk aversion ($A = 2$) and wealth levels ($W_{0i} = 1$) are held constant.

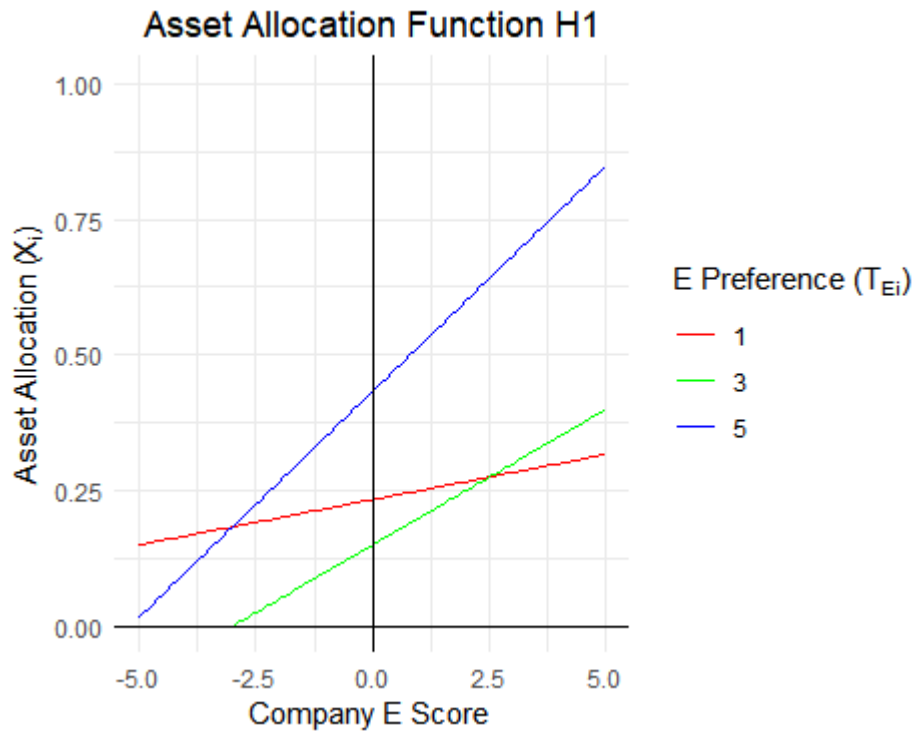


FIGURE 6 – ASSET ALLOCATION FUNCTION H1

AGENT 1 PARAMETERS: $S = -1$, $G = 2$, $T_{Si} = 2$ AND $T_{Gi} = 3$

AGENT 2 PARAMETERS: $S = -3$, $G = -2$, $T_{Si} = 1$ AND $T_{Gi} = 2$

AGENT 3 PARAMETERS: $S = 0$, $G = 4$, $T_{Si} = 1$ AND $T_{Gi} = 4$

The plot illustrates the relationship between the environmental preference (T_{Ei}) and the E score, highlighting how varying levels of T_{Ei} (1, 3, and 5) influence asset allocation. Additionally, it underscores the importance of integrating separate E, S and G scores and preferences, which results in a more nuanced and diverse asset allocation strategy.

As observed in the plot, higher T_{Ei} generally lead to increased asset allocation in response to positive E scores. Specifically, the blue line represents the highest E preference ($T_{Ei} = 5$) shows a significant increase in asset allocation as the E score improves. This indicates that agents with

strong environmental preferences are more likely to allocate their assets to investments with high E scores, reflecting their prioritization of environmental benefits.

The increase in asset allocation is less pronounced with the green and red line, suggesting that while these agents value environmental criteria, their investment decisions are also influenced by other factors, leading to a more balanced allocation strategy.

5.5.2.3 Asset Allocation Function Second Hypothesis

The second hypothesis produced the following asset allocation function:

$$X_i = a_F^{-1} \sigma^{-1} (\mu + a_F^{-1} a_E T_{Ei} E + a_F^{-1} a_S T_{Si} S + a_F^{-1} a_G T_{Gi} G).$$

The equation is plotted in Figure 7 with equal parameters for the variation ($\sigma = 15\%$), expected return ($\mu = 5\%$), risk aversion ($A = 2$) and wealth levels ($W_{0i} = 1$).

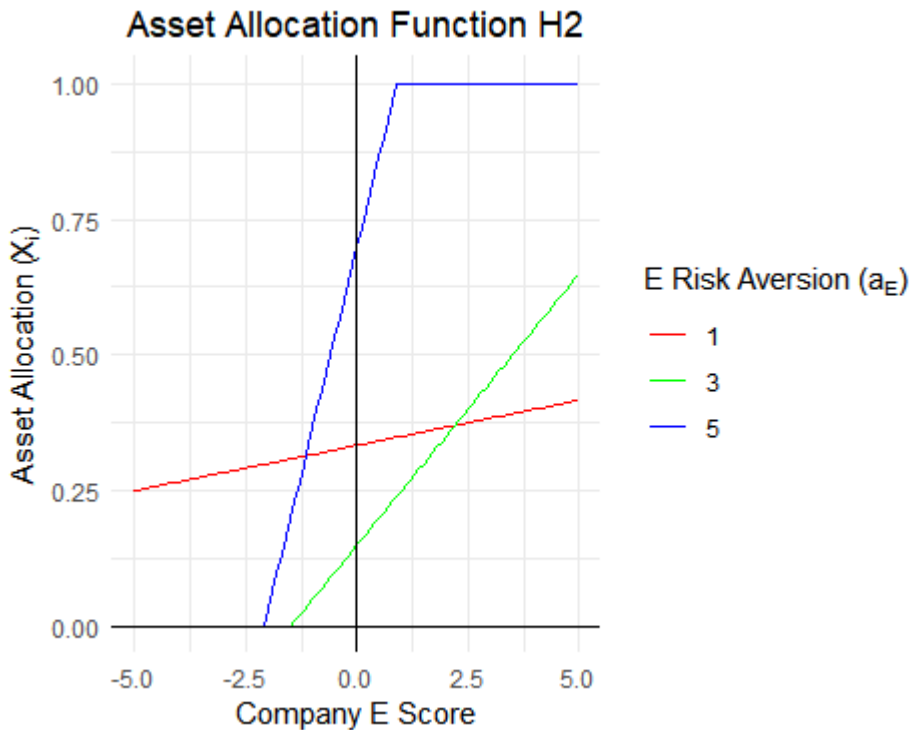


FIGURE 7 – ASSET ALLOCATION FUNCTION H2

AGENT 1 PARAMETERS: $S = -1, G = 2, T_{Ei} = 1, T_{Si} = 2, T_{Gi} = 3, a_S = 4$ AND $a_G = 3$

AGENT 2 PARAMETERS: $S = 3, G = -2, T_{Ei} = 2, T_{Si} = 1, T_{Gi} = 2, a_S = 1$ AND $a_G = 1$

AGENT 3 PARAMETERS: $S = 0, G = 4, T_{Ei} = 4, T_{Si} = 1, T_{Gi} = 4, a_S = 2$ AND $a_G = 2$

The plot in Figure 7 demonstrates the relationship between the E score and asset allocation, given different levels of E risk aversion ($a_E = 1, 3, \text{ and } 5$). The agent's E risk aversion now reflects their aversion to poor ESG impacts, meaning higher E risk aversion leads to a greater allocation of assets to companies with good ESG scores.

The plot reveals that higher E risk aversion (a_E) leads to increased asset allocation for positive E scores, with the blue line ($a_E = 5$) showing the most significant increase. This indicates that agents with strong environmental risk aversion are more likely to allocate a more substantial portion of their assets to investments with high E scores, reflecting their prioritization of environmental benefits. However, higher E risk aversion also results in a sharper decrease in asset allocation for negative E scores.

Compared to the previous figure, including ESG risk aversions in the current plot enhances the positive relationship between asset allocation and ESG scores. It shows that agents with higher ESG risk aversions increase their allocation more significantly with better ESG scores and reduce it more severely with poorer ESG scores. This dual effect underscores the heightened sensitivity introduced by ESG risk aversion. Overall, including ESG risk aversions adds a nuanced layer of risk consideration to the asset allocation decision.

5.5.2.4 Asset Allocation Function Third Hypothesis

The third hypothesis proposes the following asset allocation function:

$$X_i = a^{-1}\sigma^{-1}(\mu + a^{-1}gd_i).$$

The equation is plotted in Figure 8 with equal parameters for the variation ($\sigma = 15\%$), expected return ($\mu = 5\%$), risk aversion ($A = 2$) and wealth levels ($W_{0i} = 1$).

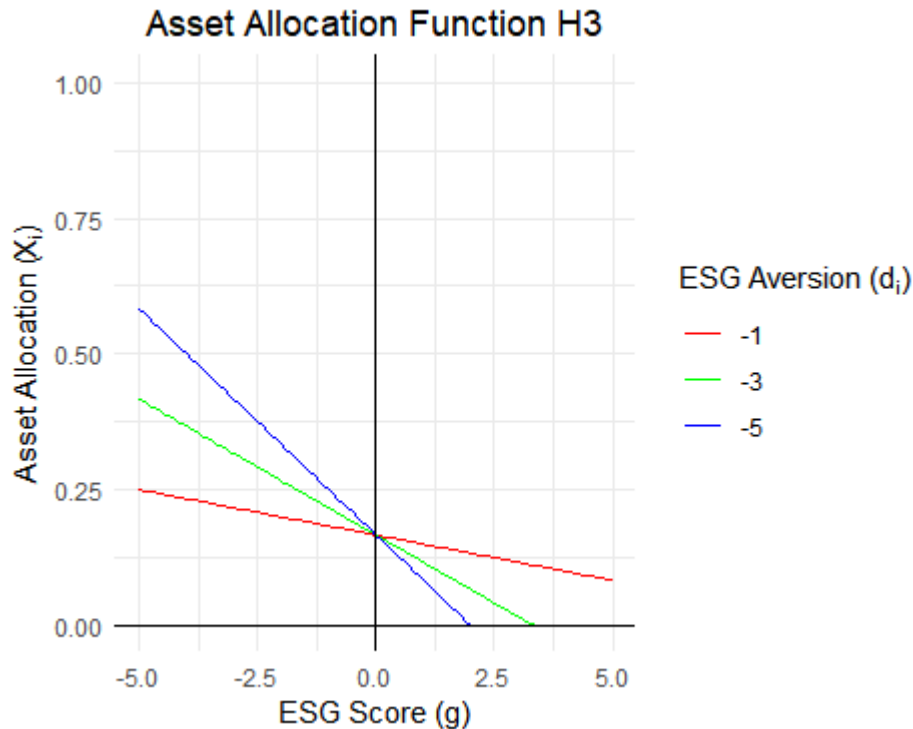


FIGURE 8 – ASSET ALLOCATION FUNCTION H3

The plot illustrates the impact of incorporating negative ESG tastes, or ESG aversion, on asset allocations. Incorporating ESG aversion into the model impacts the asset allocation of all agents. For negative ESG scores, all agents increase their asset allocation, reflecting the increase in utility derived from the negative ESG scores. However, asset allocation decreases as the ESG score shifts from negative to positive.

The plot highlights that agents with higher negative ESG tastes (i.e., greater ESG aversion) exhibit a more pronounced response to changes in ESG scores. Specifically, the blue line represents an ESG aversion (d_i) of -5 and shows a significant increase in asset allocation when ESG scores are negative, indicating a stronger preference for investments with poor ESG performance. This is contrasted with the red line ($d_i = -1$), which shows a more moderate increase in allocation for negative ESG scores. As the ESG score shifts from negative to positive, agents with higher ESG aversion reduce their asset allocation more drastically.

Overall, the plot underscores the dual impact of negative ESG tastes on asset allocation: positively influencing allocations for negative ESG scores and causing a sharper decline for

positive ESG scores. This relationship highlights the sensitivity of asset allocation to ESG performance, amplified by the level of ESG aversion.

5.5.3 Expected Excess Portfolio Returns

This section examines the average expected excess portfolio returns for an agent's stock portfolio by plotting the outcomes of functions incorporating ESG factors. The analysis is based on several constant parameters, including a market return (μ_m) of 3%, relative risk aversion (a) of 2, and stock variance (σ) of 15%. Additionally, the models integrate ESG considerations through parameters such as the average ESG preference of market agents (\bar{d}) and the ESG impact scores (g' and g) of the companies, both set at 3.

In this paragraph, the focus shifts from plotting the ESG score (or E score) on the x-axis to plotting the difference in ESG tastes (δ_i) on the x-axis. This approach is employed to signify the effect of changing the difference in ESG tastes of the agent compared to the average taste of the market. By focusing on δ_i , the analysis aims to illustrate more clearly how variations in the agent's ESG preferences relative to the average market preference influence expected excess portfolio returns.

5.5.3.1 Original Excess Portfolio Returns Function

The original model of Pástor et al. (2021) proposed the following average expected excess portfolio return function:

$$E[\tilde{r}_i] = \mu_m - \delta_i(a^{-3}\sigma^{-1}\bar{d}g'g).$$

This function is plotted in Figure 9 by comparing the effect of the changing difference in ESG tastes between the agent and the average ESG taste of the market (measured by δ_i on a scale of -5 to 5).

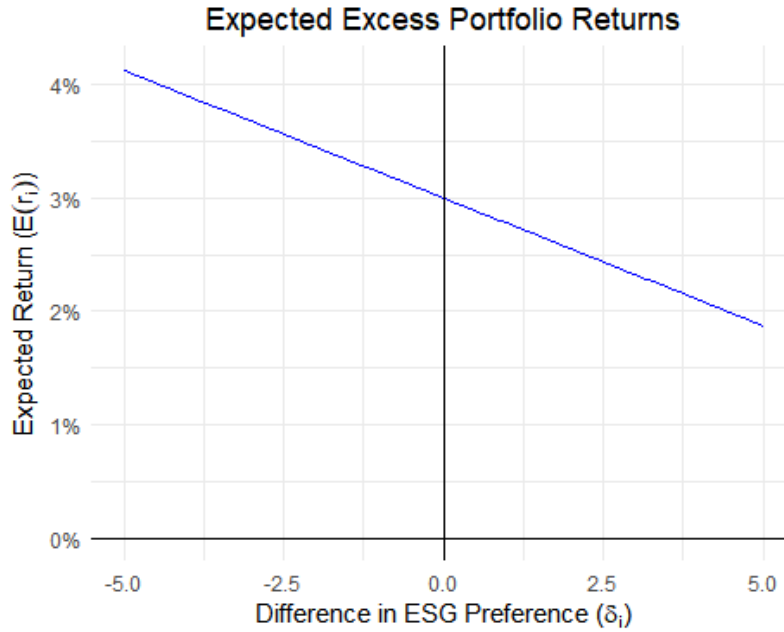


FIGURE 9 – EXPECTED EXCESS PORTFOLIO RETURNS

The plot demonstrates the expected excess portfolio returns as a function of the difference in ESG preference (δ_i) between an agent and the market's average ESG preference. As δ_i increases from -5 to 5, there is an apparent linear decrease in expected returns, indicating that agents whose ESG preferences deviate positively from the market average experience lower expected returns. This inverse relationship shows the trade-off between aligning investments with stronger ESG preferences and achieving higher financial returns. These agents expect and accept lower returns by investing with stronger ESG preferences in companies with a more positive ESG impact (higher ESG score).

5.5.3.2 Excess Portfolio Returns Function First Hypothesis

The excess portfolio returns function from the first hypothesis is the following:

$$E[\tilde{r}_i] = \mu_m - \alpha^{-3} \sigma^{-1} (\delta_{Ei} \bar{T}_E E'E + \delta_{Si} \bar{T}_S S'S + \delta_{Gi} \bar{T}_G G'G + \delta_{Ei} \bar{T}_S E'S + \delta_{Ei} \bar{T}_G E'G + \delta_{Si} \bar{T}_E S'E + \delta_{Si} \bar{T}_G S'G + \delta_{Gi} \bar{T}_E G'E + \delta_{Gi} \bar{T}_S G'S).$$

The function is plotted in Figure 10 below.

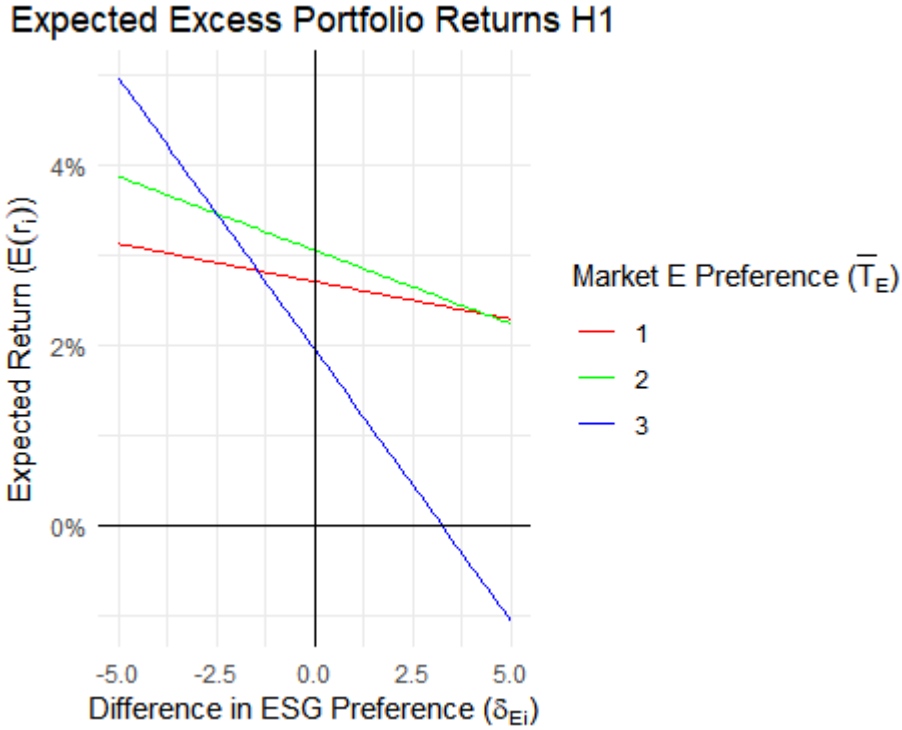


FIGURE 10 – EXPECTED EXCESS PORTFOLIO RETURNS H1

AGENT 1 PARAMETERS: $E = 2, S = -2, G = 3, \bar{T}_S = 1.5, \bar{T}_G = 2, \delta_{Si} = -2$ AND $\delta_{Gi} = 1$

AGENT 2 PARAMETERS: $E = -3, S = -1, G = -1, \bar{T}_S = 2.5, \bar{T}_G = 3, \delta_{Si} = 0$ AND $\delta_{Gi} = 1$

AGENT 3 PARAMETERS: $E = 4, S = 4, G = 5, \bar{T}_S = 3.5, \bar{T}_G = 4, \delta_{Si} = 2$ AND $\delta_{Gi} = 3$

The plot compares the expected excess portfolio returns for three distinct agents, each characterized by different ESG scores and average market ESG preferences (\bar{T}_E, \bar{T}_S and \bar{T}_G). The agents expected returns to decline, with different sensitivities, as δ_{Ei} increases, showing an inverse relationship with companies' E scores and \bar{T}_E . Agents within a higher average market ESG preference are willing to accept negative expected returns if these agents have even stronger ESG preferences than the market.

Figure 10 demonstrates an inverse relationship between the expected returns and the difference in ESG preferences (δ_{Ei}), with varying sensitivities based on individual agent parameters. Agents with higher ESG scores and stronger market preferences experience a steeper decline in expected returns as the difference in ESG preferences increases. This highlights the varying financial impacts based on individual and diverging ESG preferences.

5.5.3.3 Excess Portfolio Returns Function Second Hypothesis

The excess portfolio returns function from the second hypothesis is the following:

$$E[\tilde{r}_i] = \mu_m - a_F^{-3} \sigma^{-1} (a_E^2 \delta_{Ei} \bar{T}_E E' E + a_S^2 \delta_{Si} \bar{T}_S S' S + a_G^2 \delta_{Gi} \bar{T}_G G' G + a_E a_S \delta_{Ei} \bar{T}_S E' S + a_E a_G \delta_{Ei} \bar{T}_G E' G + a_S a_E \delta_{Si} \bar{T}_E S' E + a_S a_G \delta_{Si} \bar{T}_G S' G + a_G a_E \delta_{Gi} \bar{T}_E G' E + a_G a_S \delta_{Gi} \bar{T}_S G' S).$$

The function is plotted in Figure 11 below.

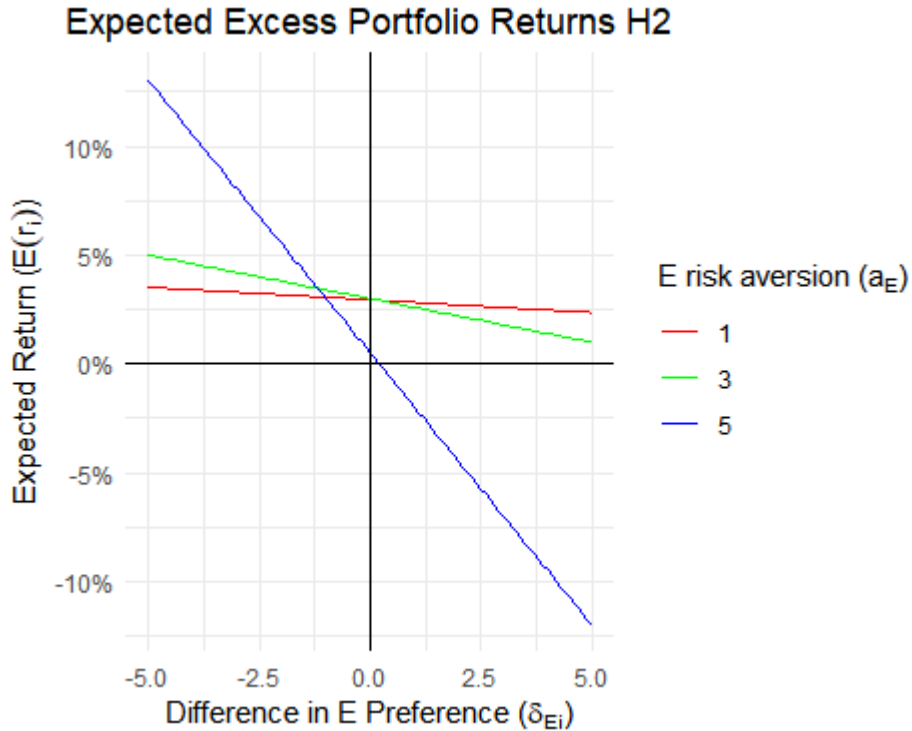


FIGURE 11 – EXPECTED EXCESS PORTFOLIO RETURNS H2

AGENT 1: $E = -2, S = -2, G = -1, \bar{T}_E = 0, \bar{T}_S = 1, \bar{T}_G = 1, \delta_{Si} = -2, \delta_{Gi} = 3, a_S = 2$ AND $a_G = 3$

AGENT 2: $E = 1, S = 1, G = 1, \bar{T}_E = 2, \bar{T}_S = 2, \bar{T}_G = 3, \delta_{Si} = 0, \delta_{Gi} = 0, a_S = 2$ AND $a_G = 2$

AGENT 3: $E = 2, S = 2, G = 1, \bar{T}_E = 1, \bar{T}_S = 3, \bar{T}_G = 2, \delta_{Si} = 2, \delta_{Gi} = -2, a_S = 3$ AND $a_G = 1$

The function introduces financial risk aversion (a_F) alongside relative ESG risk aversions (a_E, a_S and a_G) and the expected excess returns are plotted against the difference in ESG preference between the agent and the market average (δ_{Ei}). The results show an enhanced impact of ESG preferences on expected returns, with agents displaying a relatively more substantial decrease in returns as δ_{Ei} increases. The third agent again shows the highest sensitivity, expecting stronger negative returns than the previous model. Incorporating ESG risk aversions into the model thus

enhances the impact of ESG preferences on expected returns, leading to a more diverse expected excess portfolio return across different agents.

5.5.3.4 Excess Portfolio Returns Function Third Hypothesis

The excess portfolio returns function from the third hypothesis is the following:

$$E[\tilde{r}_i] = \mu_m - \delta_i(a^{-3}\sigma^{-1}\bar{d}g'g).$$

The function is plotted in Figure 12 below.

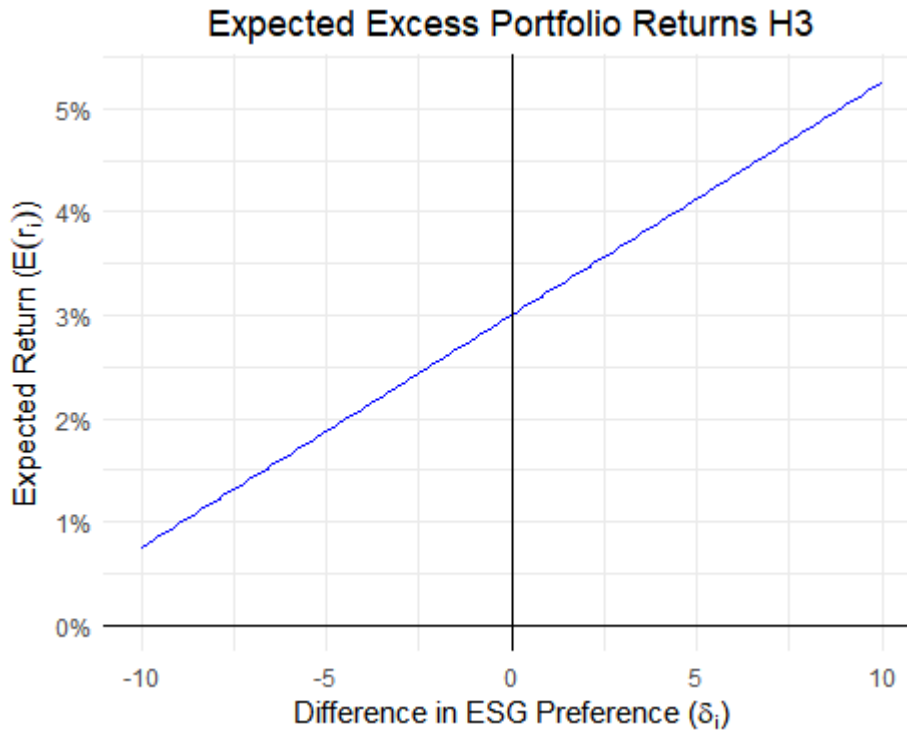


FIGURE 12 – EXPECTED EXCESS PORTFOLIO RETURNS H3

Figure 12 provides an alternative perspective by examining the excess returns under the assumption that the average preference of market agents for ESG is negative ($\bar{d} = -3$). The range of the difference in ESG taste between the agent and the market average (δ_i) is increased to -10 until 10 due to the addition of ESG aversion (as the ESG aversion increases, the ESG taste range increases with 5). In this scenario, the relationship between δ_i and expected returns are positive, indicating that agents with higher ESG preferences than the market experience higher expected returns. Compared to the first plot, this inversion of the relationship highlights the significant role that market-wide ESG preferences play in shaping individual investment outcomes. It suggests

that in markets where ESG aversion is prevalent, not aligning with these aversions and having a positive ESG preference as an agent can lead to enhanced financial returns.

These plots illustrate the complex interplay between ESG preferences and financial returns, highlighting how individual and market-wide ESG considerations can significantly influence expected portfolio performance. The varying impacts observed across agents and model specifications emphasize the need for tailored investment strategies that carefully balance ESG objectives with financial goals.

5.5.4 ESG Portfolio Fraction

This section delves into the fraction of wealth invested in an ESG portfolio, as determined by the various previously discussed models. The analysis employs key parameters such as relative risk aversion (α) set at 2, stock variance (σ) at 15%, an ESG impact score (g) of 2, and a scaling factor (ι) of 1. By examining the range of the differences in ESG preference between the agent and the market average (δ_i) from -5 to 5, the models aim to illustrate how these differences influence the proportion of total investments allocated to the ESG portfolio by the agent. The resulting plots will depict the relationship between δ_i and investment weight, providing insights into how varying degrees of ESG aversion or preference impact portfolio composition.

5.5.4.1 Original ESG Portfolio Fraction Function

The original model of Pástor et al. (2021) proposed the following function to express the fraction of wealth invested in the ESG portfolio by an agent:

$$\phi_i = \frac{\alpha^{-2} \sigma^{-1} \nu(\delta_i g)}{1 + \alpha^{-2} \sigma^{-1} \nu(\delta_i g)}.$$

This function is plotted in Figure 13.

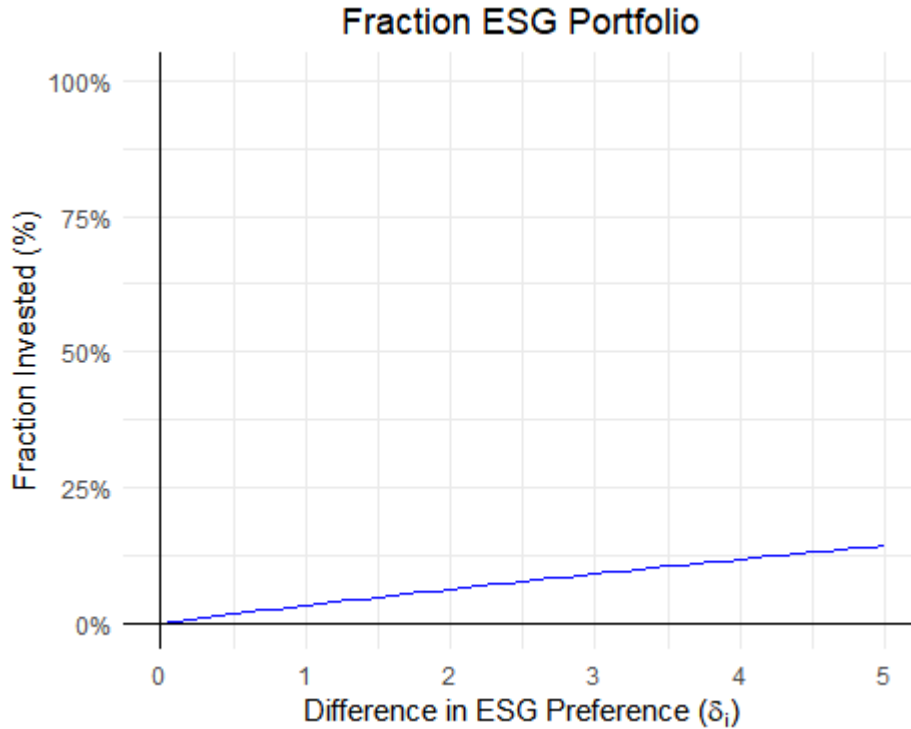


FIGURE 13 – ORIGINAL ESG PORTFOLIO FRACTION

Figure 13 illustrates the relationship between the difference in ESG preference (δ_i) and the fraction of weight invested in the ESG portfolio. As δ_i increases from 0 to 5, indicating that the agent has a higher preference for ESG compared to the market average, the fraction of investment in the ESG portfolio also increases. This relationship shows that as an agent's preference for ESG intensifies relative to the market, their allocation to ESG portfolios proportionally increases, reaching just above 20% at $\delta_i = 5$. This suggests that agents with stronger ESG preferences than the market are willing to invest more heavily in ESG portfolios to align their investments with their values.

5.5.4.2 ESG Portfolio Fraction Function First Hypothesis

The following function expresses the fraction of wealth invested in the ESG portfolio for three agents with varying ESG scores and delta values:

$$\phi_i = \frac{a^{-2} \sigma^{-1} u(\delta_{Ei}E + \delta_{Si}S + \delta_{Gi}G)}{1 + a^{-2} \sigma^{-1} u(\delta_{Ei}E + \delta_{Si}S + \delta_{Gi}G)}$$

This function is plotted in Figure 14.

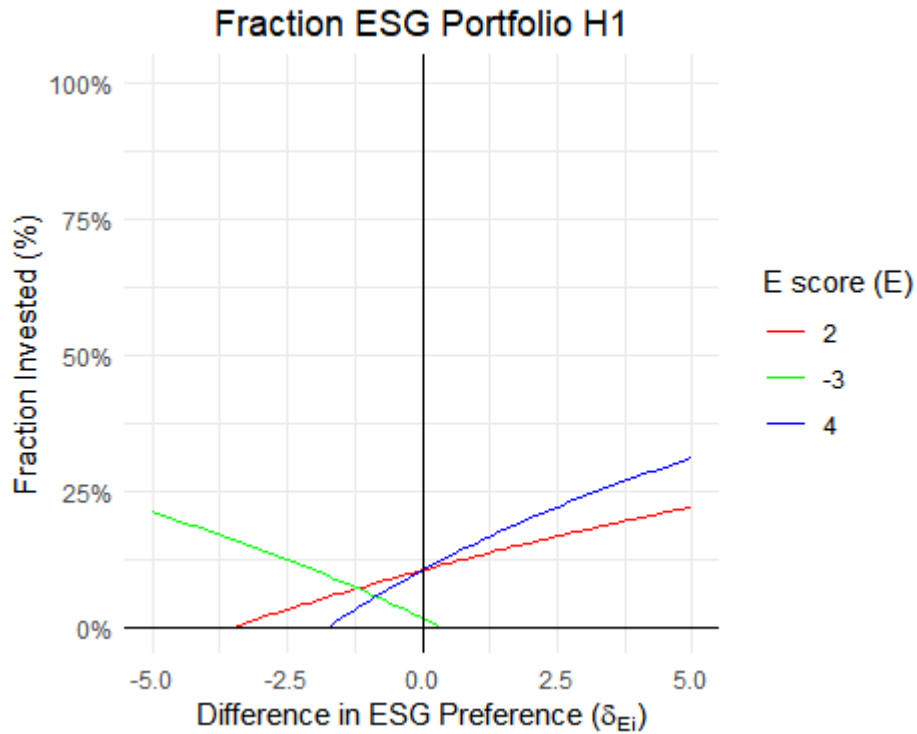


FIGURE 14 – ESG PORTFOLIO FRACTION H1

AGENT 1 PARAMETERS: $S = -2$, $G = 3$, $\delta_{Si} = -2$ AND $\delta_{Gi} = 1$

AGENT 2 PARAMETERS: $S = 1$, $G = -1$, $\delta_{Si} = 0$ AND $\delta_{Gi} = -1$

AGENT 3 PARAMETERS: $S = -4$, $G = 5$, $\delta_{Si} = 2$ AND $\delta_{Gi} = 3$

Figure 14 depicts the investment behaviour of three different agents based on varying differences in ESG preference (δ_{Ei}) relative to the market average. Each agent's curve reflects their unique ESG impact scores and delta values. The red and blue lines show increasing investment fractions as δ_{Ei} becomes positive, indicating that these agents have higher E preferences than the market average, leading them to increase their ESG investments. The green line shows a decreasing investment fraction as δ_{Ei} increases, reflecting that that agent has to deal with a negative E score (-3). The ESG portfolio thus has a negative environmental impact, and the agent will only increase the fraction invested in that ESG portfolio if the agent has a lower ESG preference than the market average (negative δ_{Ei}). This plot shows the heterogeneity in ESG investment strategies driven by individual differences in ESG impact scores and preferences relative to the market average.

5.5.4.3 ESG Portfolio Fraction Function Second Hypothesis

The following function expresses the fraction of wealth invested in the ESG portfolio for three agents considering different levels of relative ESG risk aversion:

$$\phi_i = \frac{a_F^{-2} \sigma^{-1} \nu (a_E \delta_{Ei} E + a_S \delta_{Si} S + a_G \delta_{Gi} G)}{1 + a_F^{-2} \sigma^{-1} \nu (a_E \delta_{Ei} E + a_S \delta_{Si} S + a_G \delta_{Gi} G)}$$

This function is plotted in Figure 15.

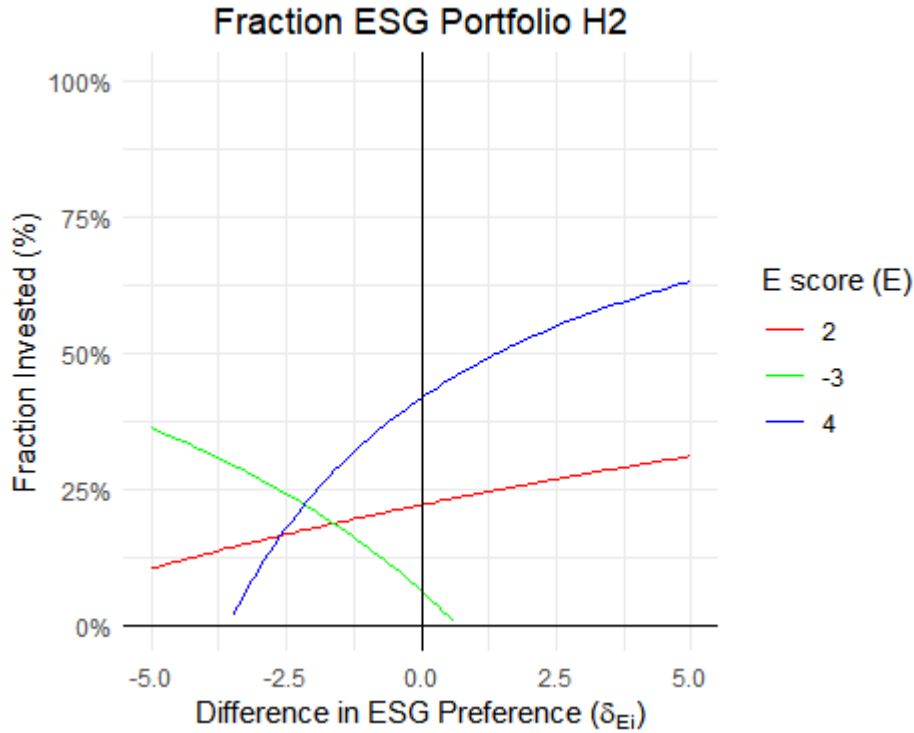


FIGURE 15 – ESG PORTFOLIO FRACTION H2

AGENT 1: $S = -2, G = 3, \delta_{Si} = -2, \delta_{Gi} = 1, a_E = 1, a_S = 2$ AND $a_G = 3$

AGENT 2: $S = 1, G = -1, \delta_{Si} = 0, \delta_{Gi} = -1, a_E = 2, a_S = 3$ AND $a_G = 4$

AGENT 3: $S = -4, G = 5, \delta_{Si} = 2, \delta_{Gi} = 3, a_E = 3, a_S = 4$ AND $a_G = 5$

Figure 15 incorporates differing levels of relative risk aversion for each ESG component. The red and blue lines continue to show positive relationships between δ_{Ei} and their investment fractions, though the slopes differ from those in the scenario of the first hypothesis. The green line still exhibits a negative slope with an even steeper decline, indicating that environmental risk aversion enhances the allocation of assets to negative ESG portfolios. This plot highlights the impact of relative risk aversion on ESG investment decisions, showing that risk tolerance influences how

differences in ESG preference translate into portfolio allocations. Notably, the relative ESG risk aversions enhance the investment fraction, as agents might be concerned about the ESG risk of their investments.

5.5.4.4 ESG Portfolio Fraction Function Third Hypothesis

The following function expresses the fraction of wealth invested in the ESG portfolio for three agents with specific ESG impact scores over an extended range of δ_i :

$$\phi_i = \frac{a^{-2}\sigma^{-1}\nu(\delta_i g)}{1+a^{-2}\sigma^{-1}\nu(\delta_i g)}$$

This function is plotted in Figure 16.

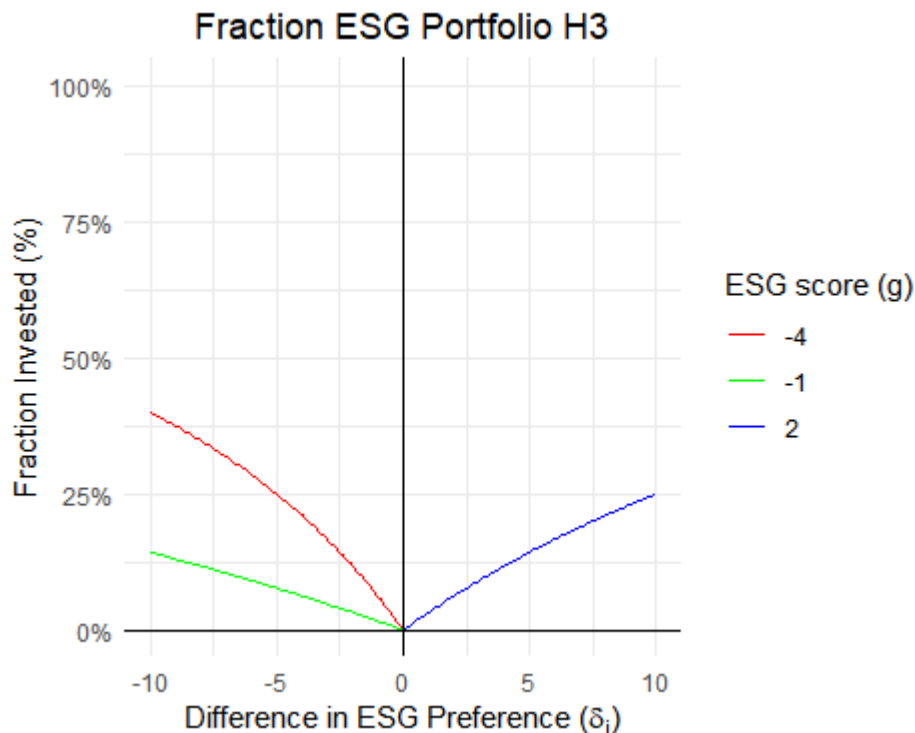


FIGURE 16 – ESG PORTFOLIO FRACTION H3

Figure 16 extends the range of δ_i to -10 to 10 and examines the investment fractions for three agents with specific ESG impact scores (g). Here, δ_i incorporates the possibility of both positive and negative ESG tastes (ESG aversion). The red and green lines have a negative ESG score, and the blue line has a positive score. The plot reveals that investment fractions of the first two agents increase as δ_i becomes more negative, indicating that these agents have a stronger negative ESG preference than the market average and thus increase their investment in a negatively scored

ESG portfolio. However, the third agent's investment fraction increases significantly with higher δ_i , indicating that he has a higher positive ESG preference than the market, increasing their investment in positively scored ESG portfolios.

In summary, these four plots collectively illustrate the nuanced and diverse ways ESG preferences relative to the market and risk aversion levels influence the fraction of total wealth invested in stocks that would be invested in ESG portfolios. The analysis shows that while a general trend of increased ESG investment with higher relative preferences exists, individual characteristics and risk tolerances introduce significant variability in investment behaviours.

6 Discussion and Limitations

6.1 Implications of the First Hypothesis

The first hypothesis posits that separating ESG preferences into distinct Environmental, Social, and Governance components significantly influences the prices of green and brown assets. The model reveals that individual preferences for E, S, and G allow for a more detailed and accurate representation of investor utility. This leads to a market where asset prices are influenced by specific ESG factors rather than a single aggregated score. This nuanced approach aligns asset prices more closely with the distinct ESG attributes of each asset.

The key results indicate that higher ESG preferences lead to lower expected returns for green assets, as investors are willing to accept reduced financial returns in exchange for higher nonpecuniary benefits. This is reflected in the lower equity premium and lower alpha for green assets with high ESG scores, implying that investors are willing to accept lower returns for assets with positive ESG impacts.

Furthermore, the model demonstrates how varying E, S, and G preferences among investors create a more segmented market. This segmentation allows for a better match between investor preferences and asset characteristics, enhancing the accuracy of the asset pricing model. By incorporating divergent ESG components, the models capture the complex interplay between financial returns and ESG factors, leading to more informed and effective investment strategies. Additionally, these preferences influence the fraction invested in stocks and the proportion invested in the ESG portfolio from the total stock investment, demonstrating the broad impact on portfolio allocation.

6.2 Implications of the Second Hypothesis

The second hypothesis explores the impact of integrating relative risk aversion linked to ESG preferences on the prices of green and brown assets. The results indicate that higher relative risk aversion towards ESG risks decreases the equity premium, reflecting lower demand for compensation as perceived ESG risks diminish with higher ESG scores. Investors with higher ESG risk aversions require lower returns to compensate for these decreased perceived risks.

The model also illustrates an increased demand for assets with positive ESG scores as ESG risk aversions rise. This shift results in higher prices for green assets and relatively lower prices for brown assets due to their higher perceived ESG risks. Higher relative ESG risk aversions further lower the alpha for green assets, reflecting investors' increased willingness to accept lower returns due to reduced perceived ESG risks.

These findings underscore the importance of considering financial and non-financial risks in investment decisions. By acknowledging the varied risk perceptions of investors, the model captures a more accurate picture of market behaviour, reflecting the complexities of modern investing. The adjustments in equity premium and investment fractions in green assets ensure that the models align better with real-world scenarios, where investors' risk preferences significantly influence their investment choices.

6.3 Implications of the Third Hypothesis

The third hypothesis examines the effect of incorporating ESG aversion into the utility function on the prices of green and brown assets. The results suggest that investors with ESG aversion prioritize higher financial returns over positive ESG impacts, favouring brown assets. This incorporation reveals that ESG aversion leads to lower prices for green assets and higher prices for brown assets, as investors seeking higher returns may opt for investments with negative ESG impacts.

The results show that investors with negative ESG preferences demand higher returns as compensation for holding green assets, leading to an increase in the alpha for these assets. Conversely, green assets with positive ESG scores experience a decline in prices due to reduced demand, while brown assets increase prices as demand rises.

This model adjustment provides a more comprehensive understanding of negative attitudes towards companies' ESG characteristics. It highlights the importance of considering both positive and negative ESG tastes in asset pricing models. By extending the range of ESG preferences to include negative values, the models capture a broader spectrum of investor behaviour, offering a more nuanced view of market dynamics. This broader perspective on investor preferences

impacts the fraction of total investment allocated to the ESG portfolio, demonstrating the wide-ranging implications of investor preferences on asset allocation and market behaviour.

6.4 Limitations

6.4.1 Assumptions used in the Models

6.4.1.1 Uniform Relative Risk Aversion

The models assume that relative risk aversions (a , a_{Fi} , a_{Ei} , a_{Si} and a_{Gi}) are constant across all agents in the market. Although risk aversion varies among individuals, this simplification is made for three reasons. First, it enhances analytical tractability, allowing more precise, better interpretable results. Second, it facilitates comparative analysis by isolating the effects of other variables on portfolio distribution and asset prices. Third, it enables the examination of financial components of the entire market and interactions between the agent and the market, such as the agent's portfolio investment weight based on the market portfolio's components and the greenness of the ESG portfolio in the market. This assumption, however, may not reflect the varying degrees of risk aversion observed among different investors due to personal circumstances, investment horizons, and market conditions.

6.4.1.2 Assumption of Homogeneous Investor Behavior

The model assumes that investors within each preference category (E, S, G) exhibit homogeneous behavior. In reality, investor preferences and behaviours are highly diverse and may not be accurately captured by such simplifications. This limitation may lead to oversimplification of complex market dynamics and investor motivations.

6.4.1.3 Market Average ESG Neutrality

Another critical assumption is that the market average ESG score is zero. This assumption implies that the market, on average, is indifferent to ESG characteristics and simplifies the model by eliminating the need to account for aggregate market bias towards or against ESG factors. However, in practice, markets could have a positive or negative bias towards ESG factors, influenced by regulatory environments, societal norms, and investor sentiment.

6.4.1.4 Normal Distribution Of Returns

The assumption that the returns of a firm's shares are typically distributed is employed for mathematical convenience. Asset returns often exhibit fat tails, skewness, and other deviations from normality, leading to underestimations of extreme market events and risks. This limitation could affect the robustness of the model in predicting real-world outcomes, particularly during periods of market stress or volatility.

6.4.1.5 Market Equilibrium Assumption

The model operates under the assumption of market equilibrium, where supply and demand are balanced. This assumption may not hold in all market conditions, particularly during significant market turbulence or structural changes. Therefore, the model's applicability to real-world scenarios with market disequilibria is limited.

6.4.1.6 Exclusion of External Factors

The model focuses on ESG preferences and risk aversions without considering other external factors influencing asset prices, such as macroeconomic conditions, geopolitical events, and technological advancements. The exclusion of these factors may result in an incomplete understanding of the determinants of asset prices.

6.4.1.7 No Transaction Costs and Market Frictions

The models assume a frictionless market without transaction costs, taxes, or other imperfections. This assumption simplifies the analysis but overlooks factors that can significantly influence investment decisions and asset prices. Real markets are subject to various frictions that can affect liquidity, trading volumes, and, ultimately, the prices of assets, especially those with high ESG scores.

6.4.1.8 Single Period and Static Analysis

The models developed in this thesis operate within a single time period framework, considering only two points in time: time 0 and time 1. This single period does not account for the dynamic nature of financial markets, where investor preferences, market conditions, and asset prices

evolve. The absence of multi-period analysis limits the understanding of long-term investment behaviours and the temporal impacts of ESG factors on asset prices.

Additionally, the models provide a static analysis of asset prices without considering dynamic factors such as time-varying risk aversion, changing market conditions, and evolving investor preferences. Financial markets are inherently dynamic, and a static approach may not fully capture the temporal aspects of investment decision-making and market behaviour.

6.4.2 ESG Risk Aversion

One notable limitation of this thesis lies in incorporating ESG risk aversions into the utility function and the resulting asset allocation equation. The currently used interpretation of relative ESG risk aversion is that agents are risk-averse to having a negative ESG impact. However, an alternative interpretation of ESG risks presents a potential misalignment with the model and plots. One could suggest that ESG risk aversion reflects the perception of ESG scores as risky due to their possible lack of objectivity or variability (see paragraph 3.3.1). Under this view, an agent perceives ESG scores as inherently uncertain, which could influence investment decisions differently.

Incorporating this interpretation would imply that higher ESG risk aversion might not uniformly increase stock investment of positive ESG stocks, as agents might seek to hedge against the perceived risks associated with fluctuating ESG scores. This nuanced perspective suggests that while the current model captures one dimension of ESG risk aversion (sensitivity to poor ESG impacts), another dimension exists where investors consider the variability and subjectivity of ESG scores risky.

Future research should focus on refining the model to accommodate both dimensions of ESG risk aversion, thereby developing a more comprehensive representation of how ESG risk perceptions influence asset allocation in practice.

6.4.3 Data Limitation

A significant limitation of this thesis is the absence of a quantitative analysis to validate the strength and fit of the models using real-world data. Due to limited time, conducting empirical tests that would provide insights into how well these theoretical models perform in practice was

impossible. Consequently, the fit and strength of the models with actual market data remain unknown.

The absence of quantitative analysis means that conclusions are theoretical and must be interpreted cautiously. Further empirical research is needed to assess these models' practical implications and robustness in different market environments.

6.5 Future Research Directions

Future research should focus on empirically validating the theoretical models proposed in this thesis. This involves collecting and analysing real-world data to test and refine the models' predictions based on empirical findings. Expanding the models to include more complex dynamics, such as time-varying risk aversion and market frictions, could provide a more comprehensive understanding of ESG investing and its impact on asset prices. Addressing these limitations will enhance the robustness and applicability of the models, providing deeper insights into the interplay between ESG factors and financial markets.

7 Conclusion

This thesis examines the impact of incorporating investors' Environmental, Social, and Governance (ESG) preferences into a general equilibrium asset pricing model on the asset prices of green and brown assets. By extending the work of Pástor et al. (2021), this research dissects the nuances of ESG preferences and explores how these preferences influence market dynamics and asset prices. The central research question is: "*What is the effect of incorporating investors' Environmental, Social, and Governance (ESG) preferences in a general equilibrium asset pricing model on the asset prices of green and brown assets?*"

Three hypotheses were tested to address this research question, each focusing on a unique aspect of ESG preferences and their implications for asset prices. The first hypothesis investigated the effect of disaggregating ESG preferences into individual components on asset prices. The findings indicate that separating these components leads to a more precise representation of investor preferences, resulting in asset prices that better reflect the distinct ESG characteristics of firms. This approach creates a differentiated market where green and brown assets are priced more accurately according to specific ESG factors rather than a single aggregated score. The increased accuracy leads to prices that could more closely reflect the true market spectrum of green and brown asset values.

The second hypothesis examined the incorporation of relative risk aversion linked to ESG preferences into the utility function. The results suggest that accounting for varying levels of ESG risk aversion among investors enhances the model's ability to capture the interplay between financial outcomes and ESG motivations. Higher relative risk aversion towards ESG risks decreases the equity premium of green assets and increases the premium of brown ones, thereby impacting the prices of both types of assets. Specifically, green assets with higher ESG scores might see increased prices due to the lower risk premium demanded by investors. In contrast, brown assets could experience relatively lower prices due to higher perceived ESG risks.

The third hypothesis explored the possibility of negative ESG tastes, or ESG aversion, and its impact on asset prices. The analysis reveals that investors with ESG aversion prioritize higher financial returns over positive ESG impacts, favouring brown assets. This leads to lower prices for

green assets and higher prices for brown assets, reflecting shifting investor preferences towards financial returns over nonpecuniary ESG benefits.

This thesis provides a comprehensive framework for understanding how diverse ESG preferences influence asset prices. The findings underscore the importance of incorporating detailed ESG factors and ESG risk aversions into asset pricing models to capture investor behavior and market dynamics more accurately. These insights are valuable for financial institutions, policymakers, and researchers, highlighting the complex interactions between ESG considerations and asset pricing. Future research should focus on empirically validating these models and developing theoretical models with less stringent assumptions to reflect real-world dynamics better.

This research contributes significantly to the existing literature by demonstrating that ESG preferences and risk aversions are crucial factors in asset pricing. By incorporating these elements, the models present a more accurate and nuanced understanding of market behaviour, essential for developing effective investment strategies and policies promoting sustainable finance.

7.1 Practical Implications

The insights from this thesis have broad implications for various types of investors, from large financial institutions to private investors. For large financial institutions such as banks and asset managers, understanding the impact of ESG preferences on asset prices is critical for optimizing portfolio allocation strategies and aligning investments with financial and ethical objectives. This research provides a framework that supports the development of models reflecting diverse ESG preferences, enhancing compliance with regulatory requirements and fostering sustainable investment practices.

Incorporating detailed ESG factors into investment decisions also enhances the risk management framework. Recognizing varying levels of risk aversion towards ESG risks helps tailor investment strategies to achieve a balanced and diversified portfolio, meeting the expectations of stakeholders who prioritize sustainable investing.

Private investors can benefit from these insights by making more informed investment decisions aligning with their values and financial goals. The results of this thesis allow investors to improve their portfolios to achieve a balanced and diversified investment strategy, meeting their sustainability priorities.

For financial institutions such as pension funds, the insights from this thesis are highly valuable, particularly in the context of EU regulations that mandate the incorporation of ESG preferences of pension plan participants. Understanding the nuanced impacts of ESG preferences on asset prices enables these institutions to optimize their portfolio allocation strategies, aligning investments with financial and ethical objectives. This thesis provides a framework that can help pension funds develop models that accurately reflect the ESG preferences of their contributors, ensuring compliance with regulatory requirements.

7.2 Policy Implications

The findings have significant policy implications, particularly for regulators and policymakers promoting sustainable investing. By providing a clearer understanding of how divergent ESG preferences and ESG risk aversions affect asset prices, this research can inform the development of policies and regulations that encourage transparency and standardization in ESG reporting.

The research shows that the ESG investment industry thrives on the dispersion of ESG preferences and risk aversions. Therefore, policies that acknowledge and support this dispersion can help foster a more dynamic and resilient ESG investment landscape. For instance, encouraging firms to disclose detailed ESG metrics can help investors with varying preferences and risk aversions make more informed decisions, stimulating the ESG investment industry.

Furthermore, the models developed in this research can guide the creation of frameworks that integrate ESG risks into financial regulations, ensuring these risks are adequately addressed and managed within the financial system. By recognizing the role of ESG risk aversions in investment decisions, regulators can develop policies that promote more resilient and sustainable financial markets. For example, regulators might consider requiring financial institutions to account for ESG risk aversions in their risk management and portfolio allocation processes, thereby enhancing the stability and sustainability of the financial system.

7.3 Research Implications

This thesis's theoretical models and findings open several avenues for future research. A critical next step involves empirical validation using real-world data to assess the models' practical applicability and effectiveness. Future research should test the models across different market environments and economic conditions to evaluate their robustness and generalizability.

Additionally, developing theoretical models with less stringent assumptions could provide a framework that accurately reflects real-world conditions. This development would involve relaxing assumptions about uniform relative risk aversion, single-period analysis, and static market dynamics. Researchers can create more dynamic models that better capture the complexities of investor behaviour and market interactions. This approach would enhance the robustness and applicability of the models, providing deeper insights into the effects of ESG preferences on asset prices.

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9 Appendices

9.1 Appendix A - List of Abbreviations

Abbreviation	Meaning
APM	Asset pricing model
CAPM	Capital Asset Pricing Model
CAR	Cumulative Abnormal Returns
CSR	Corporate Social Responsibility
ESG	Environmental, Social and Governance
EU or E.U.	European Union
FP	Financial performance
GSI	Global Sustainable Investment Alliance
MiFID II	The second Markets in Financial Instruments Directive
Multilatinas	Latin American multinationals
ROA	Return on Assets
SRI	Socially Responsible Investing
The U.S.	The United States of America

9.2 Appendix B - List of Variables

Variable	Meaning
V	The utility level of an agent
W_{0i}	The wealth level of an agent at time 0
\tilde{W}_{1i}	The wealth level of an agent at time 1
ω_i	The ratio of an agent's initial wealth to the total initial wealth of all agents
X_i	The fraction of the agent i 's wealth invested in stocks
A_i	The absolute risk aversion of an agent

A_{Fi}	The absolute financial risk aversion of an agent
A_{Ei}, A_{Si} and A_{Gi}	The absolute E, S or G risk aversion of an agent
a_i	The relative risk aversion of an agent
a_{Fi}	The relative financial risk aversion of an agent
a_{Ei}, a_{Si} and a_{Gi}	The relative E, S or G risk aversion of an agent
b_i	The nonpecuniary benefit of an agent
b_{Ei}, b_{Si} and b_{Gi}	The nonpecuniary E, S or G benefit of an agent
d_i	The ESG preference of an agent
T_{Ei}, T_{Si} and T_{Gi}	The E, S or G preference of an agent
\bar{d}	The wealth-weighted mean of the ESG preference of all agents
\bar{T}_E, \bar{T}_S and \bar{T}_G	The wealth-weighted mean of the E, S or G preference of all agents
δ_i	The difference in ESG preference between an agent and the wealth-weighted mean of the ESG preference of all agents
δ_{Ei}, δ_{Si} and δ_{Gi}	The difference in E, S or G preference between an agent and the wealth-weighted mean of the E, S or G preference of all agents
g	The ESG characteristic of a firm (g_n) or the market
E, S and G	The E, S or G characteristic of a firm (E_n, S_n and G_n) or the market
r_f	The riskless rate of return
\tilde{r}_n	The return of a firm n's shares above the riskless rate
μ	The equilibrium expected excess returns
μ_m	The market equity premium
σ	The standard deviation of the stock

σ_m^2	The market variance
w_m	The vector of weights in the market portfolio
β_m	The market beta
α	The CAPM alpha
α_g	The CAPM alpha of the ESG portfolio
ι	A vector of ones
ϕ_i	The fraction of wealth of an agent invested into the ESG portfolio
w_i	The weights within the agent's stock portfolio
w_g	The weights within an agent's ESG portfolio
g_g	The greenness of the ESG portfolio
\tilde{r}_g	The excess return on the ESG portfolio
β_g	The beta of the ESG portfolio
μ_g	The expected excess return on the ESG portfolio
σ_g^2	The variance of the ESG portfolio

9.3 Appendix C – Extended Literature Review

9.3.1 Introduction

This Appendix presents an extended literature review, comprehensively examining the relevant literature surrounding ESG preferences and asset pricing models. The extended review provides a broader and more detailed exploration compared to the literature review included in the main text of this thesis.

The research question addressed is: *“What is the effect of incorporating ESG preferences of investors in a general equilibrium asset pricing model on the asset prices of green and brown assets?”* The question is broken down into four parts.

9.3.2 Sustainable Investing and ESG

9.3.2.1 Business Ethics

The investing landscape has significantly shifted from traditional financial performance measures to a more inclusive approach considering ESG factors. This evolution is deeply rooted in the broader discussion of business ethics and its gradual integration into companies' operations and policies. The work of Werhane and Edward Freeman (Werhane & Edward Freeman, 1999) highlights the critical reassessment of the separation hypothesis, which posited a clear dividing line between ethical and business decisions. Freeman (Freeman, 1994) defines the separation hypothesis as the following theory:

The discourse of business and the discourse of ethics can be separated so that sentences like 'x is a business decision' have no moral content, and 'x is a moral decision' have no business content.

This hypothesis has been challenged (Werhane & Edward Freeman, 1999), recognising that business decisions are inherently infused with moral aspects. Werhane and Freeman laid the foundation for integrating ESG criteria into investment analysis.

The shift towards sustainable investing is not just a response to changing social norms but a reflection of a deeper understanding of corporate agency and responsibility. Werhane and Freeman argue that companies exist as moral entities within a broader social fabric, with responsibilities that extend beyond maximising shareholder value and encompassing stakeholder interests (Werhane & Edward Freeman, 1999). This perspective is in line with the Stakeholder theory, which argues that companies should conduct business while considering the impact of their actions on all stakeholders, including employees, communities, customers and the environment (Donaldson & Preston, 1995; Freeman, 1994, 2010; Mitchell et al., 1997; Wood, 1991). The definition of stakeholders is not clearly defined. Donaldson and Preston (1995) describe it as those who are instrumental to the firm and its well-being, one way or another.

Building on Werhane and Freeman's perspectives on corporate agency and responsibility, the transition to sustainable and green investing emerges as an extension of these ethical considerations. This shift is not only a response to changing societal norms but also stems from the recognition of corporations as moral entities that are obliged to respect and support the interests of their stakeholders (Werhane & Edward Freeman, 1999).

Green investing moves beyond traditional investment by valuing environmental management and sustainability as core components of long-term business success. As Townsend (2020) argues, the historical evolution and growing validation of green investment strategies reveal a landscape in which sustainability is not just a strategic advantage but a fundamental investment criterion. This approach aligns with the broader goals of social welfare and sustainability. It underscores the potential of investment practices to contribute positively to global sustainability goals (Talan & Sharma, 2019). The synthesis of more than 2,000 empirical studies further reinforces this view, illustrating that integrating ESG considerations can secure and potentially improve financial returns by addressing environmental, social, and good governance risks (Friede et al., 2015).

To dive deeper into the connection between business ethics and investing and highlight some prominent forms of impact investing, corporate social responsibility (CSR), socially responsible investing (SRI), green bonds, and ESG investing are discussed.

9.3.2.2 SRI and CSR Investing

Based on Hill et al. (2007), the discussion of corporate social responsibility (CSR) and socially responsible investing (SRI) has evolved considerably from its initial stages in the mid-20th century. Initially, CSR activities were linked to fulfilling social objectives alongside business activities, influenced by the social movements and political agendas of the 1960s and 1970s. These movements demanded a broader corporate focus on social issues. By the 1980s, attention expanded to CSR based on its impact on internal and external stakeholders (Carroll, 1998; Epstein, 1998; Frederick, 1994). The emergence of the Stakeholder theory in the mid-1980s further fine-tuned the CSR debate by highlighting the interconnection of companies and society (Freeman, 1994; Wood, 1991).

With SRI, investors align their financial goals with their social values. SRI runs parallel to the development of CSR, which originated in the labour movements of the 1940s and gained momentum with the social disruptions of the 1970s (Hill et al., 2007). The initial objective of SRI was to promote societal welfare. However, it has deviated from that perspective and focused increasingly on profitability (Revelli, 2017). This shift towards mainstreaming SRI raises concerns about eroding its ethical basis. Rivelli argues that to uphold its ethical principles, SRI must refocus on ethical considerations rather than financial gains.

With this shift towards profitability, research has also shifted towards the relationship between financial returns and social impact. Some studies find they can coexist (Hill et al., 2007b; Krumsiek, 2003; Laufer, 2003; Muñoz-Torres et al., 2004). Nevertheless, the literature presents an overall complex picture of the relationship between CSR initiatives and shareholder value, with studies producing mixed results on whether ethical and social considerations improve or decrease financial performance (Renneboog et al., 2008a; Revelli, 2017). Renneboog et al. (2008) review the literature on S and critically examine several key areas. The main findings of their study suggest a complex relationship between SRI and financial performance. They show that some research has found that SRI funds perform worse than conventional funds.

The evidence is not indisputable. This ambiguity suggests SRI investors might accept lower financial returns to achieve their social or ethical goals (Renneboog et al., 2008). The findings of Riedl and Smeets (2017) support this. They investigate why investors choose socially responsible funds by linking administrative data, survey responses and results of incentivised experiments to understand the underlying motives. Their findings suggest that investing in SRIs is driven more by social preferences than financial motives, despite recognising that SRI funds tend to have higher management costs and investors' expectations of potentially lower returns than conventional funds (Riedl & Smeets, 2017). The study shows a willingness among investors to trade financial performance for investments that align with their social values. This suggests a desire among SRI investors to give up certain economic benefits to support their social reasons.

On the other hand, Flammer (2015) finds that CSR proposals can lead to positive announcement returns and improved accounting performance. Flammer analyses shareholder proposals related to CSR that narrowly pass or fail. Using a quasi-experimental regression discontinuity design, Flammer shows that adopting CSR proposals that barely meet the vote threshold results in positive announcement returns and improved accounting performance. The study further reveals that improved labour productivity and sales growth significantly contribute to the perceived financial surplus. This evidence suggests that CSR initiatives align with ethical and social values and serve as profitable investments, potentially challenging other views on the trade-off between social responsibility and financial gain.

Revelli and Viviani's (2015) meta-analysis attempts to find a definitive answer on the relationship between CSR and financial performance. They join the findings of 85 studies involving 190 experiments. The outcomes demonstrate that CSR in stock market portfolios does not have an inherent effect of changing financial performance compared to traditional investments (Revelli & Viviani, 2015). These results indicate, however, that the divergence of findings from previous studies is primarily due to the specific SRI dimensions studied.

9.3.2.3 Green Bonds

Green bonds are unique fixed-income securities created to raise funds for projects with positive environmental impacts. Unlike traditional bonds, the funds generated from green bonds are dedicated to environmentally friendly projects, offering investors a straightforward way to support environmental sustainability while earning returns similar to conventional bonds. The Green bond market has experienced significant growth since its inception. The Climate Bonds Initiative reported that the issuance of green bonds has increased from a small beginning to over 250 billion USD worldwide in 2019, indicating a growing interest among investors and issuers (Harrison & Muething, 2021).

As the Green bond market matures, its expansion is supported by establishing standards and guidelines, such as the Green Bond Principles (Green bond Principles, 2021). These Principles are designed to improve transparency, disclosure, and credibility in the green bond market.

The most prominent question in research on green bonds has been what incentivises borrowers to use them. The signalling theory proposes that using a green bond reduces information asymmetry between the company's management and investors and provides a credible signal regarding the company's sustainability goals (Flammer, 2021). The Greenwashing theory provides reasoning that issuing green bonds is costly due to the costs of accreditation and possible higher costs of capital. Besides that, the lack of public governance in the green bond market creates a greenwashing incentive for issuing green bonds (Flammer, 2021). A third theory is the cost of capital theory, which proclaims that investors benefit from holding green assets (Fama & French, 2007). Due to the increase in utility, investors would accept lower returns, and green bonds would have lower capital costs (Fama & French, 2007). Green bonds would thus be cheaper than their conventional counterparts. Flammer (2021) examines the possible theories on the use of green

bonds. Her research looks into the stock market's response to the announcement of green bond issuances, revealing a positive reaction particularly pronounced for first-time issuers and bonds certified by third parties. Therefore, Flammer suggests that these bonds provide a credible signal of a company's environmental commitment.

Moreover, the issuance of green bonds is linked to improved environmental performance among issuers, including higher environmental ratings and reduced CO2 emissions (Flammer, 2021). Additionally, Flammer observes an increase in ownership by long-term and environmentally conscious investors after the issuance of green bonds. All these findings align with the signalling theory and contradict the greenwashing theory.

Regarding the cost of capital theory, Flammer (2021) and Tang and Zhang (2020) do not find evidence of a pricing premium for green bonds compared to conventional bonds. Tang and Zhang studied the positive impact of green bond issuance on issuers' stock prices. Concerning the issuance of green bonds, their study does not find evidence of a green premium in bond pricing.

However, Baker, Bergstresser, Serafeim, and Wurgler (2018) present a U.S. green bond market analysis focusing on how these bonds are priced. The findings indicate that green municipal bonds tend to be issued at a premium to ordinary bonds, which increases for bonds externally certified as green. Zerbib (2019) also investigates the possible green bond premium and finds a small, yet statistically significant, negative green bond premium, suggesting that, on average, green bonds yield slightly lower than conventional bonds by around two basis points. This negative premium increases with financial and lower-rated bonds (Zerbib, 2019).

The pricing behaviour found in Baker et al. (2018) and Zerbib (2019) underlines the market's valuation of the environmental attributes of green bonds, contrary to Tang and Zhang (2020) and Flammer (2021). Additionally, the ownership of green bonds, particularly those certified as green, is more concentrated, suggesting a strong preference among certain investors for environmentally beneficial investments.

Overall, research thus far has found strong arguments to support the signalling theory. However, the debate about the cost of capital theory is still undecided, with both sides finding robust empirical evidence.

The search for a significant positive relationship between the use of green bonds and financial performance has also been a prominent research subject in this domain. As stated earlier, Flammer (2021) found a positive share price reaction of green bond issuers, particularly pronounced for first-time issuers and bonds certified by third parties. Tang and Zhang (2020) also studied the positive impact of green bond issuance on issuers' stock prices. The analysis, which covers 28 countries from 2007 to 2017, indicates that firm stock prices generally react positively to announcements of green bond issuance. The study also reveals an increase in institutional ownership, particularly from domestic institutions, and significant enhancements in stock liquidity following bond issuance. These results imply that issuing green bonds can be a strategic decision for firms, benefiting current shareholders by improving firm value, attracting institutional investors, and enhancing market liquidity (Tang & Zhang, 2020).

9.3.2.4 ESG Investing and ESG Divergence

ESG investing has emerged from its predecessor, Socially Responsible Investing (SRI), by incorporating a broader range of ethical considerations (Townsend, 2020). This transition towards ESG criteria has gained considerable traction since the late 20th century, emphasising the integration of environmental stewardship, social responsibility, and governance ethics into investment decision-making (Townsend, 2020). The shift from traditional SRI practices to ESG-focused investing has resulted in substantial asset growth under management, as the Global Sustainable Investment Alliance (GSI) reported in 2022. In the five major markets, sustainable investment assets reached an impressive 21.9 trillion USD, marking a remarkable 20% increase from 2020 (Global Sustainable Investment Review 2022, 2023). This exponential growth signifies a broader recognition within the investment community regarding the significance of ESG factors in risk mitigation and positive financial opportunities. The increasing availability of ESG data has played a crucial role in facilitating this transition, enabling diverse investors to incorporate ESG considerations into their investment strategies (Global Sustainable Investment Review 2022, 2023).

Before paragraph 3.3 dives into the benefits of ESG investing, the problem of ESG divergence must not be overlooked. ESG divergence occurs when the ESG scores of companies differ amongst ESG rating agencies. Berg, Kölbel, and Rigobon (2022) address the significant ESG divergence

observed from various providers. Using data from six prominent ESG rating agencies, their study highlights substantial discrepancies, with correlations between ESG ratings ranging from 0.38 to 0.71. The authors attribute this variation primarily to differences in ‘measurement,’ accounting for 56% of the variability, as agencies use different indicators to evaluate equal ESG factors. ‘Scope’ divergence, which refers to the differences in the ESG aspects that agencies choose to consider, contributes 38% of the variability. The differences in the weighting of ESG components (‘weights’) only contribute 6%.

Next to divergence, ESG scores might be inflated based on company characteristics or a ‘rater effect’. The rater effect is the tendency of ESG rating agencies to adjust the scores of specific ESG components based on the scores for other components (Berg et al., 2022). This effect shows the substantial conflict of interest rating agencies have by being paid by the companies they are rating (Berg et al., 2022). Dremptic, Klein, and Zwergel (2020) reveal a notable positive relationship between firm size and the ESG scores issued by rating agencies. Their results indicate a potential bias in ESG scoring that benefits larger corporations, potentially due to their higher capacity to report and handle ESG-related information.

The ESG divergence and score inflation pose significant challenges in evaluating a company’s ESG performance. It can weaken companies’ motivation to enhance their ESG practices and result in a fragmented market pricing of ESG actions (Berg et al., 2022). Standardised ESG measurements would simplify the assessment of a firm’s ESG profile for investors and shareholders, provide borrowers and companies with more precise benchmarks, and encourage more focused efforts towards sustainability (Berg et al., 2022).

9.3.3 Investor Benefits of ESG Investing

This paragraph examines the benefits of increasing ESG scores for a company’s investors (commonly shareholders). The nonpecuniary benefits of ESG investing are first analysed, after which a potential positive relationship is investigated between the firm’s financial performance and insurance benefits.

9.3.3.1 Non-pecuniary Benefits of ESG

A driver behind the growth in ESG investments may be that investors obtain non-pecuniary utility from aligning their investments with their social preferences. If shareholders have ESG preferences, firms could and should pursue maximising shareholder welfare and incorporate these preferences (Hart & Zingales, 2017). Some empirical studies find evidence of non-pecuniary preferences. For instance, flows to SRI mutual funds are less volatile than flows to non-SRI funds (Bollen, 2007), and these flows are less responsive to negative past performance (Renneboog et al., 2011). These results show that investors have preferences past the conventional financial benefits. Additionally, investors in SRI funds indicate a willingness to forgo financial performance to align with their social preferences (Riedl & Smeets, 2017).

Amir and Serafeim (2018) present a thorough assessment of the reasons and methods through which investors use ESG information. They note a substantial increase in companies disclosing ESG data, from fewer than 20 in the early 1990s to nearly 9,000 by 2016. Ethical concerns drive ESG investment decisions (Amir & Serafeim, 2018). Nevertheless, the relevance of ESG to investment (financial) performance is shown to be the primary driver of ESG investments (Amir & Serafeim, 2018).

Barber et al. (2021) find that venture capital funds that aim for both financial return and social impact tend to earn lower returns than other funds. They argue that this discrepancy is due to the non-pecuniary satisfaction investors receive from investing in social impact funds.

Expanding on this work, Kräussl et al. (2024) explore investors' expectations, beliefs, and perceptions regarding ESG investing. Their review emphasises the importance of understanding investor psychology and the societal implications of investment choices (Kräussl et al., 2024). They show that nonpecuniary benefits, such as ethical alignment and social responsibility, are vital in shaping investor preferences and strategies in ESG investing (Kräussl et al., 2024).

Duchêne et al. (2022) bring a nuance to the non-pecuniary ESG benefit debate. They studied the impact of environmental externalities on portfolio decisions with an experiment involving finance professionals and students. Their findings reveal that participants accepted lower returns for investments with positive environmental impacts, showing the non-pecuniary benefits the investors had. However, participants were reluctant to take higher risks for non-pecuniary

benefits, particularly when portfolios were riskier. Duchêne et al. link these results to the implications of systematic economic downturns. This tendency to seek higher returns at the expense of non-pecuniary benefits in riskier times is supported by Bansal et al. (2022), who show a wealth-dependent preference for SRI. They find that investors' demand for SRI decreases in dire economic conditions. This decrease indicates wealth influences the degree to which investors prioritise ESG criteria.

9.3.3.2 Financial Performance Benefits of ESG

As shown by Amir and Serafeim (2018), one of the primary drivers of ESG investing is the financial performance of investments. A wide array of research has been done on the possible positive relationship between a company's financial performance (FP) and its ESG performance. According to the conventional neoclassical perspective, there would not be such a positive relationship. Engaging in ESG activities imposes additional expenses on a company (Hassel et al., 2005; Palmer et al., 1995; Semenova & Hassel, 2008), subsequently affecting its financial performance. For example, the investments required to decrease emissions or increase the efficient use of natural resources could be deemed excessive compared to traditional methods (Rassier & Earnhart, 2011; Sueyoshi & Goto, 2010). Consequently, the costs associated with transitioning to cleaner technologies become higher. When these firms opt to invest in environmental initiatives, their resources are compromised, which leads to a decline in their overall financial performance.

This classical approach has, however, been shown to be inconsistent. Friede et al. (2015) conducted a meta-review of over 2200 individual studies on the relationship between ESG and FP. They showed a positive relationship and that the positive correlations have been stable since the mid-1990s (Friede et al., 2015). Approximately 90% of studies find a non-negative ESG–FP relation, of which 79.2% yield positive findings with a central average correlation level of around 0.15 (Friede et al., 2015).

Velte (2017) builds upon the foundational work of Friede et al. (2015) by further exploring the connection between ESG factors and financial performance in the context of German-listed companies (DAX30, TecDAX, MDAX) from 2010 to 2014. The analysis of 412 firm-year observations reveals that ESG positively impacts the Return on Assets (ROA). However, no significant effect on Tobin's Q was found. Furthermore, when examining the individual

components of ESG, governance performance emerges as the most influential factor in F.P. Yoon, Lee, and Byun (2018) build upon this by investigating the ESG-FP connection in the Korean market. Their study reveals that ESG practices contribute to firm market value in Korea. However, unlike in Germany, the impact of ESG on firm value in Korea varies depending on firm characteristics and industry ESG sensitivity. The firm value enhancement is weakened for firms in environmentally sensitive sectors. Additionally, governance practices drive market value for chaebols, large family-run conglomerates in Korea. This market driver suggests that country- and sector-specific aspects and corporate governance structures influence the increase in F.P. through ESG efforts.

Despite the findings of Friede et al. (2015), Velte (2017) and Yoon, Lee, and Byun (2018), it is not all unicorns and rainbows in the ESG and financial performance relationship. Duque-Grisales and Aguilera-Caracuel (2021) show a more nuanced image of the relationship between ESG scores and the financial performance of multinationals in emerging markets. Duque-Grisales and Aguilera-Caracuel (2021) specifically look at Multilatinas, Latin American multinationals, and they focused on measuring financial performance through Return on Assets (R.O.). Surprisingly, their findings revealed a significant negative correlation between higher ESG scores and ROA, challenging the commonly observed positive association in developed markets (Duque-Grisales & Aguilera-Caracuel, 2021). Additionally, the study showed moderating effects of financial slack and geographic international diversification. They define financial slack as the level of liquid assets, such as cash, that a firm has without commitments to any specific goals, and geographic international diversification is a firm's sales distribution across different global regions. Financial slack positively influenced the relationship between ESG and financial performance, and the effect of geographic diversification on this relationship was more nuanced (Duque-Grisales & Aguilera-Caracuel, 2021).

Adding to the nuance of the ESG-FP relation is the disclosure level of ESG information. The study by Fatemi et al. (2018) uncovers a nuanced relationship between the disclosure of ESG practices and firm value. Their findings suggest that when companies openly discuss their ESG initiatives, it can have a dual effect on firm value. While transparency may weaken the perceived value of ESG strengths due to concerns about greenwashing, it can also help mitigate the negative impact of

ESG weaknesses by demonstrating accountability and commitment (Fatemi et al., 2018). This research highlights how a firm communicates about its ESG activities, which can significantly influence investor perception and market valuation. The findings of Xie et al. (2019) partly support these findings by showing that more disclosure is not always advantageous and that there is a 'bell-curve effect' of ESG disclosure. There is an ideal level of ESG disclosure that can optimise a firm's operational efficiency (Xie et al., 2019). Insufficient disclosure hinders stakeholders from accurately assessing a company's ESG efforts. Too much disclosure may burden stakeholders with irrelevant information and increase administrative costs (Xie et al., 2019). Therefore, maintaining a balanced level of disclosure provides stakeholders with valuable insights into a company's ESG practices without the downsides of signalling greenwashing, information overload or high reporting costs.

9.3.3.3 Risk Management Benefits of ESG

Besides looking at direct financial performance and non-pecuniary benefits, ESG could also positively affect investors through the hedging possibilities of ESG investments.

Before ESG activities and ESG investing grew to their current size, investors and research focused on CSR activities and investing. Godfrey et al. (2009) looked into the notion of CSR as a means of managing risk, and they propose that CSR initiatives can function as a form of 'insurance-like' safeguard for companies. CSR activities aimed at a firm's secondary stakeholders (institutional CSR activities) provided insurance of shareholder value in the face of unfavourable circumstances: the Cumulative Abnormal Returns (CAR) of firms around adverse events decreased significantly less if the firm was engaged in institutional CSR activities (Godfrey et al., 2009). The authors argue that engaging in CSR activities creates positive perceptions among supervisory authorities and other stakeholders, which can help alleviate penalties and decrease negative judgments directed towards firms during challenging situations.

More recent studies have emphasised the crucial importance of ESG factors in improving corporate risk management. Sassen et al. (2016) conducted a thorough analysis of the influence of ESG factors on market-based firm risk in Europe. Their investigation, covering an extensive panel dataset of European companies between 2002 and 2014, discovered a nuanced connection between social performance and various dimensions of firm risk. Specifically, improving social

performance is linked to decreasing total and idiosyncratic risk. Environmental performance primarily decreases idiosyncratic risk and, to a lesser extent, affects total and systematic risk in environmentally sensitive industries. The study does not find any significant influence of corporate governance performance on firm risk, indicating the intricate relationship between different ESG aspects and risk mitigation (Sassen et al., 2016).

Kumar et al. (2016) take a different approach to studying the correlation between ESG activities and risk management by using a quantitative model to assess the risk-adjusted performance of companies that incorporate ESG factors compared to those that do not. Their research reveals that ESG companies display decreased volatility in stock performance when contrasted with their non-ESG counterparts, indicating a concrete advantage in risk mitigation. Remarkably, this risk reduction does not compromise returns: Kumar et al. find that ESG companies exhibited superior returns, challenging the traditional financial belief that lower risk inevitably leads to lower returns (Kumar et al., 2016).

Verheyden, Eccles, and Feiner (2016) specifically focus on the quantitative impact of ESG screening on investment portfolios, offering valuable insights for risk management and investment strategy development. The results of their analysis show that portfolios that incorporate ESG screening not only maintain returns but also have the potential to improve risk-adjusted returns. This improvement shows again that there could be a win-win game regarding ethical considerations and financial performance.

Lastly, Moalla and Dammak (2023) present a detailed analysis of the relationship between ESG performance and stock market volatility in the context of the COVID-19 pandemic. By examining 500 U.S. companies listed on the S&P 500, the authors find that strong ESG performance is associated with decreased stock price volatility during the pandemic. This decrease in volatility highlights the additional potential of using ESG investing as a risk management tool in times of crisis.

Instead of looking at the positive side of high ESG performance on risk management, Luo and Balvers (2017) and Hoepner et al. (2023) research the negative implications of low ESG performance. Luo and Balvers (2017) find a premium for boycott risk. Boycott risk emerges because socially responsible investors reduce the demand for public firms' stocks that produce

alcohol, tobacco, and gaming (sin stocks) by avoiding them. This forces other investors, who do not exclude these stocks based on ESG criteria, to demand extra compensation for holding them in their portfolios due to the increased risk. This scenario leads to a premium for systematic investor boycott risk (Luo & Balvers, 2017). Hoepner et al. (2023) find that ESG engagement reduces firms' downside risk and their exposures to a downside risk factor. The downside risk is the market's potential undervaluation of assets or sectors, which stems from the possibility that companies with a bad ESG performance may encounter unforeseen challenges or liabilities. These factors can harm their financial performance and, consequently, their market valuation (Hoepner et al., 2023).

9.3.4 Asset Pricing Models

An asset pricing model (APM) is a theoretical model that aims to determine the expected return on an asset, thereby providing insight into the fundamental value of financial assets. The fundamental value of an asset is the natural price: a price that gives the owner a sufficient profit, dependent on several characteristics of the commodity (Smith, 1776). These models serve as elementary tools in finance, guiding researchers, investors, portfolio managers, and policymakers by outlining how different risk factors should be considered when pricing assets. At their core, APMs seek to explain why assets are priced differently and how expected returns are related to an asset's risk characteristics. By quantifying the connection between risk factors and return, APMs facilitate constructing optimal portfolios, allocating capital, and implementing risk management strategies. They incorporate various economic and financial principles, including market efficiency, investor behaviour, and equilibrium mechanisms. With those principles, APMs provide a systematic approach to evaluating investment opportunities in intricate financial markets.

The beginning of APMs lies in the work of Harry Markowitz (1952). His Modern Portfolio Theory introduced the concept of mean-variance efficiency, emphasising the importance of diversification and the trade-off between risk and return. This trade-off involves distinguishing between several types of risks: systematic risks (which cannot be eliminated through diversification and are inherent to the market) and idiosyncratic risks (which are specific to a particular asset and can be mitigated through diversification). According to Markowitz, investors

should choose portfolios not just based on expected return but also considering the variance of portfolio returns, leading to the construction of efficient portfolios that maximise returns for a given level of risk or minimise risk for a given level of return.

The Single Index Model is then introduced as a practical application of the Modern Portfolio Theory (Sharpe, 1963). Sharpe's model simplifies the complex covariance analysis required and proposes that the return on any asset can be described by its relationship with a single market index and a security-specific return. The computational requirements for portfolio optimisation are drastically reduced, allowing for analysing a significantly larger number of securities.

9.3.4.1 Capital Asset Pricing Model

Building upon Markowitz's and Sharpe's work, William Sharpe (1964) and John Lintner (1965) developed the Capital Asset Pricing Model (CAPM), a significant breakthrough in the theory of asset pricing. The CAPM theorises a linear relationship between the expected return of an investment and its beta, a measure of the investment's systematic risk relative to the market. This revolutionary model provided a simple yet powerful basis to assess how market risk should be compensated in the expected returns of assets, distinguishing between diversifiable (unsystematic) and non-diversifiable (systematic) risks. CAPM's introduction marked a critical moment in the evolution of financial theory, setting the stage for decades of research and debate (Rossi, 2016).

Black (1972) extends CAPM by exploring the implications of limited borrowing on capital markets. Black proposes a variant of the CAPM that accounts for scenarios where investors are restricted from borrowing at the risk-free rate. This variant led to a market equilibrium where the expected returns on assets are not solely explained by their market beta but also by other factors introduced by the borrowing constraints.

Another expansion of the CAPM is to incorporate time into the valuation of assets (Merton, 1973). Merton's model acknowledges that investment opportunities and rates of return are not constant over time but evolve, introducing the Intertemporal Capital Asset Pricing Model (ICAPM). ICAPM accounts for investors adjusting their portfolios in response to shifting economic conditions, significantly impacting asset prices and expected returns.

The consumption-based capital asset pricing model (CCAPM) is another extension of the CAPM that integrates consumer preferences and consumption patterns into the pricing of assets (Duffie & Zame, 1989; Lucas, 1978). Lucas (1978) introduces a model that illustrates how asset prices are determined in an exchange economy, highlighting the role of consumption in influencing prices. In his model, asset prices reflect the anticipated utility derived from future consumption, and the utility fluctuates with changes in the economic environment and the consumption preferences of individuals. Building on these ideas, Duffie and Zame (Duffie & Zame, 1989) break down the specific mathematics required for the CCAPM to work as expected. They built on Douglas Breeden's CCAPM (1979) and improved how interest rates were understood, thanks to Cox, Ingersoll, and Ross's (1985) work. Duffie and Zame's model does not assume the economic environment is predictable or follows a set pattern over time, known as the Markovian state assumption. In that way, Duffie and Zame's CCAPM could be applied to more real-world scenarios and increase the understanding of the ups and downs of asset prices that resemble the real economy more closely.

9.3.4.2 Arbitrage Pricing Theory

The Arbitrage Pricing Theory (APT) provides an alternative to the CAPM by introducing multiple factors influencing asset returns and prices based on the absence of arbitrage (Ross, 1976). Ross's theory states that returns can be predicted by the asset's sensitivity to various macroeconomic factors, not just the market's overall movement. With no arbitrage opportunities, Ross stipulates that there should be no room for quick, risk-free profits for investors. APT's innovation lies in its flexibility: it does not specify the exact factors a priori, allowing for a broader interpretation and use.

In 1982, Huberman clarified the definition of arbitrage and provided an intuitive, simplified proof that the absence of arbitrage opportunities leads to a linear relationship among asset returns and their covariances with certain factors (Huberman, 1982).

Solnik extends the APT into a global context. The International Arbitrage Pricing Theory (IAPT) addresses the complexities of international asset pricing without requiring utility-based models (Solnik, 1983). By focusing on perfect capital markets, Solnik illustrates that differences in investors' consumption tastes or the currencies in which they measure returns do not hinder the

use of APT, provided there is a common belief in a multi-factor model governing asset returns. Furthermore, he suggests that the world market portfolio will not be universally optimal due to the necessity of 'hedge' portfolios, which depend on the covariance of asset returns with state variables.

9.3.4.3 Multiple Factor Models

Following the creation of CAPM, it became clear that the model was accessible and quickly adopted by researchers, investors, and regulators alike. However, criticisms arose regarding its empirical strength and potential inherent flaws of CAPM (Blume & Friend, 1973; Roll, 1977). Fama and MacBeth tested the predictions of CAPM and examined the possibility of additional risk factors affecting asset prices (Fama & Macbeth, 1973). One of the most significant findings is the confirmation that the market portfolio's risk (bet) is a critical determinant of asset prices. However, Fama and MacBeth's work suggests that other risk factors beyond market beta could influence expected returns, pointing towards developing multi-factor asset pricing models.

Eugene F. Fama and Kenneth R. French continued the notion of multiple risk factors. Their groundbreaking work in the early 1990s, particularly their 1992 study, introduced the Three-Factor Model (Fama & French, 1992). Besides CAPM's market risk factor, the Three-Factor Model states two other factors are essential in explaining the variations in stock returns: the size of firms and the book-to-market equity ratios. Fama and French suggest that smaller firms (small size effect) and firms with high book-to-market ratios (value effect) tend to offer higher average returns than what could be predicted by their market risk alone. Their extensive empirical work demonstrated that these factors capture a sizeable portion of the variance in stock returns that CAPM could not explain, thereby providing a more robust model (Fama & French, 1993). Their subsequent studies, including those in 1995 and 1996, further examined these variances and the robustness of the Three-Factor Model, consistently finding evidence that contradicted the CAPM's predictions (Fama & French, 1995, 1996).

Fama and French's Three-Factor Model has more recently been evaluated on its global applicability, providing a nuanced perspective on whether these factors hold across different national markets or are predominantly country-specific (Griffin et al., 2002). The study demonstrates that domestic versions of the Three-Factor Model outperform a global approach in

explaining stock returns. This finding suggests that while Fama and French factors are robust, their influences are more pronounced when analysed within the context of individual countries rather than on a global scale.

The next advancement came from Carhart with his Four-Factor Model, which extends the three-factor model by incorporating momentum as an additional factor (Carhart, 1997). This additional factor is based on the observed phenomenon that stocks showing strong performance over the past year tend to continue to perform well in the near term. Carhart's analysis shows that this momentum factor is crucial for explaining the differences in mutual fund returns. His work also challenges mutual fund performance and persistence. It suggests that common factors in stock returns, combined with investment expenses and momentum strategies, largely explain the variations in mutual fund returns.

In their 2015 publication, Fama and French introduced the Five-Factor Model (Fama & French, 2015). This model builds upon the Three-Factor Model and overcomes some limitations by incorporating two additional factors: profitability (RMW, robust minus weak) and investment (CMA, conservative minus aggressive). Considering a firm's profitability and investment patterns, this model thoroughly explains stock returns. Nevertheless, the Five-Factor Model struggles with small stocks that exhibit similar return patterns to firms engaging in high investment despite low profitability. The aforementioned highlights the complexities within financial markets that the model, despite its progress, fails to comprehend completely.

The applicability of the Five-Factor Model across different global regions has also been evaluated (Fama & French, 2017). Fama and French confirm that stock returns increase with the book-to-market ratio (B/M) and profitability while negatively related to investment across most regions, with some variation. For example, while the relationship between average returns and B/M remains strong in Japan, the connections to profitability and investments are less pronounced. The Five-Factor Model is mainly successful in capturing patterns in average returns.

9.3.5 Asset Pricing Models with ESG

A more recent phenomenon in Asset Pricing Models is the inclusion of ESG aspects, including ESG factors that evolved from the empirical work on the implication of ESG risks. As described in paragraph 3.3.4, ESG performance significantly affects several company risks. These risk aspects

are combined with the insight that green assets underperform brown assets. The findings of Barber et al. underscore this (see paragraph 3.3.1), and Hong and Kacperczyk (2009) discovered that sin stocks outperform stocks of non-sin firms.

Heinkel, Kraus, and Zechner (2001) model environmental ethics directly into the financial market's equilibrium framework. They demonstrate that through exclusionary practices, ethical investing can effectively alter a firm's cost of capital by reducing the pool of potential investors for non-compliant firms. This alteration incentivises polluting firms to adopt greener practices and attract ethical investors. Their approach quantifies the impact of green investment preferences on corporate behaviour in a risk-averse equilibrium setting.

Fama and French (2007) also propose a model that relaxes the assumption that investors are solely motivated by financial returns. Besides that, they include disagreement among investors about future payoffs. Their main contributions are the following:

1. When the market includes a substantial number of investors influenced by non-financial considerations or who hold different beliefs about future asset payoffs, the differences in asset prices can become noticeable under certain circumstances.
2. The permanence of these effects is uncertain. The influence of misinformation among investors might decrease as consensus builds, and preferences rooted in individual tastes could persist indefinitely.
3. Existing anomalies within the CAPM, such as the size, value, and momentum effects, might be partly explained by the relative wealth or certain investor behaviours.

Albuquerque, Koskinen, and Zhang (2019) created a comprehensive equilibrium model where CSR activities influence a firm's systematic risk and valuation. Their model states that CSR, as an investment in product differentiation, enhances a firm's profit margins by catering to consumer preferences for socially responsible products. This strategic positioning decreases systematic risk, increasing firm value, especially in firms with high product differentiation. They also empirically analyse their model with a dataset of U.S. firms and confirm that CSR engagement is significantly associated with lower systematic risk and higher firm valuations. Moreover, these effects are increased in firms with more significant product differentiation.

Pedersen, Fitzgibbons, and Pomorski (2021) introduce a model incorporating ESG considerations into portfolio choice and asset pricing. Building upon the classic Markowitz mean-variance optimisation, their model defines an ESG-efficient frontier, offering investors a tool to maximise their portfolios' Sharpe ratio while achieving desired ESG levels. This approach reveals that assets with high ESG scores can exhibit lower expected returns due to the non-pecuniary benefits of holding socially responsible investments. However, these green assets may offer higher returns during positive ESG-related shocks, reflecting changes in consumer and investor preferences towards sustainability.

ESG criteria can also be implemented into an investor's utility function. Ahmed, Gao, and Satchell (2021) demonstrate that investors who value ESG factors alongside financial wealth can achieve enhanced utility without giving in on return performance. Pástor, Stambaugh, and Taylor (2021) continue the implementation of ESG considerations in investors' utility functions. Their model proposes that green assets have lower expected returns for two main reasons: investors derive utility from holding these assets, and these assets serve as a hedge against climate risk. Despite their lower expected returns, green assets can outperform when positive shocks to the ESG factor exist. This shock is manifested through the changes in consumers' and investors' preferences for green products and investments—this ESG factor and the market portfolio efficiently price assets within a two-factor model.

Their findings showed the implications of sustainable investing on both financial markets and real-world corporate behaviours. A notable outcome is the prediction that a substantial presence of green investors in the market can lower green firms' capital costs. These lower capital costs, in turn, incentivise firms to adopt greener practices, thereby having a tangible positive impact on the environment. The study also suggests that the size of the ESG investment industry is contingent upon the variance in investors' ESG preferences, marking a significant contribution to understanding the economic forces behind the growing trend of sustainable investing.

Moreover, the model challenges conventional notions within asset pricing by demonstrating that the ESG factor does not solely operate on risk aversion but is fundamentally driven by investor utility derived from ESG characteristics. This insight provides a comprehensive

framework to explain why investors might willingly accept lower expected financial returns in exchange for the non-pecuniary benefits of holding green assets.

Escobar-Anel (2022) explores integrating ESG considerations into portfolio optimisation by assigning risk aversion levels to green and brown assets. He employs a multivariate utility model and demonstrates that investors' different risk preferences towards green and brown stocks significantly influence optimal asset allocation. The multivariate utility model leads to an increased investment in green assets when investors are less risk-averse towards them.

Grim, Renzi-Ricci, and Madamba (2023) create a model that allows investors to simultaneously optimise for financial goals and personal ESG tastes, eliminating the need for 'one size fits all' solutions. Practical case studies demonstrate that the intensity of non-pecuniary preferences, typical financial expectations, and risk preferences significantly influence optimal portfolio choices. One illustrative case study they conducted involves varying the ESG Propensity Score, which reflects an investor's non-financial utility from investing in ESG-aligned assets. They examine scenarios where this score is adjusted, showing how it affects the allocation to ESG versus conventional funds within a portfolio. The study highlights a trade-off between pecuniary and non-pecuniary preferences, revealing that as the non-pecuniary ESG preference increases, along with specific risk aversion levels, the optimal portfolio choice shifts towards a higher allocation in ESG investments.

One problem is the divergence and inflation of ESG scores. Xu, C. Fei and W. Fei (2024) address this problem by modelling the dynamics of principal-agent relationships under Knightian uncertainty of ESG scores. Knightian uncertainty refers to a situation where the probability of outcomes is unknown, making it impossible to assign specific probabilities to the range of potential outcomes (Knight, 1921). In the context of ESG ratings, Knightian uncertainty arises due to the lack of a standard measure or prediction model for ESG performance. This uncertainty leads to unpredictable impacts on firm value and investor behaviour.

The authors create a continuous-time model that accounts for the ambiguity of investor aversion towards ESG rating uncertainties. Through stochastic calculus, they show the optimal contract dynamics under conditions where ESG ratings wield significant but unpredictable impacts on corporate behaviour. Additionally, they reveal that higher levels of uncertainty

regarding ESG ratings encourage firms towards greener initiatives. This shift, however, comes with a nuanced trade-off, impacting the expected returns for principals (investors or owners) and the incentive mechanisms for agents (managers).

Rojo-Suarez and Alonso-Conde (2024) implement an expanded version of Pástor, Stambaugh, and Taylor’s (2021) model and examine the influence of changing investor ESG preferences on the explanatory power of the market portfolio in asset pricing. Their findings show that as the market portfolio’s ‘greenness’ increases, the traditional CAPM begins to capture ESG factors. This reflects a significant shift towards sustainability in investor preferences. Specifically, their analysis of U.S. equity markets reveals that brown assets display negative ESG betas, indicating a negative price of ESG risk trending towards zero over time. This implies that efforts by public authorities to enhance corporate ESG performance could effectively lower the cost of capital, particularly during periods of decreasing corporate ESG performance.

9.4 Appendix D – Dutch Household Wealth Invested in Securities

The Central Bureau of Statistics in the Netherlands (Centraal Bureau voor de Statistiek) systematically monitors and reports on the economic conditions of households within the nation, publishing annual data concerning their financial statuses. Presented in Table 1 are the consolidated figures presenting the average household wealth spanning from 2018 to 2022. A notable observation from the data is the allocation of household assets into securities. On average, approximately 32.31% of total assets were invested in securities over this period. This statistic has been used to represent the typical proportion of assets allocated to stocks, as discussed in paragraph 5.5.

TABLE 1 – AVERAGE ASSET CHARACTERISTICS OF HOUSEHOLDS IN THE NETHERLANDS BETWEEN 2018 AND 2022

Period (x 1000 EUR)	2018	2019	2020	2021	2022
1 Assets	307.1	326.3	349.3	372.3	425.6
1.1 Financial Assets	58.9	57.9	61.4	66.6	70.2
1.1.1 Bank and Savings Accounts	40.7	41.1	42.7	47.2	49.5
1.1.2 Securities	118.6	108.3	118.3	113	108.6

1.2 Real Estate	324.8	353.2	377.7	414.9	495.9
1.3 Business Assets	78.4	82	84.6	86.5	91
1.4 Substantial Interest	858.1	903.7	977	878.7	893.2
1.5 Other Assets	131.6	130	133.1	133.5	132.3
Fraction invested in securities	38.62%	33.19%	33.87%	30.35%	25.52%
Average	32.31%				