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Comparative analysis of High- versus Low-Rated ESG Investment Strategies: Evidence from Portfolio Optimisation and Factor Exposures in the S&P 500

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Abstract

The proposed research investigates the comparative performance and risk-adjusted returns of portfolios composed of firms with high and low ESG (Environmental, Social and Governance) ratings, and the extent to which those comparisons depend on the method by which capital is allocated across the selected securities. Using historical constituents of the S&P 500 over the period 2005 to 2024, a period covering both the financial crisis of 2008 and the Covid-19 pandemic, portfolios are formed by ranking firms on their lagged aggregate ESG score and on each pillar separately and are evaluated under equal weighting and under Markowitz mean-variance optimisation. The determinants of excess returns are then examined at firm level using the Fama–French five-factor model.

The findings reveal that equally weighted portfolios of lower-rated firms delivered higher absolute returns over the period, but that this advantage reflects greater risk rather than superior performance: high- and low-rated firms show no statistically significant difference once returns are adjusted for risk. Mean-variance optimisation reverses this outcome, with higher-rated portfolios delivering better risk-adjusted performance in three of the four dimensions examined. At firm level, the negative relationship between ESG ratings and returns is attributable to the Environmental and Social pillars, whereas Governance is positively associated with returns and emerges as the dimension most consistently linked to financial performance. This relationship deteriorates further during periods of market stress, indicating that higher ratings did not protect investors during the crisis of 2008 and the Covid-19 pandemic of 2020. The study contributes to the growing literature on sustainable finance by providing empirical evidence on the performance trade-offs of ESG strategies within portfolio optimisation goals. It also supports the view that investors can integrate sustainability values into portfolio construction without compromising financial performance, provided that the allocation method and the choice of sustainability dimension are given explicit consideration.

Keywords: Sustainability, Portfolio Optimisation, Risk-Adjusted Returns, S&P 500, Factor exposures

JEL-Codes: G11, G12, Q56

Resumo

Este estudo analisa comparativamente o desempenho e os retornos ajustados ao risco de portfólios compostos por empresas com classificações ESG (Environmental, Social and Governance) elevadas e baixas, bem como a medida em que essas comparações dependem do método de alocação de capital entre os títulos selecionados. Utilizando os constituintes históricos do índice S&P 500 no período de 2005 a 2024, que abrange tanto a crise financeira de 2008 como a pandemia de Covid-19, as carteiras são construídas através da ordenação das empresas com base na sua pontuação ESG agregada desfasada e em cada pilar individualmente, sendo avaliadas sob ponderação igual e sob otimização média-variância de Markowitz. Os determinantes dos retornos excedentários são posteriormente examinados ao nível da empresa através do Modelo de Cinco Fatores de Fama-French.

Os resultados mostram que carteiras equiponderadas de empresas com classificações ESG mais baixas apresentaram retornos absolutos superiores, embora esta vantagem resulte de maior risco, desaparecendo após o ajustamento ao risco. A otimização *mean-variance* inverte este resultado, com carteiras de empresas com classificações mais elevadas a apresentarem melhor desempenho ajustado ao risco em três das quatro dimensões analisadas. Ao nível das empresas, a relação negativa entre ESG e retornos é explicada pelos pilares Ambiental e Social, enquanto Governance apresenta uma associação positiva e mais consistente com o desempenho financeiro. Em períodos de stress, esta relação deteriora-se, indicando que classificações ESG mais elevadas não protegeram os investidores durante a crise de 2008 e a pandemia Covid-19 em 2020.

O estudo contribui para a crescente literatura sobre finanças sustentáveis, fornecendo evidência empírica sobre os *trade-offs* de desempenho associados às estratégias ESG. Os resultados sustentam ainda a possibilidade de os investidores integrarem critérios de sustentabilidade sem comprometer o desempenho financeiro, desde que sejam explicitamente considerados o método de alocação e a dimensão de sustentabilidade selecionada.

Palavras-Chave: Sustentabilidade, Otimização de Portfólios, Retornos Ajustados ao Risco, *S&P500*, *Factor Exposures*

JEL-Codes: G11, G12, Q56

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1. Introduction

Over the last years, sustainable finance and ESG investments have arisen as a critical field within financial markets, driven by growing awareness of ESG issues (Wen et al., 2024) and the need for meaningful solutions to address climate change and social inequalities. Sustainable finance involves integrating environmental, social, and governance (ESG) factors into investment decisions within the financial sector, with the objective of supporting long-term economic growth while accounting for sustainability-related risks and opportunities (Eccles & Serafeim, 2013).

Within the European Union, sustainable finance has become an important component of the broader transition towards a more sustainable economy. The European Commission emphasises the role of the financial system in supporting economic growth while reducing environmental pressures, contributing to climate and environmental objectives, and appropriately managing ESG-related risks that could affect the financial system, by aiming to mitigate the risks through effective governance practices across financial and corporate entities (European Commission, 2018).

The adoption of ESG practices by firms has intensified as a result of regulatory pressures, the pursuit of reputational benefits, and heightened interest from investors in managing ESG-related risks while contributing to wide sustainability efforts (Boudt et al., 2013; M. A. Khan, 2022). In today's financial environment, where investors are increasingly committed to balancing financial performance with ethical considerations, investors, both institutional and individual, seek to understand if responsible investments can reliably contribute to portfolio returns while managing risk levels effectively (Revelli, 2017), so ESG investment analysis informs whether these SRI choices can deliver competitive returns without compromising on responsible investing values.

This research also holds broader implications for sustainable finance. As the EU and other jurisdictions push forward ambitious climate and sustainability agendas (European Commission, 2018), financial markets need innovative strategies that enable companies and investors to integrate ESG considerations effectively. If ESG portfolio strategies prove to offer a favourable risk-adjusted return profile, they could drive greater interest and adoption

of sustainable investments, encouraging financial markets to channel more capital into environmentally and socially responsible companies (M. A. Khan, 2022).

Moreover, the study could reveal insights into the specific dynamics of ESG factors in the stock market, such as how various ESG criteria are related to the performance of these instruments, specifically at the index level. This knowledge can also inform regulatory bodies and asset managers seeking to understand the role of ESG investments in the financial system, that is a constraint sometimes due to the lack of accurate ESG data (M. Chen et al., 2021).

Despite the existing research on ESG investing, the evidence on its financial performance remains inconclusive. This lack of consensus can be explained by several factors. First, results depend on how risk is considered, as differences in raw returns may simply reflect differences in volatility rather than superior risk-adjusted performance. Second, portfolio construction can influence results, since the way capital is allocated across selected securities may be as important as the criteria used to select them. Results may also vary depending on the ESG rating methodology, as providers differ in how they measure and combine sustainability characteristics. In addition, sector composition and exposure to traditional asset-pricing factors may explain part of the performance often attributed to ESG characteristics.

Another important limitation is that aggregate ESG scores combine three distinct dimensions - Environmental, Social and Governance. Relatively few studies analyse them on an individual basis, with many tending to focus solely on the aggregate ESG score. This dissertation addresses these limitations by examining ESG-based portfolio performance, the impact of mean-variance optimisation, factor and sector effects, the individual Environmental, Social and Governance pillars, and portfolio behaviour during periods of market stress. The analysis is conducted using historical S&P 500 constituents over the period from 2005 to 2024.

This dissertation examines the financial implications of incorporating ESG considerations into portfolio strategies using constituents of the S&P 500. The study combines portfolio optimisation with an empirical analysis of the relationship between ESG characteristics and stock returns through the Fama-French Five Factor Model. This dual

approach makes it possible to evaluate ESG investing from both a portfolio construction and a firm-level perspective.

First, the study applies the Markowitz mean-variance optimisation framework rather than relying on equally weighted portfolios. The optimisation procedure determines portfolio weights based on the expected return and covariance structure of the underlying securities. This allows the analysis to examine whether ESG considerations affect the efficient allocation of capital and whether ESG-oriented portfolios exhibit different return, volatility and risk-adjusted performance characteristics.

The empirical analysis is based on historical constituents of the S&P 500, allowing the investment universe to reflect changes in index membership over time rather than relying solely on current constituents, reducing potential survivorship bias.

Second, the study investigates the relationship between ESG characteristics and stock returns at the firm level. In contrast to approaches relying exclusively on an aggregate ESG score, the Environmental, Social and Governance pillars are considered separately. This distinction enables the analysis to assess whether the individual sustainability dimensions exhibit different relationships with financial performance and to identify which pillar, if any, is more strongly associated with stock returns.

The main contribution of this dissertation is to show that conclusions about ESG investment performance depend significantly on two choices that are often overlooked: how capital is allocated across selected securities and which sustainability dimension is used for selection. Regarding portfolio construction, the results show that keeping the selection rule unchanged while moving from equal weighting to mean-variance optimisation can change the relative performance of high- and low-rated portfolios. Regarding ESG measurement, the results show that the aggregate ESG score can hide important differences across its three pillars. Environmental and Social scores are negatively associated with subsequent excess returns, while the Governance score shows a positive association and provides the most consistent results across both the portfolio and regression analyses. Overall, these findings suggest that the question of whether ESG investing improves financial performance cannot be answered by relying on the aggregate ESG score alone. Instead, both portfolio construction and the individual ESG dimensions need to be considered when assessing the relationship between sustainability characteristics and financial performance.

The remainder of the dissertation is structured as follows. Chapter 2 reviews the relevant theoretical and empirical literature on sustainable finance, ESG investing, asset pricing, factor exposures, portfolio performance and ESG considerations during periods of market stress. Following this, Chapter 3 describes the data sample and empirical methodology, including the construction of the investment universe, the Markowitz mean-variance optimisation framework and the firm-level regression analysis. Chapter 4 presents the empirical results, comparing the performance and risk characteristics of the portfolio strategies and examining the relationship between the individual ESG pillars and stock returns. Chapter 5 discusses these results in relation to the literature reviewed in Chapter 2 and considers their implications for theory and for practice. To conclude, Chapter 6 summarises the main findings, discussing their implications and identifying limitations and opportunities for future research.

2. Literature Review

2.1. Sustainable finance and ESG criteria definition

Financial markets worldwide are experiencing a remarkable boost in new products and practices driven by increasing investor demand for "green" investments - those dedicated to environmental, social, and corporate governance (ESG) principles (Ahmed et al., 2021). These shifts in investor tastes that surged naturally over time can strongly influence expected returns (Rojo-Suárez & Alonso-Conde, 2024).

Sustainability in finance represents an improvement in how financial decisions are made, aiming to go beyond short-term profitability to account for long-term environmental, social, and governance (ESG) outcomes. This approach reflects the growing recognition that financial systems play a fundamental role in addressing global challenges such as climate change, social inequality, and unsustainable business practices (Wen et al., 2024).

At its core, sustainable finance integrates ESG considerations into financial processes, encouraging investments that are not only economically viable but also contribute to a more inclusive and environmentally responsible economy. According to the European Commission (2018), this alignment between finance and sustainability goals is central to fostering a transition toward a greener, more resilient economic model. It implies channeling capital into projects and companies that promote responsible use of resources, social well-being, and strong governance standards.

This multidimensional perspective on sustainability resonates with the triple bottom line principle, which highlights the interdependence between environmental integrity, social equity, and economic performance. Although the terminology may differ across institutions, the underlying objective remains consistent: to ensure that financial decisions contribute to a sustainable transformation of the economy while managing long-term risks associated with ESG factors (Ademi & Klungseth, 2022).

The environmental, social, and governance (ESG) pillars represent the main framework through which sustainability is assessed in financial decision-making. These criteria have become central in evaluating both the risk exposure and sustainability performance of economic activities and corporate entities. Environmental criteria generally

refer to issues such as climate risk mitigation, pollution prevention, energy efficiency, and the preservation of biodiversity, focusing on how companies manage their impact on the natural world and adapt to environmental challenges. Social criteria encompass themes like labour practices, diversity and inclusion, community engagement, and human rights. These are considered essential for understanding how an organisation affects - and is affected by - the society in which it operates. Finally, governance criteria relate to the internal structures and processes of organisations, including board composition, transparency, executive compensation, and accountability. Sound governance is seen as critical for ensuring the credibility and consistency of sustainability commitments (European Commission, 2018).

The application of ESG criteria has evolved significantly over time. Initially, they were used primarily for risk avoidance and ethical screening. However, their role has expanded to include more strategic functions such as portfolio optimisation, capital allocation, and performance evaluation, emphasising ESG integration as a key tool for enhancing financial resilience and aligning markets with long-term sustainability goals (Ahmed et al., 2021).

2.2. Theoretical Foundations of ESG Performance

Several theoretical frameworks have been proposed to explain why ESG characteristics may affect firm value and stock market performance. Among the most influential perspectives is stakeholder theory, introduced by Freeman (1984). Stakeholder theory challenges the traditional shareholder-centred view of the firm by arguing that corporations create value through their relationships with a broad set of stakeholders, including employees, customers, suppliers, regulators, and local communities. Firms that successfully manage these relationships may benefit from enhanced reputation, greater customer loyalty, improved employee productivity, and stronger long-term competitiveness.

The financial implications of stakeholder theory have received considerable empirical support. Edmans (2011), in a seminal study published in the Journal of Financial Economics, finds that firms appearing on Fortune's list of the "100 Best Companies to Work For in America" generated significantly higher stock returns than their peers over an extended period. These findings suggest that investments in stakeholder welfare may ultimately translate into superior shareholder value creation. Within the ESG context, environmental

care, social responsibility, and effective governance may therefore contribute to stronger financial performance by improving stakeholder relationships and reducing potential conflicts.

A complementary explanation is provided by the resource-based view of the firm. Barney (1991) argues that sustainable competitive advantages arise from resources and capabilities that are valuable, rare, difficult to imitate, and non-substitutable. ESG-related capabilities may constitute strategic intangible assets that enhance corporate performance. Investments in sustainability initiatives can strengthen corporate reputation, improve access to capital, attract talented employees, and foster innovation, thereby creating long-term competitive advantages. Consequently, firms exhibiting strong ESG performance may be better positioned to generate sustainable economic rents.

Another important perspective focuses on risk management. According to this view, ESG practices contribute to firm value primarily by reducing exposure to various forms of risk. Environmental controversies, governance failures, labour disputes, and regulatory sanctions can generate substantial financial losses and reputational damage. Firms with robust ESG frameworks may therefore be better positioned to monitor and mitigate risks before they materialize.

Godfrey et al. (2009) argue that corporate social responsibility generates reputational capital that functions as a form of insurance during adverse events. Similarly, (Giese et al., 2019) find that firms with stronger ESG characteristics tend to exhibit lower systematic risk, lower idiosyncratic risk, and reduced downside exposure. These findings suggest that ESG performance may enhance firm value through its impact on risk rather than through direct improvements in profitability.

The importance of ESG as a risk management tool became particularly evident during the COVID-19 pandemic. (Albuquerque et al., 2020) demonstrate that firms with higher ESG ratings experienced lower stock return volatility and superior operating performance during the crisis. The authors argue that strong stakeholder relationships and sustainable business practices contribute to corporate resilience during periods of economic uncertainty. These findings provide empirical support for both stakeholder theory and risk mitigation arguments.

However, not all theoretical perspectives predict a positive relationship between ESG and financial performance. Recent developments in asset pricing theory have introduced the concept of investor preferences as a key determinant of ESG valuations. (Pástor et al., 2022) propose that investors derive utility not only from financial returns but also from holding assets aligned with their social and environmental values. As demand for sustainable investments increases, capital flows into high-ESG firms, driving valuations upward and potentially reducing future expected returns.

Under this framework, ESG investments may outperform during periods when sustainability preferences strengthen, but high ESG ratings may ultimately become associated with lower expected returns due to elevated valuations. This perspective challenges the assumption that strong ESG performance necessarily translates into superior investment outcomes and highlights the importance of distinguishing between realized returns and expected returns.

Taken together, these theoretical perspectives suggest that the relationship between ESG performance and financial outcomes is inherently complex. While stakeholder theory, resource-based arguments, and risk mitigation frameworks generally predict positive effects, investor preference models imply that sustainability may become incorporated into asset prices, thereby reducing future return potential. Moreover, these mechanisms may differ across the Environmental, Social and Governance dimensions, reinforcing the importance of examining the individual pillars rather than treating ESG as a homogeneous firm characteristic. Determining which of these mechanisms dominates empirically therefore remains a central question within the ESG literature.

2.3. ESG and Modern Asset Pricing Theory

The growing integration of ESG considerations into investment decisions has increasingly attracted the attention of asset pricing researchers. Traditional financial theory explains expected returns as compensation for bearing systematic risk. The Capital Asset Pricing Model (CAPM), developed by Sharpe (1964), posits that market beta represents the sole determinant of expected returns. However, extensive empirical evidence has demonstrated that market risk alone cannot fully explain observed return patterns across securities.

This led to the development of multifactor asset pricing models, most notably the Fama and French three-factor model and its subsequent extension, the (Fama & French, 2015) five-factor model. In addition to market risk, the five-factor model incorporates size, value, profitability, and investment factors. Specifically, the profitability factor (RMW) captures the tendency of highly profitable firms to outperform less profitable firms, while the investment factor (CMA) reflects differences between firms pursuing conservative and aggressive investment policies.

The relevance of these factors for ESG investing has become increasingly apparent. Numerous studies suggest that firms with strong ESG profiles often exhibit higher profitability, stronger governance structures, lower leverage, and more conservative investment behaviour. Consequently, high-rated ESG portfolios may naturally load on profitability and investment factors, raising an important question: does ESG generate an independent return premium, or does it merely provide exposure to traditional sources of systematic return?

This debate lies at the heart of contemporary sustainable finance research. (Pedersen et al., 2021) argue that ESG investing should be analysed within a standard asset pricing framework. Their ESG-efficient frontier framework demonstrates that investors face trade-offs between sustainability objectives and financial performance, implying that ESG considerations cannot be evaluated independently from traditional risk-return considerations.

2.4. ESG portfolios, factor exposures and sector composition

While much of the early ESG literature focused on whether sustainable firms outperform their conventional counterparts, more recent research has shifted attention towards understanding the underlying drivers of ESG portfolio performance. In particular, researchers have increasingly questioned whether observed ESG-related returns represent a distinct sustainability premium or simply reflect exposure to well-established investment factors.

One of the most prominent explanations for the performance of high-rated ESG portfolios is the existence of a quality tilt. Quality investing refers to the systematic allocation of capital towards firms characterised by strong profitability, stable earnings, prudent capital

allocation, low leverage, and effective corporate governance. These firms are generally viewed as financially robust and capable of generating sustainable long-term value. Importantly, many of these characteristics overlap significantly with the dimensions evaluated by ESG rating agencies.

The relationship between quality and stock returns has been extensively documented in the finance literature. Asness et al. (2019) introduced the Quality Minus Junk (QMJ) factor and demonstrated that firms exhibiting superior quality characteristics consistently outperform lower-quality firms across multiple international markets. Their findings suggest that investors systematically undervalue high-quality businesses despite their stronger fundamentals. Given that firms with high ESG ratings frequently exhibit similar characteristics, it is possible that high-rated ESG portfolios derive part of their performance from an implicit exposure to quality-related factors rather than from sustainability considerations alone.

This argument is particularly relevant because governance represents a substantial component of most ESG rating methodologies. Firms with strong governance structures typically exhibit better board oversight, more effective managerial incentives, improved transparency and greater accountability to shareholders. These characteristics are often associated with superior financial performance and lower operational risk. Consequently, the governance component of ESG scores may overlap significantly with traditional measures of corporate quality.

A similar relationship exists between ESG characteristics and profitability. The profitability factor introduced by Fama & French (2015), commonly referred to as Robust Minus Weak (RMW), reflects the tendency of highly profitable firms to outperform firms with weaker operating performance. The importance of profitability within asset pricing was previously highlighted by Novy-Marx (2013), who demonstrates that gross profitability possesses predictive power comparable to traditional value measures. Firms with strong ESG profiles frequently exhibit higher profitability due to stronger stakeholder relationships, more effective risk management practices and greater operational efficiency. Consequently, high-rated ESG portfolios often display positive exposure to the profitability factor, raising questions regarding whether observed ESG performance reflects sustainability characteristics or profitability-related effects.

The investment factor, Conservative Minus Aggressive (CMA), provides another potential explanation for ESG portfolio performance. According to Fama & French (2015), firms pursuing conservative investment strategies tend to outperform those engaging in aggressive expansion. As a result, high-rated ESG portfolios may systematically benefit from positive exposure to the CMA factor. This relationship suggests that part of the observed performance of high-rated ESG portfolios may arise from their tendency to favour firms with more conservative corporate policies.

In addition to quality, profitability and investment exposures, high-rated ESG portfolios frequently exhibit a pronounced growth tilt. Growth stocks are typically characterised by high expected earnings growth, substantial investments in innovation and relatively high valuation multiples. Many firms operating in technology and healthcare sectors, which often receive favourable ESG assessments, exhibit these characteristics. Conversely, sectors such as energy, mining and utilities frequently receive lower ESG scores due to their environmental footprint despite often displaying value-oriented characteristics.

This creates an important challenge when evaluating ESG performance. During periods in which growth stocks outperform value stocks, high-rated ESG portfolios may generate superior returns regardless of whether sustainability itself contributes to performance. Conversely, periods characterised by strong value performance may create headwinds for ESG strategies due to their lower exposure to traditional value sectors.

Sector allocation represents another important source of ESG portfolio performance. Many ESG methodologies explicitly or implicitly penalise firms operating in environmentally sensitive industries. Consequently, high-rated ESG portfolios tend to underweight sectors such as fossil fuels, tobacco, defence and heavy industry while overweighting sectors perceived as more sustainable. These differences in sector composition can materially influence performance outcomes and may partially explain the divergent findings observed within the empirical literature.

Recent research increasingly supports the view that high-rated ESG portfolios are characterised by significant factor exposures. (Blitz & Fabozzi, 2017) argue that much of the historical performance associated with sustainable investing can be attributed to traditional factors rather than to ESG characteristics themselves. Similarly, Alessandrini and Jondeau (2021) demonstrate that high-rated ESG portfolios frequently exhibit exposures to

profitability, quality and low-risk factors, complicating attempts to isolate the independent contribution of sustainability.

The factor-exposure literature suggests that apparent ESG outperformance may not necessarily be driven by ESG characteristics themselves. If highly rated ESG portfolios are systematically exposed to factors such as quality, profitability, conservative investment behaviour, or specific sectors, their performance may instead reflect these conventional sources of return. This is particularly relevant for the pillar-level analysis. Governance characteristics are closely related to traditional measures of corporate quality, while Environmental characteristics have a less direct link to established asset-pricing factors. The Governance pillar may therefore have a different relationship with financial performance than the Environmental pillar. This provides a rationale for controlling for Fama–French factors and sector effects in the empirical analysis, as well as for examining the Environmental, Social and Governance pillars separately rather than relying only on the aggregate ESG score.

2.5. Empirical evidence on ESG performance

The growing popularity of ESG investing has generated a substantial body of empirical research examining whether sustainable investment strategies outperform non-sustainable approaches. Despite the rapid expansion of the literature, no clear consensus has emerged regarding the financial implications of ESG investing. While some studies document positive relationships between ESG performance and stock returns, others find neutral or even negative effects.

One of the most influential contributions to the literature is provided by Friede et al. (2015), who conduct a meta-analysis of more than 2,000 empirical studies examining the relationship between ESG factors and corporate financial performance. Their findings indicate that approximately 90% of studies report either positive or neutral relationships, with the majority documenting positive effects. The authors conclude that ESG integration generally does not harm financial performance and may, in many cases, contribute to improved investment outcomes.

Further support for a positive ESG-performance relationship is provided by M. Khan et al. (2016), who examined the role of material sustainability issues in corporate

performance. Using a large sample of US firms, the authors demonstrate that companies performing well on sustainability issues that are financially material to their business significantly outperform firms with weaker sustainability performance. Importantly, the study highlights that not all ESG activities generate value equally. Rather, sustainability initiatives create financial benefits when they address issues that are directly relevant to a firm's operations and competitive environment. These findings suggest that investors should focus on the quality and relevance of ESG practices rather than simply on aggregate ESG scores.

Similarly, (Edmans, 2011) finds that firms characterised by high employee satisfaction generate abnormal stock returns over extended periods. The study argues that investments in human capital create value by improving productivity, innovation and stakeholder relationships. Although employee satisfaction represents only one component of the broader ESG framework, the findings provide indirect support for the argument that sustainability-related practices can contribute positively to shareholder value.

Additional evidence supporting ESG investing is provided by studies examining portfolio-level performance. (Cesarone et al., 2022), through an extensive analysis of global equity markets, find that sustainable portfolios generally exhibit improved risk-adjusted performance relative to conventional portfolios after 2014, when the second commitment period of the Kyoto Protocol started and when the Paris COP21 agreement was signed, the ESG impact on portfolio profitability became significant on four out of five datasets. Similarly, Chen et al. (2021) report higher excess returns among socially responsible investment portfolios, suggesting that ESG integration may enhance portfolio efficiency.

Despite these positive results, a considerable body of research reports neutral relationships between ESG characteristics and financial performance. (Halbritter & Dorfleitner, 2015) examine various ESG rating methodologies and find limited evidence that ESG scores consistently explain stock returns once traditional risk factors are considered. Their findings suggest that the apparent benefits of ESG investing may be sensitive to the specific rating methodology employed and may disappear after controlling for firm characteristics.

Similarly, (Revelli & Viviani, 2015) conducted a meta-analysis of socially responsible investment performance and conclude that ESG-oriented strategies generally perform

comparably to conventional investment approaches. While their results do not indicate that investors sacrifice returns by pursuing sustainability objectives, they also provide limited support for claims of systematic ESG outperformance.

The absence of consistent evidence becomes even more apparent when examining recent studies that challenge the traditional narrative surrounding ESG investing. As previously mentioned, (Pástor et al., 2022) argue that increasing investor demand for sustainable assets may generate valuation premiums that reduce future expected returns. According to their framework, ESG assets can outperform when sustainability preferences strengthen unexpectedly, but high ESG firms may ultimately deliver lower expected returns because investors are willing to pay more for sustainable characteristics.

Recent empirical findings have increasingly supported this perspective. (Carvalho et al., 2026), analysing portfolios constructed from S&P 500 constituents over the period 2005–2024, find that portfolios composed of firms with lower ESG ratings consistently outperform portfolios containing highly rated ESG firms in terms of raw returns. Specifically, low-rated ESG portfolios generate substantially higher cumulative returns than both high-rated ESG portfolios and the broader market benchmark. However, once risk adjustments are introduced through the modified Sharpe ratio, the differences between high- and low-rated ESG portfolios become statistically insignificant. The authors conclude that while low ESG firms may offer higher nominal returns, these returns appear to compensate investors for bearing additional risk rather than representing genuine outperformance.

Evidence from portfolio optimisation studies also presents a mixed picture. Oukhouya et al. (2025) investigated the integration of ESG criteria into Markowitz portfolio optimisation within the Moroccan equity market. Comparing low-ESG rated mean-variance portfolios with high-ESG rated portfolios, the authors find that socially responsible portfolios do not outperform their counterparts. Nevertheless, they demonstrate that investors can construct portfolios that achieve attractive trade-offs between financial performance and sustainability objectives. However, their findings suggest that excessively restrictive ESG requirements may reduce diversification opportunities and potentially impair portfolio performance, whereas moderate ESG integration can be achieved without substantial financial sacrifices.

Their approach is also supported by the findings of Gallagher et al. (2014), who emphasise that funds holding high-quality stocks from various industries tend to perform better, especially during periods of market stress, due to the protective nature of quality and the benefits of diversification.

The diversity of findings reported across studies suggests that the relationship between ESG and financial performance is highly context dependent. Differences in sample periods, geographical regions, ESG measurement methodologies, portfolio construction techniques and market conditions all contribute to variations in reported results. Moreover, the increasing recognition that high-rated ESG portfolios often exhibit exposures to profitability, quality and investment factors further complicates the interpretation of empirical findings. Consequently, understanding whether ESG characteristics generate independent sources of return remains a challenging task.

Taken together, the empirical literature suggests that ESG investing cannot be characterised as universally beneficial or detrimental from a financial perspective. This lack of consensus provides a strong motivation for further research examining the mechanisms through which ESG characteristics influence portfolio performance and risk-adjusted returns.

2.6. ESG performance during periods of market stress

One of the most frequently cited arguments in favour of ESG investing is its potential to enhance portfolio resilience during periods of economic uncertainty and market turmoil. While evidence regarding the long-term return implications of ESG investing remains mixed, a growing body of research suggests that firms with strong sustainability profiles may be better equipped to withstand adverse economic conditions. Consequently, the relationship between ESG performance and corporate resilience has become an increasingly important area of investigation within sustainable finance.

The Covid-19 pandemic provided an unprecedented opportunity to evaluate these claims. As financial markets experienced extreme volatility and economic activity contracted sharply, researchers sought to determine whether ESG-oriented firms exhibited greater resilience than their conventional counterparts. One of the most influential studies in this area is conducted by Albuquerque et al. (2020), who analyse the performance of US firms

during the initial stages of the pandemic. Their findings indicate that firms with stronger ESG characteristics experienced lower stock price declines and reduced return volatility compared to firms with weaker sustainability profiles. The authors argue that ESG investments strengthen stakeholder relationships, thereby improving corporate resilience during periods of economic disruption.

Similar conclusions are reached by Broadstock et al. (2021), who investigated the performance of ESG investments during the Covid-19 crisis, covering China's CSI300 constituents. The authors find that sustainable investments demonstrated greater resilience than conventional portfolios, particularly during periods of heightened market uncertainty. Their analysis suggests that ESG characteristics may contribute to lower downside risk and facilitate faster recovery following market shocks. These findings have reinforced the perception among many investors that ESG integration can serve as an effective risk management tool.

Further evidence is provided by Ding et al. (2021), who examined the determinants of corporate resilience during the pandemic. The authors find that firms with stronger pre-existing stakeholder relationships experienced significantly better stock market performance throughout the crisis. Although their analysis is not explicitly framed within an ESG context, the findings provide indirect support for the argument that stakeholder-oriented business practices contribute to financial resilience during adverse economic conditions.

Overall, the literature suggests that ESG investments may offer certain advantages during periods of economic and financial distress, particularly through lower volatility and stronger downside protection. However, the extent to which these benefits are attributable to sustainability itself rather than to underlying factor exposures remains an open question. Following this, evaluating ESG portfolios through both traditional performance measures and multifactor asset pricing frameworks remains essential for understanding the true contribution of sustainability to investment outcomes.

2.7. Research gap

The literature reviewed in this chapter shows that the relationship between ESG characteristics and financial performance remains inconclusive and is influenced by multiple methodological choices. Reported performance depends on how risk is accounted for, how

portfolios are constructed, the ESG rating methodology used, the sector composition of the resulting portfolios, and their exposure to conventional asset-pricing factors. Another important aspect has received relatively limited attention: aggregate ESG scores combine three distinct dimensions - Environmental, Social and Governance - and these dimensions may not have the same relationship with financial performance.

Relatively few studies consider these issues together. Portfolio analyses often rely on a single weighting approach, making it difficult to distinguish the effect of portfolio allocation from that of ESG-based security selection. Firm-level analyses generally focus on aggregate ESG scores, potentially overlooking differences across the individual pillars. Similarly, studies examining ESG performance during periods of market stress often focus on a single event and a relatively short time-period. As a result, there remains a gap in understanding how these different factors interact within a common empirical structure.

This dissertation addresses this gap by examining ESG-based portfolio performance within a single framework. It compares equal weighting with mean-variance optimisation, controls for conventional risk factors and sector effects, examines the Environmental, Social and Governance pillars separately, and evaluates performance during periods of market stress. The analysis is conducted using historical S&P 500 constituents over the period from 2005 to 2024, allowing these different dimensions of ESG investment performance to be assessed consistently within the same sample.

3. Methodology and Data Collection

Based on the discussion in the previous chapter, the following research questions are proposed:

RQ1: Do portfolios composed of high-rated ESG firms outperform portfolios composed of low-rated ESG firms, in raw and in risk-adjusted terms?

RQ2: Does Markowitz mean-variance optimisation alter the relative performance of high- and low-rated ESG portfolios?

RQ3: Do high-rated ESG portfolios display greater resilience during periods of market stress?

RQ4: Which ESG pillars are associated with differences in excess returns? Do these associations persist after accounting for firm size, sector effects and the Fama–French factors?

3.1. Methodology

As previously mentioned, this study examines the relationship between corporate ESG performance and financial performance through two complementary empirical approaches: portfolio analysis and firm-level regression analysis. The methodology is primarily based on (Carvalho et al., 2026), whose analysis of S&P 500 firms over the 2005 - 2024 period provides the baseline framework for the present study. The original methodology is replicated where possible to provide a direct benchmark, while several extensions are introduced to further investigate the relationship between sustainability characteristics and stock returns.

A note on terminology is required before the empirical design is described. This dissertation compares portfolios formed from firms with high and low ESG ratings; it does not compare ESG investing with a conventional or non-ESG investment strategy. A portfolio composed of low-rated firms is not equivalent to a conventional portfolio, since it results from an active screen on sustainability characteristics rather than from the absence of such a screen. Throughout the dissertation, a high-rated portfolio denotes a portfolio composed of the firms with the highest ESG or pillar scores within the eligible universe, and

a low-rated portfolio denotes one composed of the firms with the lowest such scores. The S&P 500 index is reported alongside these portfolios as a market reference point, and is the only construction in this study that may reasonably be described as a conventional benchmark. The comparison between equal weighting and Markowitz optimisation is a separate dimension of the analysis, concerning the allocation of capital across selected securities rather than the criterion by which those securities are selected.

So, this analysis was conducted in two stages. First, firms were ranked according to their ESG performance and portfolios containing firms with relatively high and low ESG scores are constructed. The financial performance of these portfolios is subsequently evaluated using conventional return and risk measures. While the baseline specification follows the methodology employed by Carvalho et al. (2026), the present study extends the portfolio analysis by applying Markowitz mean-variance optimisation, allowing it to investigate whether optimising the allocation of capital across the selected securities alters the relative performance of high- and low-ESG investment strategies.

Second, a firm-level regression framework is employed to examine whether ESG characteristics are associated with stock returns after controlling for conventional determinants of equity performance. Following Carvalho et al. (2026), the baseline specification considers lagged aggregate ESG performance alongside market capitalisation, the Fama–French Five Factors and sector effects. The analysis is subsequently extended by decomposing the aggregate ESG score into its Environmental, Social and Governance components, enabling the analysis to determine whether the individual ESG pillars exhibit different relationships with stock returns and whether one particular sustainability dimension is primarily responsible for any association observed at the aggregate ESG level.

Together, these two approaches provide complementary perspectives on ESG investing. The portfolio analysis evaluates the implications of ESG-based security selection from an investor perspective, while the firm-level analysis investigates whether ESG characteristics may drive upwards individual stock returns after accounting for conventional risk factors and sector composition.

3.1.1. The Markowitz Model

The first empirical approach employed in this study is based on the mean-variance portfolio framework introduced by Markowitz (1952). Modern Portfolio Theory establishes

that investment decisions should not be based exclusively on the expected return and risk of individual securities, but rather on their contribution to the risk and return characteristics of the portfolio as a whole. In particular, the risk depends on both the volatility of individual securities and the covariance between their returns. Consequently, diversification across imperfectly correlated assets can reduce portfolio risk without necessarily reducing expected return.

Within this framework, the efficient frontier represents the set of portfolios offering the highest expected return for each level of risk, or equivalently the lowest level of risk for a given expected return. Portfolio optimisation therefore determines the allocation of capital across securities that provides the most favourable combination of expected return and risk subject to the imposed investment constraints.

In the present study, the Markowitz framework is applied to portfolios formed according to firms' ESG characteristics. The portfolio construction procedure follows the general approach of Carvalho et al. (2026), in which firms belonging to the S&P 500 investment universe are ranked according to their ESG performance and securities with relatively high and low ESG scores are allocated to separate portfolios. Portfolio membership is periodically updated so that changes in ESG performance and in the composition of the S&P 500 are reflected throughout the sample period.

As a baseline specification, the selected securities are combined using both an equal-weighting and cap- weighting (as a robustness check) approaches to obtain a consistent replication of Carvalho et al. (2026) study.

Even though, the use of equal weighting provides a transparent benchmark for evaluating the financial performance associated with ESG-based stock selection, it does not account for differences in expected returns, individual security risk or correlations between portfolio constituents. Assigning an identical weight to every security may therefore result in an allocation that is inefficient from a mean-variance perspective.

To address this limitation, this dissertation extends its methodology by applying Markowitz mean-variance optimisation to the securities selected for each ESG portfolio. It is important to mention that the optimisation procedure does not alter the underlying ESG-based security selection rule. Instead, the same set of securities used in the equally weighted portfolio is retained, while the allocation of capital across those securities is optimised

according to their expected returns and variance-covariance structure. This approach makes it possible to isolate the effect of portfolio weighting from the effect of ESG-based stock selection.

Returns are measured throughout in logarithmic form. The daily return on security i is defined as:

$$r_t = \ln\left(\frac{P_t}{P_{t-1}}\right) \tag{3.1.}$$

where P denotes the adjusted closing price, which accounts for dividends and corporate actions. The annual return is obtained as the sum of daily logarithmic returns over the year:

$$r_n = \sum_{t=1}^{N_n} r_t \tag{3.2.}$$

where N denotes the number of trading days in year n.

The optimisation inputs are estimated exclusively from daily returns observed during the calendar year preceding portfolio formation. For a portfolio formed in year n, the vector of expected annual returns and the annualised variance-covariance matrix are estimated as:

$$\boldsymbol{\mu} = 252 \cdot \frac{1}{D}\sum_{t=1}^{D} \mathbf{r}_t \qquad \Sigma = 252 \cdot \frac{1}{D-1}\sum_{t=1}^{D}(\mathbf{r}_t - \bar{\mathbf{r}})\,(\mathbf{r}_t - \bar{\mathbf{r}})' \tag{3.3.}$$

where D denotes the number of trading days in year n-1. A security is admitted to the estimation only if it is observed on at least 90% of those trading days, since the covariance structure cannot be reliably estimated from substantially incomplete series.

Two objective functions are considered, each corresponding to a different point on the efficient frontier (Oukhouya et al., 2025), with w denoting the vector of portfolio weights, μ the vector of expected returns, Σ the variance-covariance matrix and 1 a vector of units. The first specification identifies the global minimum variance portfolio:

$$\min_{\mathbf{w}} \mathbf{w}'\Sigma\mathbf{w} \quad \text{s.t.} \quad \mathbf{w}'\mathbf{1} = 1, \;\; 0 \le w_i \le c \tag{3.4.}$$

The second identifies the tangency portfolio, which maximises the Sharpe ratio and therefore represents the point at which a line drawn from the risk-free rate is tangent to the efficient frontier:

$$\max_{\mathbf{w}} \frac{\mathbf{w}'\boldsymbol{\mu}-r_f}{\sqrt{\mathbf{w}'\Sigma\mathbf{w}}} \quad \text{s.t.} \quad \mathbf{w}'\mathbf{1} = 1, \;\; 0 \leq w_i \leq c \tag{3.5.}$$

Both problems are convex quadratic programmes and are solved following the implementation described by (Oukhouya et al., 2025).

Two constraints are imposed. The first, requiring the weights to sum to unity and to be non-negative, ensures that the portfolio is fully invested and prohibits short selling, consistent with the formulation of Oukhouya et al. (2025). The second is an upper bound, denoted by c in the equation, on the weight attributable to any individual security. This constraint is imposed because unconstrained mean-variance optimisation is known to generate highly concentrated allocations when the input parameters are estimated from finite samples (Michaud (1989); Green & Hollifield (1992)). Weight constraints of this kind have been shown to function as a form of statistical shrinkage, improving out-of-sample performance precisely because they limit the influence of estimation error (Jagannathan & Ma, 2003).

The primary specification adopts a value of c equal to 0.10. This cap is adopted as an economically grounded reference point rather than an arbitrary numerical choice. The sensitivity of the results to this threshold is examined in Chapter 4, where the analysis is repeated for values of c of 0.10, 0.20, 0.30 and 1.00, the latest corresponding to the unconstrained case.

The distinction between the two specifications is not merely technical. The global minimum variance portfolio requires only the variance-covariance matrix, whereas the tangency portfolio additionally requires the vector of expected returns.

The optimisation is performed using information available prior to portfolio formation and the portfolios are annually rebalanced. Expected returns and the variance-covariance matrix are also estimated from historical return observations available at the corresponding portfolio formation date. Portfolio weights are subsequently applied to future returns.

The performance of the ESG-based portfolios is assessed using both absolute and risk-adjusted measures. Specifically, the analysis considers cumulative returns, annualised returns, annualised volatility, the Sharpe ratio and maximum drawdown. The Sharpe ratio is calculated as:

Portfolio returns are computed as the weighted sum of constituent daily logarithmic returns:

$$R_{p,t} = \sum_{i=1}^{n} w_i \, r_{i,t} \tag{3.6.}$$

Where a constituent does not report a return on a given day, its weight is excluded and the remaining weights are proportionally rescaled, so that the portfolio represents a fully invested position at all times. The Sharpe ratio is computed on annual excess returns as:

$$SR_p = \frac{E(R_p) - r_f}{\sigma_p} \tag{3.7.}$$

where the denominator is the standard deviation of the differential return rather than of the raw return, following the definition restated by Sharpe (1994). The risk-free rate is subtracted year by year rather than as a period average.

Comparing the equally weighted portfolios with their Markowitz-optimised counterparts allows the analysis to distinguish between the effect of ESG-based security selection and the effect of portfolio allocation. If the relative performance of high- and low-rated ESG portfolios changes substantially following optimisation, this would suggest that conclusions regarding ESG investment performance are sensitive to the weighting methodology employed. Conversely, similar results across both weighting approaches would indicate that the observed performance differences are primarily associated with the underlying security selection rather than the allocation procedure.

3.1.2. Fama-French Five Factor Model

The second empirical approach employed in this study is the Fama–French Five-Factor Model. While the portfolio analysis evaluates whether investment strategies constructed according to ESG characteristics exhibit different risk-return profiles, the regression analysis aims to determine whether ESG performance is associated with individual stock returns after controlling for conventional determinants of equity performance.

The Fama–French Five-Factor Model extends the traditional Capital Asset Pricing Model by recognising that differences in stock returns may be associated with several systematic firm characteristics beyond market risk. In addition to the market risk premium, the model incorporates factors related to firm size, value, profitability and investment behaviour (Fama & French, 2015). The five factors considered are the market risk premium

(MRP), representing the excess return of the market over the risk-free rate; SMB (Small Minus Big), capturing the return differential between small- and large-capitalisation firms; HML (High Minus Low), representing the return differential between high and low book-to-market firms; RMW (Robust Minus Weak), capturing differences between firms with robust and weak operating profitability; and CMA (Conservative Minus Aggressive), representing the return differential between firms characterised by conservative and aggressive investment policies.

Controlling for these factors is particularly relevant in the context of ESG investing. As discussed in Chapter 2, firms with stronger ESG characteristics may systematically differ from lower-rated firms in terms of size, profitability, growth characteristics and investment behaviour. Consequently, an observed relationship between ESG scores and stock returns may reflect exposures to conventional asset-pricing factors rather than an independent association with sustainability performance. The Fama–French framework therefore provides a means of controlling for these established sources of return variation.

$$r_{i,n} - r_{f,n} = \alpha + \gamma ESG_{i,n-1} + \delta(logMktCap)_{i,n} + \sum_{j=1}^{5} \beta_j F_{j,n} + \lambda_i + \varepsilon_{i,n} \qquad (3.8.)$$

Where $r_{i,n}$ represents the return of firm i in year n, $r_{f,n}$ is the risk-free rate, $ESG_{i,n-1}$ denotes the lagged ESG aggregate score, (log Market Cap) is the firm's market capitalisation, and $F_{j,n}$ stands for the five Fama–French factors - market risk premium (MRP), size (SMB), value (HML), profitability (RMW), and investment (CMA). These were retrieved from the Kenneth French Data Library, as was the risk-free rate. Sector fixed effects are denoted by λ_i. While α and βj are parameters, $\varepsilon_{i,n}$ is the error term.

The ESG factors are lagged by one year in order to mitigate potential endogeneity between contemporaneous ESG ratings and stock returns. This ensures that the ESG information used to explain returns in year n corresponds to sustainability performance measured in the preceding year, as the authors did.

The principal extension to this specification consists of decomposing the aggregate ESG score into its three underlying pillars. Rather than assuming that the Environmental, Social and Governance dimensions exhibit the same relationship with financial performance, the extended specification estimates their associations with stock returns separately:

$$r_{i,n} - r_{f,n} = \alpha + \gamma_E E_{i,n-1} + \gamma_S S_{i,n-1} + \gamma_G G_{i,n-1} + \delta(\log MktCap)_{i,n} + \sum_{j=1}^{5} \beta_j F_{j,n} + \lambda_i + \varepsilon_{i,n}$$

(3.9.)

where E, S and G denote the lagged Environmental, Social and Governance scores respectively, and the remaining terms are defined as above. This specification makes it possible to determine whether one particular sustainability dimension is responsible for any association observed at the aggregate level.

A further specification examines whether the relationship between ESG ratings and returns differs during periods of market stress. An indicator variable MT is defined, taking the value one in 2008 and 2020 and zero otherwise, and is interacted with the lagged aggregate ESG score:

$$r_{i,n} - r_{f,n} = \alpha + \gamma ESG_{i,n-1} + \phi\left(MT_n \times ESG_{i,n-1}\right) + \delta(\log MktCap)_{i,n} + \sum_{j=1}^{5} \beta_j F_{j,n} + \lambda_i + \varepsilon_{i,n}$$

(3.10.)

The coefficient on the interaction term measures the change in the ESG-return relationship during periods of market disruption. A negative estimate would indicate that higher-rated firms perform relatively worse when markets fall, contrary to the downside protection frequently attributed to sustainable investments in the literature reviewed in Section 2.6.

Firm size is additionally controlled for through the logarithm of market capitalisation. Although size is already indirectly represented through the SMB factor, the inclusion of firm-level market capitalisation follows Carvalho et al. (2026) and controls directly for differences in the scale of individual firms.

Sector effects are incorporated to account for systematic differences in both ESG ratings and financial performance across industries. This is particularly important given the potential sector tilt associated with ESG investing. For example, firms operating in sectors that experienced particularly strong financial performance during the sample period may simultaneously exhibit relatively high ESG scores. Without controlling for sector composition, part of the resulting return differential could therefore be incorrectly attributed to ESG performance.

The baseline model is estimated using both pooled Ordinary Least Squares (OLS) and a fixed-effects (FE) specification. The use of fixed effects allows the analysis to control for unobserved firm-specific characteristics that remain relatively constant over time and may simultaneously influence ESG performance and stock returns. Standard errors are double grouped by firm and year to account for potential dependence both across observations belonging to the same company and across firms within the same year, consistent with the original study.

Additionally, in the original study, the coefficient on lagged ESG is negative and statistically significant under both pooled OLS and fixed-effects estimation, suggesting a negative association between aggregate ESG ratings and subsequent excess returns after controlling for firm size, conventional risk factors and sector effects. The purpose of the present replication is not to assume that the same result will necessarily be obtained, but rather to establish a comparable benchmark before introducing the principal regression extension of this dissertation. The principal extension to the baseline regression consists of decomposing the aggregate ESG score into its three underlying pillars. Rather than assuming that Environmental, Social and Governance characteristics exhibit the same relationship with financial performance, the extended specification estimates their associations with stock returns separately.

Risk-adjusted performance: the modified Sharpe ratio

The Sharpe ratio defined in Equation (3.7) assumes that returns are adequately described by their first two moments. Equity returns, however, are typically characterised by negative skewness and excess kurtosis, so that the standard deviation understates the risk of adverse outcomes. The analysis is therefore supplemented with the modified Sharpe ratio, which replaces the standard deviation in the denominator with a modified Value-at-Risk following the methodology of Gregoriou & Gueyie (2003), Eling (2008) and Ardia & Boudt (2015):

$$MSR_i = \frac{r_{i,n} - r_{f,n}}{-\left\{r_{i,n} + \sigma_{i,n}\left[z_\alpha + (z_\alpha^2 - 1)\frac{Sk_{i,n}}{6} + (z_\alpha^3 - 3z_\alpha)\frac{Ku_{i,n}}{24} - (2z_\alpha^3 - 5z_\alpha)\frac{Sk_{i,n}^2}{36}\right]\right\}} \quad (3.11.)$$

where $r_{i,n}$ denotes the annual return of asset i in year n, $r_{f,n}$ is the risk-free rate, $\sigma_{i,n}$ the corresponding annualised standard deviation computed from daily returns, $Sk_{i,n}$ the

skewness, $Ku_{i,n}$ the excess kurtosis, and z_α is the α-quantile of the standard normal distribution. Following Carvalho et al. (2026), α is set to 1%.

In implementing this measure, the annual return is taken to be the logarithmic return defined in Equation (3.2), consistent with the return measurement convention adopted throughout.

Differences in mean modified Sharpe ratios between the top-rated and bottom-rated subsamples are assessed using Welch's t-test, which accommodates unequal variances and unequal sample sizes:

$$t = \frac{\overline{MSR_1} - \overline{MSR_2}}{\left(\frac{\sigma_1^2}{N_1} + \frac{\sigma_2^2}{N_2}\right)^{0.5}} \tag{3.12.}$$

where subscript 1 denotes the top-rated tier and subscript 2 the bottom-rated tier, σ^2 is the variance and N the number of observations in each subsample.

3.2. Portfolio construction

Portfolio formation (Table 1) follows the same procedure for the aggregate ESG score and for each of the Environmental, Social and Governance pillars. At the beginning of each annual portfolio formation period, firms belonging to the historical S&P 500 investment universe are ranked according to their lagged score for the relevant ESG dimension. Following Carvalho et al. (2026), the 25 highest-rated and 25 lowest-rated eligible firms are allocated to the corresponding top- and bottom-rated portfolios, respectively, resulting in eight portfolios in each year. Only firms for which the relevant ESG or pillar score is available are included in the ranking, and the portfolios are rebalanced annually to reflect changes in both ESG performance and S&P 500 membership. The same selection threshold is applied across all four sustainability dimensions.

The portfolios are not sector neutral. Consequently, differences in sector composition arise naturally from the ESG-based selection process and are examined separately in the analysis. To prevent look-ahead bias, portfolio membership is determined using sustainability information available prior to the corresponding return period. For the Environmental pillar, observations with a score of exactly zero are excluded from the bottom-rated portfolio because, as discussed in the following section, these values may

reflect non-disclosure rather than measured environmental performance. Portfolio returns are calculated using daily constituent returns.

Table 1 - Portfolio construction rules

Element	Explanation
Eligible universe	Historical S&P 500 constituents with an annual return, a market capitalisation and a score on the relevant dimension
Ranking variable	Lagged aggregate ESG score, or lagged Environmental, Social or Governance pillar score
Portfolio size	25 securities
Portfolios formed	8 portfolios: high- and low-rated on each of four dimensions
Rebalancing	Annual, using scores observed at the end of the previous year
Weighting, baseline	Equal, at 1/25 per security
Weighting, optimised	Markowitz mean-variance: global minimum variance and maximum Sharpe
Optimisation constraints	No short-selling, fully invested, maximum 10% per security
Estimation window	Daily returns of the preceding calendar year
Eligibility for optimisation	At least 90 per cent of the preceding year's trading days observed
Exclusion rule	Environmental score of exactly zero excluded from the low-rated Environmental portfolio only

3.3. Data Collection

The empirical analysis focuses on firms included in the S&P 500 over the study period. Rather than defining the historical investment universe using the current constituents of the index, historical S&P 500 membership is reconstructed for each year. This approach ensures that firms entering and leaving the index over time are appropriately represented and reduces the survivorship bias that would arise from retrospectively applying today's constituent list to historical periods.

The S&P 500 Index, created in 1957, includes approximately 500 large-cap U.S. companies selected based on criteria such as liquidity, market capitalisation, and sector

representation (S&P Dow Jones Indices, 2024). It is broadly regarded as the main benchmark of U.S. stock market performance.

The sample period broadly follows Carvalho et al. (2026), who examines S&P 500 firms between 2005 and 2024. Historical constituent information is obtained from Datastream/LSEG, while firm-level financial and ESG information is retrieved from LSEG.

For each firm, the dataset contains security identifiers, historical stock prices, ESG scores, Environmental scores, Social scores, Governance scores, market capitalisation and sector classification.

Stock-price information is used to calculate returns for both the portfolio and regression analyses. Daily observations are used for portfolio performance calculations, while the firm-level regression is conducted at a lower frequency consistent with the empirical specification adopted from Carvalho et al. (2026). ESG variables are lagged relative to stock returns in order to ensure that portfolio formation and regression analysis rely only on sustainability information available prior to the corresponding return period.

The Fama–French Five Factors, market excess return (MKT), size (SMB), value (HML), profitability (RMW) and investment (CMA) are obtained from the Kenneth R. French Data Library, following the approach used by Carvalho et al. (2026), based on a sample of 32 developed U.S. portfolios comprising stock constituents of the S&P 500. These factors are used in the firm-level regressions to control for systematic sources of equity returns. The risk-free rate is additionally used when calculating excess returns and risk-adjusted portfolio performance and is proxied by yields on 3-month U.S. Treasury bills. The latest is widely used as a proxy on the literature.

Table 2 summarises the variables used in the empirical analysis and their respective definitions:

Table 2 - Definition of variables

Element	Explanation
Excess return	Annual logarithmic return less the risk-free rate. The annual return is the sum of daily logarithmic returns over the year (Equations 3.1 and 3.2)
ESG score	Aggregate LSEG ESG score, lagged one year (scale 0 to 100)
Environmental score	Environmental pillar score, lagged one year, (scale 0 to 100)
Social score	Social pillar score, lagged one year, (scale 0 to 100)
Governance score	Governance pillar score, lagged one year, (scale 0 to 100)
Log market capitalisation	Natural logarithm of average annual market capitalisation
MRP	Market risk premium: excess return of the market over the risk-free rate
SMB	Small minus big: return differential between small- and large-capitalisation firms
HML	High minus low: return differential between high and low book-to-market firms
RMW	Robust minus weak: return differential between firms with robust and weak operating profitability
CMA	Conservative minus aggressive: return differential between firms with conservative and aggressive investment policies
GICS sector	Sector classification under the Global Industry Classification Standard (11 sectors)
MT	Market turmoil indicator, equal to 1 in 2008 and 2020 and 0 otherwise
Risk-free rate	Yield on 3-month U.S. Treasury bills

3.4. Descriptive statistics

Table 3.A. - Sample composition

	Value
Firm-year observations	9,616
Distinct firms	828
Period	2005–2024
Years	20
GICS sectors	11
Average firms per year	481
Observations with no environmental disclosure	1,009 (10.5%)

Table 3.B. - ESG scores

Variable	N	Mean	Median	Std. dev.	Min	Max
ESG score	9,616	53.36	55.27	19.82	1.90	95.16
Environmental score	9,616	46.07	49.60	28.45	0.00	98.55
Social score	9,616	55.35	56.89	21.89	0.26	98.12
Governance score	9,616	57.44	59.85	21.49	0.70	99.73

Table 3.C. - Coverage by year

Year	Firms	Mean ESG	Mean E	Mean S	Mean G	Missing Env. Disclosure	%
2005	272	32.78	15.59	33.14	48.95	126.00	46.32%
2006	440	34.75	19.87	34.92	49.11	177.00	40.23%
2007	470	35.69	20.98	38.35	46.53	168.00	35.74%
2008	483	41.66	30.30	44.75	48.71	100.00	20.70%
2009	492	45.08	34.98	47.88	51.35	80.00	16.26%
2010	497	47.32	39.65	49.62	52.42	71.00	14.29%
2011	493	49.12	43.09	51.33	53.09	49.00	9.94%
2012	494	50.75	44.87	52.33	55.10	35.00	7.09%
2013	491	51.04	46.19	52.07	54.94	33.00	6.72%
2014	497	51.17	45.68	52.69	54.94	36.00	7.24%
2015	494	51.93	46.96	53.34	54.64	29.00	5.87%
2016	498	54.76	48.64	55.81	59.12	27.00	5.42%
2017	499	57.08	50.40	58.70	60.64	23.00	4.61%
2018	502	59.15	52.54	61.34	61.84	23.00	4.58%
2019	498	61.16	55.68	63.18	62.99	18.00	3.61%
2020	496	63.35	59.68	65.77	63.30	8.00	1.61%
2021	496	65.58	59.63	68.39	65.36	6.00	1.21%
2022	501	67.03	61.67	69.60	66.79	0.00	0.00%
2023	501	67.86	63.65	70.58	66.79	0.00	0.00%
2024	502	66.54	62.11	69.07	66.16	0.00	0.00%

Table 3 reports descriptive statistics for the firm-year panel underlying the empirical analysis. The investment universe from which portfolios are formed comprises 9,619 firm-year observations, and the panel used for the firm-level regression comprises 9,616 observations after the exclusion of firm-years lacking a complete set of explanatory variables. Both correspond to 828 distinct companies across 11 GICS sectors over the period 2005–2024. The mean annual excess return across the panel is 3.76%.

The mean aggregate ESG score is 53.36. At pillar level the Social and Governance means are 55.35 and 57.44 respectively. The Environmental mean of 46.07 is materially lower than the 52.66 reported by Carvalho et al. (2026). This divergence is attributable to the treatment of non-disclosure in the LSEG methodology, discussed below; when firm-years

for which no environmental data have been disclosed are excluded, the mean rises to 51.47 and the discrepancy substantially disappears.

Coverage of ESG ratings is incomplete in the earliest years of the sample. In 2005 scores are available for 272 of the approximately 500 index constituents (54.4%), rising to 88.0% in 2006, 94.0% in 2007 and exceeding 96% from 2008 onwards. This pattern reflects the progressive expansion of ESG data coverage by commercial providers rather than any characteristic of the sample construction and implies that portfolios formed in the first two years of the period are selected from a smaller eligible universe than those formed subsequently.

A specific feature of the LSEG explicates this. The Environmental Pillar Score is recorded as exactly zero in 1,748 of the raw observations retrieved, corresponding to 406 distinct securities, whereas the aggregate ESG score and the Social and Governance pillar scores are never observed at exactly zero. Within the portfolio panel this affects 1,009 firm-years, or approximately 10.5% of the sample, and the incidence is heavily concentrated in the earlier years, declining from 126 observations in 2005 and 177 in 2006 to fewer than 10 by 2021. This pattern is consistent with the documented practice of recording non-disclosure of environmental data as a scoreable zero rather than as a missing value, with the consequence that firms which have not yet reported are treated as though they had performed at the minimum of the scale (Sahin et al., 2023). Because such observations reflect the absence of disclosure rather than environmental performance, firms with an Environmental score of exactly zero are excluded from the bottom-rated Environmental portfolio. The treatment of these observations in the regression analysis is addressed in robustness checks.

4. Results

This chapter presents the empirical findings. Section 4.1 describes the performance and risk characteristics of the 8 ESG-based portfolios by replicating the methodology of Carvalho et al. (2026), which establishes the baseline against which the optimisation results are assessed. Section 4.2 addresses the RQ1 and RQ2 by applying Markowitz mean-variance optimisation to the same securities and analysing the performance of these portfolios. Section 4.3 addresses the RQ3, examining the behaviour of the ESG-return relationship during periods of market stress. Section 4.4 addresses the RQ4 through the firm-level regression and its decomposition into the three ESG pillars. Section 4.5 illustrates the robustness checks and Section 4.6 summarises the findings.

4.1. Portfolio performance and risk characteristics

Table 4 - Performance of top- and bottom-ranked ESG portfolios, 2005–2024

Year	Top-ESG	Bottom-ESG	Top-Env.	Bottom-Env.	Top-Social	Bottom-Social	Top-Gov.	Bottom-Gov.	S&P500
2005	9.3%	5.2%	1.7%	2.8%	9.6%	9.0%	9.9%	(3.5%)	4.3%
2006	12.0%	12.4%	9.3%	22.9%	15.8%	5.6%	16.7%	8.5%	13.5%
2007	8.9%	(10.4%)	2.0%	(8.7%)	8.6%	(13.8%)	14.8%	(9.6%)	2.8%
2008	(43.8%)	(41.8%)	(54.3%)	(53.3%)	(42.1%)	(46.4%)	(37.3%)	(47.7%)	(39.3%)
2009	44.1%	45.6%	35.6%	53.3%	45.0%	47.2%	15.1%	40.6%	25.0%
2010	11.4%	21.2%	8.1%	20.2%	11.5%	29.6%	14.0%	15.5%	13.2%
2011	(3.0%)	0.2%	(10.6%)	(0.2%)	(0.8%)	1.7%	(3.0%)	(7.6%)	(0.5%)
2012	9.0%	16.1%	13.7%	22.7%	12.6%	13.8%	8.8%	17.7%	14.1%
2013	22.4%	46.4%	32.5%	27.3%	27.0%	40.6%	20.8%	49.0%	30.5%
2014	12.6%	8.2%	11.2%	0.0%	13.5%	2.8%	15.6%	8.6%	11.0%
2015	(9.6%)	0.4%	(8.7%)	(5.5%)	(6.4%)	(4.6%)	(9.5%)	9.5%	(0.2%)
2016	11.1%	1.3%	17.5%	(1.5%)	6.3%	5.0%	25.5%	(1.2%)	9.1%
2017	23.5%	6.2%	18.0%	18.2%	12.0%	15.4%	17.5%	6.9%	20.5%
2018	(16.8%)	(4.8%)	(14.5%)	(4.3%)	(5.9%)	(11.3%)	(14.9%)	(6.0%)	(6.0%)
2019	25.7%	27.6%	22.5%	35.2%	21.7%	23.0%	31.4%	21.0%	29.1%
2020	(3.4%)	16.5%	(2.5%)	16.4%	7.9%	11.6%	14.9%	21.4%	21.5%
2021	23.2%	21.9%	27.0%	28.7%	20.2%	29.1%	31.7%	16.6%	28.4%
2022	(13.4%)	(10.3%)	(14.9%)	(15.0%)	(8.3%)	(15.2%)	(7.7%)	(19.7%)	(20.1%)
2023	6.2%	30.7%	6.3%	27.3%	(3.8%)	22.6%	9.6%	16.0%	28.6%
2024	0.6%	25.2%	2.8%	32.1%	5.0%	12.9%	14.5%	18.7%	25.5%
AR	6.5%	10.9%	5.1%	10.9%	7.5%	8.9%	9.4%	7.7%	10.5%
TR	150.5%	448.3%	73.9%	371.5%	218.6%	261.9%	366.7%	190.9%	449.8%

Table 4 reports the annual and cumulative returns of the eight ESG-based portfolios alongside the S&P 500 benchmark. Portfolios composed of lower-rated firms outperform their higher-rated counterparts in absolute terms across three of the four sustainability dimensions. The bottom-rated aggregate ESG portfolio delivers a cumulative return of

448.3% over the period, against 150.5% for the top-rated portfolio, and the ordering is comparable for the Environmental and Social dimensions, where the bottom-rated portfolios return 371.5% and 261.9% against 73.9% and 218.6%, respectively.

Governance is the exception. The top-rated Governance portfolio returns 366.7% against 190.9% for the bottom-rated portfolio, reversing the pattern observed elsewhere. It is the only dimension in which higher ratings are associated with superior absolute performance.

The comparison with the market is unfavourable to ESG-based selection. The reconstructed S&P 500 returns 449.8% over the period, and only two of the eight portfolios exceed it in annualised terms: Bottom-ESG by 0.35 p.p. and Bottom-Environmental by 0.39 p.p.; The top-rated aggregate ESG portfolio underperforms the benchmark by 4.04 p.p. annually and the top-rated Environmental portfolio by 5.40 p.p.. On the evidence of absolute returns alone, a strategy of selecting the highest-rated firms in the index would have delivered materially less than a passive holding of the index itself.

Dispersion across the portfolios is greatest during periods of market disruption. In 2008 annual returns range from (37.3%) for the top-rated Governance portfolio to (54.3%) for the top-rated Environmental portfolio, a spread of 17 p.p.. In 2020, the range is wider still in relative terms, from (3.4%) for the top-rated ESG portfolio to +21.4% for the bottom-rated Governance portfolio.

Table 5 - Descriptive statistics of portfolio returns

Portfolio	Mean	Median	Std. Dev	Min	Max	Positive years	Sharpe ratio	Max. drawdown
Top-ESG	6.5%	9.1%	18.8%	(43.8%)	44.1%	14	0.258	(61.7%)
Bottom-ESG	10.9%	10.3%	20.4%	(41.8%)	46.4%	16	0.452	(63.4%)
Top-Env.	5.1%	7.2%	20.2%	(54.3%)	35.6%	14	0.173	(72.4%)
Bottom-Env.	10.9%	17.3%	23.3%	(53.3%)	53.3%	13	0.402	(71.4%)
Top-Social	7.5%	9.1%	17.2%	(42.1%)	45.0%	14	0.335	(57.8%)
Bottom-Social	8.9%	10.3%	21.3%	(46.4%)	47.2%	15	0.338	(69.3%)
Top-Gov.	9.4%	14.6%	16.6%	(37.3%)	31.7%	15	0.470	(55.2%)
Bottom-Gov.	7.7%	9.1%	20.9%	(47.7%)	49.0%	13	0.288	(66.5%)

Table 5 reports the distribution of annual returns together with risk and risk-adjusted performance measures. A consistent pattern emerges: bottom-rated portfolios exhibit higher annualised volatility than their top-rated counterparts in all four dimensions, and deeper maximum drawdowns in three of the four. Annualised volatility among the top-rated

portfolios ranges from 16.61% to 20.20%, against 20.43% to 23.27% among the bottom-rated portfolios. The top-rated Governance portfolio is the least volatile of the eight at 16.61% and records the lowest maximum drawdown at (55.2%).

This pattern qualifies the return evidence presented above. The superior absolute returns of the lower-rated portfolios are accompanied by systematically greater risk, and the appropriate question is therefore whether the additional return compensates for the additional risk assumed.

Table 6 - Raw return differential versus risk-adjusted differential

Dimension	Top mean	Bottom mean	Return gap (p.p.)	Top Sharpe	Bottom Sharpe	Sharpe gap
ESG	6.5%	10.9%	+4.39	0.258	0.452	+0.193
Environmental	5.1%	10.9%	+5.79	0.173	0.402	+0.229
Social	7.5%	8.9%	+1.46	0.335	0.338	+0.003
Governance	9.4%	7.7%	-1.69	0.470	0.288	-0.181

Table 6 addresses this directly by setting the raw return differential against the differential in Sharpe ratios. For the Social dimension the effect is particularly evident: a raw return advantage of 1.46 p.p. in favor of the bottom-rated portfolio translates into a Sharpe ratio differential of 0.003, so that the entire return advantage is accounted for by the additional volatility. For the aggregate ESG and Environmental dimensions the advantage is attenuated but persists, falling from 4.39 and 5.79 p.p. in raw terms to Sharpe differentials of 0.193 and 0.229. For Governance the top-rated portfolio is superior on both measures.

The top-rated Governance portfolio records the highest Sharpe ratio of the eight at 0.470, and the top-rated Environmental portfolio the lowest at 0.173. This is the first of several results in which the Governance and Environmental dimensions behave in opposing directions.

Table 7 - Mean annual modified Sharpe ratios, top versus bottom tiers

Component	Subsample	Mean	Std. Dev	N	Welch's *t*	DF	*p*-value
ESG	Top 25	0.4806	1.5530	499	-1.1416	876.01	0.2539
	Bottom 25	0.6201	2.2275	492			
Environmental	Top 25	0.4553	1.6780	496	-0.7772	948.15	0.4372
	Bottom 25	0.5474	2.0279	491			
Social	Top 25	0.4904	1.6998	497	-0.2681	942.81	0.7887
	Bottom 25	0.5231	2.1157	494			
Governance	Top 25	0.5048	1.4989	494	+0.7249	978.55	0.4687
	Bottom 25	0.4336	1.5779	490			

Table 7 supplements the analysis with the modified Sharpe ratio defined in Equation (3.11), computed for each firm in each year and pooled by rating tier.

The mean modified Sharpe ratios of the top- and bottom-rated tiers are statistically insignificant in every dimension. The differences between tiers are small relative to their cross-sectional dispersion, and Welch's t-test returns p-values of 0.2539 for the aggregate ESG score, 0.4372 for Environmental, 0.7887 for Social and 0.4687 for Governance. At firm level, therefore, ESG ratings do not identify companies that are more efficient in converting risk into return.

The sign of the Governance comparison differs from the other three: the top-rated Governance tier records a higher mean modified Sharpe ratio than its bottom-rated counterpart, whereas the reverse holds for the aggregate score and for the Environmental and Social pillars. The difference is not statistically significant, and no inference is drawn from it in isolation, but it is consistent with the pattern identified so far.

4.2. The Markowitz Model Results

This section addresses the first and second research questions. The ESG-based selection rule is held constant and only the allocation of capital across the selected securities is varied, so that any difference in performance is attributable to the weighting scheme rather than to the screening criterion at a first stage.

Table 8 - Concentration and turnover of the optimised portfolios

Portfolio	Effective N (GMV)	Effective N (Max-Sharpe)	Turnover: equal weight	Turnover: GMV	Turnover: Max-Sharpe
Top-ESG	11.8	10.5	35.4%	53.3%	65.0%
Bottom-ESG	11.7	10.7	42.5%	57.9%	82.9%
Top-Env.	11.6	11.9	33.3%	50.5%	64.3%
Bottom-Env.	11.7	11.3	52.2%	69.2%	82.3%
Top-Social	11.7	10.5	31.4%	52.2%	68.4%
Bottom-Social	11.7	10.7	39.4%	58.8%	79.3%
Top-Gov.	11.6	11.3	53.3%	60.8%	72.4%
Bottom-Gov.	11.8	11.3	48.6%	62.9%	80.9%
Mean	11.7	11	42.0%	58.2%	74.4%

Table 8 reports the concentration and turnover of the optimised portfolios. Under the base methodology each portfolio holds 25 securities and the effective number of holdings is 25 by construction. Under the global minimum variance specification this falls to between 11.6 and 11.8, and under the maximum Sharpe specification to between 10.5 and 11.9. The weight constraint binds in the majority of portfolio-years under both specifications, indicating that the optimiser would concentrate the allocation further were it permitted to do so.

Table 9 - Allocation of the Top-ESG portfolio, 2024, example

Company	**Equal weight**	**GMV**	**Max Sharpe**
Linde	4.00%	9.81%	20.00%
Microsoft	4.00%	6.23%	20.00%
S&P Global	4.00%	0.00%	20.00%
Waste Management	4.00%	13.32%	20.00%
Carnival	4.00%	0.00%	20.00%
Johnson & Johnson	4.00%	17.44%	0.00%
Hershey	4.00%	14.58%	0.00%
Cisco Systems	4.00%	9.22%	0.00%
Altria Group	4.00%	5.92%	0.00%
Philip Morris Intl.	4.00%	5.21%	0.00%
Newmont	4.00%	4.60%	0.00%
Dow	4.00%	3.42%	0.00%
Interpublic Group	4.00%	3.29%	0.00%
Becton Dickinson	4.00%	3.19%	0.00%
CVS Health	4.00%	2.79%	0.00%
Citigroup	4.00%	0.55%	0.00%
Bank of New York Mellon	4.00%	0.42%	0.00%
Remaining 8 securities	4.00% each	0.00%	0.00%
Effective N	25.0	9.6	5.0

Table 9 illustrates this tendency for a single portfolio and year, reporting the allocation of the top-rated ESG portfolio in 2024 under all three weighting schemes. At the 20% constraint used for illustration, the maximum Sharpe specification allocates the entire portfolio to 5 securities, each at the ceiling weight, and assigns nothing to the remaining 20. The global minimum variance specification is better diversified, holding 14 securities with a maximum weight of 17.44%. This behaviour is a known property of long-only mean-variance optimisation under estimated inputs (Green & Hollifield, 1992) rather than a feature of the present implementation, and it is the principal justification for the weight constraint presented in Section 3.

Turnover is reported against the equally weighted portfolio, which isolates the trading generated by the allocation procedure from that generated by the selection rule. Annual changes in ESG-based membership produce a mean turnover of 42.0% before any optimisation is applied. The minimum variance specification adds 16.2 p.p. and the maximum Sharpe specification 32.4 p.p.. Approximately 70% of the turnover associated with the minimum variance portfolios is therefore attributable to the underlying selection rule, a distinction that would remain undetected if the optimised figures were reported in isolation.

Table 10 - Effect of the allocation rule on risk-adjusted performance

Portfolio	Vol.: EW	Vol.: GMV	Sharpe: EW	Sharpe: GMV	Sharpe: Max Sharpe	Δ GMV	Δ Max Sharpe
Top-ESG	18.75%	15.45%	0.258	0.189	0.386	-0.070	+0.128
Bottom-ESG	20.43%	16.33%	0.452	0.346	0.314	-0.106	-0.138
Top-Env.	20.20%	14.41%	0.173	0.268	0.301	+0.095	+0.128
Bottom-Env.	23.27%	18.44%	0.402	0.468	0.336	+0.066	-0.066
Top-Social	17.18%	12.46%	0.335	0.267	0.328	-0.068	-0.007
Bottom-Social	21.33%	17.97%	0.338	0.262	0.243	-0.076	-0.094
Top-Gov.	16.61%	13.40%	0.47	0.331	0.561	-0.138	+0.091
Bottom-Gov.	20.94%	19.70%	0.288	0.197	0.165	-0.092	-0.123

Table 11 - Difference in Sharpe ratios, top minus bottom

Dimension	Equal weight	Max Sharpe (10%)	Max Sharpe (20%)	Max Sharpe (30%)	Max Sharpe (unconstrained)
ESG	-0.193	+0.073	+0.360	+0.315	+0.287
Environmental	-0.229	-0.035	-0.068	-0.077	-0.119
Social	-0.003	+0.084	+0.267	+0.247	+0.217
Governance	+0.181	+0.396	+0.577	+0.637	+0.576

Table 10 presents the Sharpe ratios under the three weighting schemes together with the change relative to equal weighting. A systematic asymmetry emerges: under maximum Sharpe optimisation, all four bottom-rated portfolios record a lower Sharpe ratio, while three of the four top-rated portfolios record an improvement. The top-rated ESG portfolio improves by 0.128, the top-rated Environmental portfolio by 0.128 and the top-rated Governance portfolio by 0.091, while the bottom-rated portfolios deteriorate by between 0.066 and 0.138.

Table 11 reports the difference in Sharpe ratios between top- and bottom-rated portfolios under each weighting scheme. Under equal weighting the differential is negative for the aggregate ESG, Environmental and Social dimensions, indicating that lower-rated portfolios are superior on a risk-adjusted basis. Under maximum Sharpe optimisation it

becomes positive for the aggregate ESG, Social and Governance dimensions. The Environmental dimension is the sole exception, remaining negative under all the tested scenarios.

An economic interpretation follows directly the risk evidence presented on Table 5. Bottom-rated portfolios are composed of more volatile securities, whose expected returns and covariances are therefore estimated with greater error over a one-year window. The resulting weights generalize less successfully compared to the subsequent investment period. Top-rated portfolios, composed of larger and more stable firms, yield estimates that hold up better out of sample. On this reading, optimisation does not improve high-rated ESG portfolios as such; rather, it is less damaged by estimation error when applied to them.

The minimum variance specification behaves differently, and the distinction should be stated precisely. It reduces annualized volatility in every portfolio, by between 1.24 and 5.79 p.p., but reduces returns proportionally more, with the consequence that the Sharpe ratio improves in only 2 of the 8 portfolios, both of them Environmental. Minimum variance optimisation therefore delivers the risk reduction it is designed to deliver without delivering superior risk-adjusted performance - a finding consistent with the evidence of Oikonomou et al. (2018) that the choice of optimisation technique materially affects the outcome of socially responsible investment strategies.

Table 12 - Tests of the difference in risk-adjusted performance

Methodology	Dimension	Difference (MSR)	Welch *p*	Years top ahead
Carvalho's methodology	ESG	+0.985	0.7335	7/20
	Environmental	-0.074	0.8592	6/20
	Social	-0.071	0.8150	9/20
	Governance	+0.531	0.1517	11/20
GMV	ESG	-0.365	0.4432	6/20
	Environmental	-3.743	0.2627	7/20
	Social	-0.315	0.3778	11/20
	Governance	-19.255	0.3381	11/20
Max Sharpe	ESG	+0.366	0.3415	11/20
	Environmental	+0.067	0.8932	8/20
	Social	+0.038	0.8762	13/20
	Governance	+0.834	0.0671*	14/20

Table 12 presents the results of testing the difference in risk-adjusted performance between top- and bottom-rated portfolios under each weighting scheme, computed on annual modified Sharpe ratios. It shows that under maximum Sharpe optimisation the top-

tier portfolios exhibit higher mean modified Sharpe ratios than the bottom-tier ones across all four dimensions, reversing the pattern observed under equal weighting. For example, the top-rated Governance portfolio has an average modified Sharpe ratio of 1.2753 against 0.4412 for its bottom-rated counterpart, and is superior in 14/20 years. However, these differences are not statistically significant at conventional levels ($p = 0.1517$ for Governance and $p = 0.3415$ for the aggregate ESG score), indicating that although higher-rated portfolios appear to deliver better risk-adjusted outcomes once optimised, the improvement cannot be reliably distinguished from sampling variation over a twenty-year horizon.

The only comparison to attain significance is the Governance differential under Max Sharpe methodology, at the 10% level (+0.8341, $p = 0.0671$), where the top-rated portfolio is superior in eleven of the twenty years. It is notable that Governance is the dimension closest to significance under both equal weighted and Max Sharpe weighting schemes.

Figure 1 - Efficient frontiers of high- and low-rated ESG portfolios

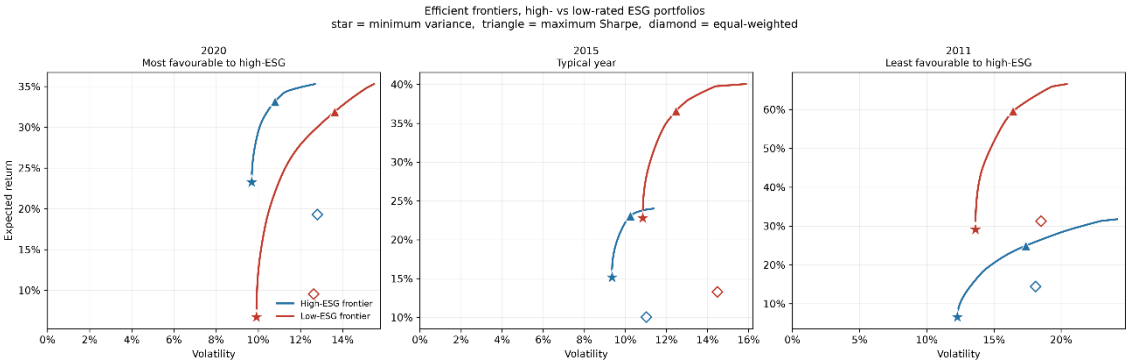
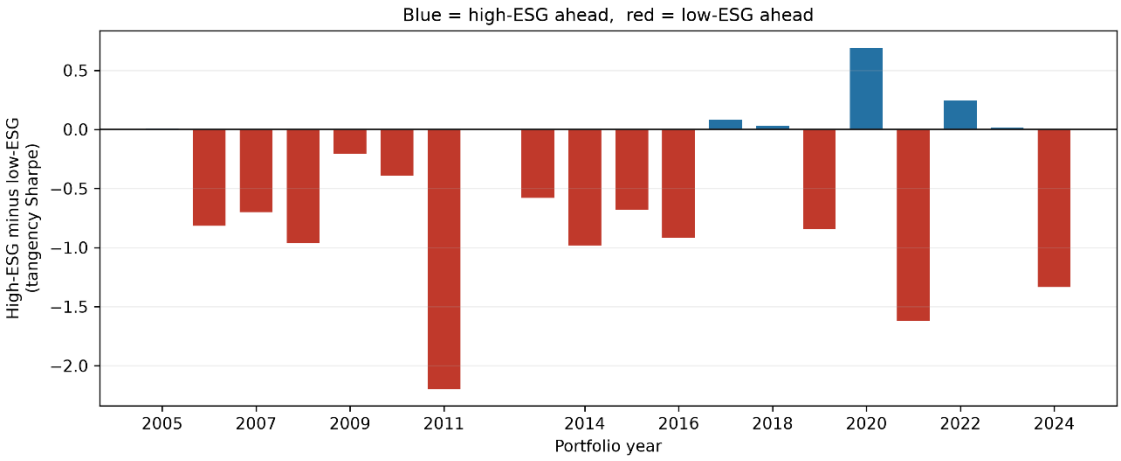


Figure 2 - Difference in tangency Sharpe ratios by year



Figures 1 and 2 present the efficient frontiers underlying the optimisation. Because the frontiers are constructed from parameters estimated over the preceding calendar year, they represent the investment opportunity set as it appeared at the point of portfolio formation rather than as it was subsequently realized.

Across the nineteen years for which frontiers can be estimated, the frontier of the top-rated ESG portfolio dominates that of the bottom-rated portfolio in only six years, and the mean difference in tangency Sharpe ratios is -0.587 in favor of the bottom-rated portfolio. In expectation, therefore, the lower-rated portfolios offered the superior risk-return trade-off in the majority of years.

The divergence between the ex ante and ex post evidence is not a contradiction but the central mechanism of this chapter. The frontiers indicate that lower-rated portfolios should perform better, because their estimated expected returns are higher; the realised results indicate that they do not. The difference between the two is estimation error. The elevated expected returns attributed to lower-rated securities on the basis of the preceding year's data are not sustained in the subsequent period, whereas the more modest estimates attached to higher-rated securities prove more durable. Figure 2 reports the difference in tangency Sharpe ratios year by year and demonstrates that the relationship varies considerably, so that no single year should be treated as representative.

In conclusion, and with respect to the first and second research questions, the incorporation of ESG considerations into portfolio optimisation does improve portfolio performance, but conditionally. Under mean-variance optimisation the higher-rated portfolios deliver superior risk-adjusted performance in three of the four dimensions examined, significantly so for Governance, whereas under equal weighting the ordering is reversed. Conclusions regarding the financial performance of ESG-based strategies are therefore sensitive to the method by which capital is allocated across the selected securities, and not only to the selection criterion itself.

4.3. ESG performance during periods of market stress

This section addresses the third research question. Table 13 states the specification in which the lagged ESG score is interacted with an indicator variable taking the value one in 2008 and 2020, the two years of pronounced market disruption within the sample period.

Table 13 - Behaviour during periods of market stress

	Pooled OLS	**Fixed effects (FE)**
Variables	Coefficient	Coefficient
Lagged ESG	-0.0011***	-0.0014***
	(0.0003)	(0.0005)
MT x *Lagged ESG*	-0.0024***	-0.0024***
	(0.0004)	(0.0004)
LogMarketCap	+0.0338***	+0.0140
	(0.0095)	(0.0221)
MRP	+1.0452***	+1.0392***
CMA	+0.5167***	+0.5121***
Sector fixed effects	Yes	-
Number of observations	9,616	9,616
Adjusted R-squared	0.3414	0.2801
Total effect in crisis years	-0.0035	-0.0038

The interaction term is -0.0024 and significant at the 1% level, and with a t-statistic of -5.465, with the estimate not changing under fixed-effects estimation. In non-crisis years the coefficient on the lagged ESG score is -0.0011; during crisis years the total effect is -0.0035 under pooled estimation and -0.0038 under fixed effects. The negative relationship between ESG ratings and excess returns is therefore more than three times stronger during periods of market stress than during normal conditions.

With respect to the third research question, higher-rated ESG portfolios do exhibit different sensitivity to market downturns, and in the opposite direction to that anticipated by much of the literature reviewed in Section 2.6. Higher ESG ratings did not provide downside protection during the disruptions of 2008 and 2020; firms with higher ratings performed materially worse during these episodes than during normal market conditions.

Table 14 - Pillar decomposition of the crisis effect

Variables	**Pooled OLS**	***p*-value**	**Fixed effects**	***p*-value**	**VIF**
Lagged Environmental	-0.0008***	0.0065	-0.0010***	0.0011	2.68
Lagged Social	-0.0006*	0.0594	-0.0009*	0.0531	2.71
Lagged Governance	+0.0004	0.1145	+0.0007**	0.0280	1.33
MT x *Environmental*	+0.0002	0.7673	+0.0004	0.5694	8.41
MT x *Social*	-0.0014	0.2972	-0.0015	0.2806	13.05
MT x *Governance*	-0.0013	0.1812	-0.0014	0.1322	6.91

An attempt was made to determine whether any individual pillar accounts for this effect, by interacting with each pillar separately with the crisis indicator. The results are

reported in Table 14 and none of the three interaction terms attains statistical significance. The explanation is evident from the diagnostic statistics: the variance inflation factors (VIF) for the three interaction terms are 8.41, 13.05 and 6.91, all above the conventional threshold of five. The crisis indicator is active in only two of the twenty years, and within those years the three pillar scores are highly correlated, with the consequence that the interaction terms are not separately identified. The aggregate crisis effect is therefore firmly established, but it cannot be attributed to a specific sustainability dimension on the available data. This is reported as a limitation of the decomposition rather than as evidence that no pillar-specific effect exists. It is noted that the direct Governance coefficient attains 5% significance under fixed-effects estimation within this specification, at +0.0007, reinforcing the pattern previously identified.

4.4. Fama-French Five Factor Model Results

This section addresses the fourth research question, examining whether ESG characteristics are associated with stock returns after controlling for conventional determinants of equity performance, and which sustainability dimension is responsible for any association observed.

Table 15 - Determinants of excess returns: baseline specification

	Pooled OLS	**Fixed effects (FE)**
Variables	Coefficient	Coefficient
Lagged ESG	-0.0014***	-0.0017***
	(0.0004)	(0.0006)
LogMarketCap	+0.0314***	+0.0044
	(0.0098)	(0.0228)
MRP	+1.1329***	+1.1314***
	(0.0840)	(0.0886)
SMB	-0.1576	-0.2163
	(0.2135)	(0.2274)
HML	+0.0654	+0.0738
	(0.0971)	(0.0888)
RMW	-0.1489	-0.1281
	(0.1386)	(0.1411)
CMA	+0.4632***	+0.4682***
	(0.1520)	(0.1627)
Constant	-0.7935***	-
	(0.2270)	-
Sector fixed effects	Yes	-
Firm fixed effects	No	Yes
Number of observations	9,616	9,616
Adjusted R-squared	0.3343	0.2782

Table 15 reports the estimation of Equation (3.8). The coefficient on the lagged aggregate ESG score is −0.0014 under pooled ordinary least squares and −0.0017 under firm fixed effects, both significant at the 1% level. After controlling for firm size, the five Fama–French factors and sector fixed effects, a higher aggregate ESG rating is therefore associated with lower subsequent excess returns. In economic terms, a 10-point increase in the aggregate score is associated with a reduction in annual excess return of approximately 1.4 p.p. under pooled estimation and 1.7 p.p. under fixed effects.

The control variables behave as expected in most respects. The market risk premium carries a coefficient close to 1 and the investment factor is positive and significant at the 1%

level in both specifications. Firm size is positive and significant under pooled estimation but not under fixed effects, which is expected given that the within-firm variation in market capitalisation over a 20-year period is limited relative to the cross-sectional variation. The size, value and profitability factors are not statistically significant in either specification. The adjusted R-squared is 0.3343 under pooled estimation and 0.2782 under fixed effects.

Table 16 - Determinants of excess returns: ESG pillars disaggregation

	Pooled OLS	**Fixed effects (FE)**
Variables	Coefficient	Coefficient
Lagged Environmental	-0.0008***	-0.0010***
	(0.0002)	(0.0003)
Lagged Social	-0.0007**	-0.0010*
	(0.0003)	(0.0005)
Lagged Governance	+0.0002	+0.0005*
	(0.0002)	(0.0003)
LogMarketCap	+0.0350***	+0.0101
	(0.0105)	(0.0227)
Fama-French Factors	Yes	Yes
Sector fixed effects	Yes	-
Firm fixed effects	No	Yes
Number of observations	9,616	9,616
Adjusted R-squared	0.3363	0.2809

Table 16 reports the principal extension of the regression analysis, in which the aggregate score is replaced by its three constituent pillars. The results demonstrate that the aggregate coefficient conceals substantial heterogeneity.

The Environmental coefficient is -0.0008 under pooled estimation and -0.0010 under fixed effects, significant at the 1% level in both. The Social coefficient is -0.0007 and -0.0010 respectively, significant at the 5% and 10% levels. The Governance coefficient is positive in both specifications, at +0.0002 and +0.0005, attaining significance at the 10% level under fixed effects.

The negative relationship identified at the aggregate level is therefore attributable to the Environmental and Social dimensions. The Governance dimension exhibits the opposite association. With respect to RQ4, the ESG factors that drive differences in returns are the Environmental and Social pillars, and their effect is negative; the Governance pillar drives in the opposite direction. These relationships persist after controlling for sector effects, firm size and the five Fama–French factors.

This finding corresponds to the portfolio evidence presented earlier in this chapter. The top-rated Governance portfolio recorded the highest Sharpe ratio of the eight portfolios; Governance was the only dimension for which the effect of optimisation on risk-adjusted performance attained statistical significance and it is the only pillar carrying a positive coefficient in the firm-level regression. That three methodologically independent approaches converge on the same dimension provides considerably stronger evidence than any of them would in isolation.

The correlation structure of the ratings offers a plausible explanation. The Environmental and Social pillars are correlated at 0.753, whereas Governance correlates with them at only 0.422 and 0.400 respectively. Governance therefore captures firm characteristics substantially distinct from those measured by the other two pillars - board composition, managerial incentives, transparency and accountability - and these characteristics are more closely aligned with conventional determinants of financial performance than are environmental or social disclosures. This interpretation is consistent with the quality-related arguments discussed in Section 2.4.

Table 17 - Variance inflation factors

Model	**Variables**	**VIF**
Baseline	*Lagged ESG*	1.40
Baseline	*LogMarketCap*	1.43
Baseline	*MRP*	1.34
Baseline	*SMB*	1.70
Baseline	*HML*	3.38
Baseline	*RMW*	1.39
Baseline	*CMA*	4.08
Pillars	*Lagged Environmental*	2.65
Pillars	*Lagged Social*	2.63
Pillars	*Lagged Governance*	1.30
Pillars x crisis	MT x *Environmental*	8.41
Pillars x crisis	MT x *Social*	13.05
Pillars x crisis	MT x *Governance*	6.91

Variance inflation factors are reported in Table 17. For the baseline specification the factor associated with the aggregate ESG score is 1.40, indicating that the score is largely orthogonal to the remaining regressors, and all factors are below five; the highest are those on the value and investment factors, at 3.38 and 4.08 respectively.

For the pillar specifications, the factors are 2.65, 2.63 and 1.30 for the Environmental, Social and Governance dimensions. Although the pillars are correlated by construction, the

degree of overlap is insufficient to compromise identification, and the individual coefficients may accordingly be interpreted directly. The low factor associated with Governance reflects its weak correlation with the other two pillars and provides further support for the interpretation presented above.

4.5. Robustness checks

Four robustness checks were undertaken to establish the sensitivity of the findings to the principal methodological choices.

4.5.1. Treatment of undisclosed environmental data

As documented in Section 3.4, approximately 10.5% of firm-years record an Environmental score of exactly zero, reflecting non-disclosure rather than measured performance. Since the Environmental pillar is one of the two dimensions exhibiting a significant negative coefficient, it is necessary to establish whether that coefficient reflects environmental performance or the coding of missing data.

Table 18 - Robustness check: Exclusion of undisclosed environmental data

Pillar	Full sample (OLS)	Restricted (OLS)	Full sample (FE)	Restricted (FE)
Environmental	-0.0008***	-0.0006**	-0.0010***	-0.0011***
Social	-0.0007**	-0.0009***	-0.0010*	-0.0013**
Governance	+0.0002	+0.0003	+0.0005*	+0.0007**
Observations	9,616	8,607	9,616	8,607

Table 18 presents the pillars estimated on the restricted sample from which these observations are excluded. All conclusions are preserved and, in two cases, strengthened. The Environmental coefficient moves from -0.0010 to -0.0011 under FE and remains significant at the 1% level. The Social coefficient strengthens from -0.0010 to -0.0013 and from 10% to 5% significance. The Governance coefficient strengthens from +0.0005 to +0.0007 and likewise attains 5% significance.

It is further observed that firms recording an Environmental score of zero earned mean excess returns of 1.76% against 4.00% for the remainder of the sample. These firms did underperform, but for reasons unrelated to environmental performance, and their exclusion sharpens rather than weakens the estimated pillar effects. The full sample is

retained as the principal specification and the restricted estimation reported as a robustness check.

4.5.2. Portfolio construction threshold

The definition of the high- and low-rated groups as the top and bottom 25 firms is a methodological choice following the authors, and it is necessary to establish that the findings do not depend upon it.

Table 19 - Robustness check: Portfolio construction threshold

Pillar	Lower tier coefficient	*p*-value	Upper tier coefficient	*p*-value
10.0%	-0.0034***	0.0006	-0.0015***	0.0001
22.5%	-0.0025***	0.0001	-0.0015***	0.0001
35.0%	-0.0022***	0.0000	-0.0016***	0.0001
50.0%	-0.0018***	0.0000	-0.0019***	0.0002
77.5%	-0.0015***	0.0000	-0.0026	0.1357
90.0%	-0.0015***	0.0000	-0.0039***	0.0089

Table 19 reports the regression estimated separately on subsamples defined by percentile cutoffs of the ESG distribution within each year, at 10, 22.5, 35, 50, 77.5 and 90%.

The coefficient on the lagged ESG score is negative in all 12 specifications and significant at the 1.0% level in 11, the exception being the upper 77.5% tier, which comprises a comparatively small subsample. The estimated coefficients range from -0.0034 to -0.0015 for the lower-tier subsamples and from -0.0039 to -0.0015 for the upper-tier subsamples. The negative association therefore does not depend on the particular threshold adopted.

4.5.3. Weight constraints

The optimisation results reported in Section 4.2 are conditioned on a 10% limit on the weight attributable to any individual security. Table 20 reports the asymmetry between top- and bottom-rated portfolios for weight caps of 10%, 20% and 30% and for the unconstrained case.

Table 20 - Sensitivity to the weight constraint

Weight cap	Mean Δ top	Mean Δ bottom	Asymmetry	Top improved	Effective N	Non-convergence
10.0%	+0.085	-0.105	+0.190	3 of 4	11.0	5 of 160
20.0%	+0.151	-0.195	+0.345	4 of 4	6.1	1 of 160
30.0%	+0.180	-0.161	+0.341	4 of 4	4.7	0 of 160
Unconstrained	+0.175	-0.126	+0.301	4 of 4	4.0	2 of 160

The asymmetry is positive under all four specifications, ranging from 0.190 to 0.345, indicating that the findings do not depend on it. The magnitude nonetheless increases as the constraint becomes less restrictive: at a 10% cap the mean improvement among top-rated portfolios is 0.085 against a mean deterioration of 0.105 among bottom-rated portfolios, whereas at 20% the corresponding figures are 0.151 and 0.195.

Additionally, under the unconstrained scenario, the effective number of holdings falls to 4.0, with some portfolios highly concentrated in a single stock, making these allocations less economically meaningful. Conversely, the 10% cap makes the optimisation more difficult, with the maximum Sharpe portfolio failing to converge in 5 out of 160 portfolio years.

4.5.4. Portfolio weighting scheme

The baseline portfolios are equally weighted. A capitalisation-weighted variant was estimated as a robustness check and is reported in Appendix B. The qualitative conclusions are unchanged: bottom-rated portfolios continue to deliver superior absolute returns in three of the four dimensions, and the Governance dimension continues to reverse the pattern. Capitalisation weighting nonetheless produces materially more concentrated portfolios, with a single security reaching 58.6% of a 25 stock portfolio at the extreme, and the resulting performance is consequently attributable to a small number of large constituents rather than to ESG-based selection. Equal weighting is retained as the principal specification for this reason.

4.6. Research questions

The findings regarding the four research questions may be summarised as follows:

RQ1/RQ2. Under equal weighting, portfolios of lower-rated firms deliver superior absolute returns, but they also exhibit higher volatility in every dimension examined, and their advantage in risk-adjusted terms is substantially attenuated. At firm level, high- and low-rated companies are statistically indistinguishable in terms of risk efficiency. When Markowitz mean-variance optimisation is applied to the same securities, the ordering reverses for three of the four dimensions: higher-rated portfolios deliver superior risk-adjusted performance, significantly so for Governance. The reversal is robust to the weight

constraint imposed. The Environmental dimension is the exception, remaining unfavourable under every specification examined.

RQ3. The negative association between ESG ratings and excess returns is more than three times stronger during the market disruptions of 2008 and 2020 than during normal conditions, and the effect is significant at the one per cent level under both estimation methods. Higher ESG ratings did not provide downside protection during these episodes. Whether any individual pillar behaves differently cannot be determined, as the three pillar-specific interaction terms are not separately identified.

RQ4. The negative association identified at the aggregate level is attributable to the Environmental and Social dimensions, both of which carry negative and statistically significant coefficients after controlling for firm size, the five Fama–French factors and sector fixed effects. The Governance dimension carries a positive coefficient. These findings are robust to the exclusion of firms that had not disclosed environmental data and to variation in the percentile threshold used to define the rating tiers.

The element common to all four is the distinctive behaviour of the Governance pillar. It produces the highest Sharpe ratio among the equally weighted portfolios, it is the only dimension for which the effect of optimisation on risk-adjusted performance attains statistical significance, and it is the only pillar carrying a positive coefficient in the firm-level regression. That three independent methodological approaches converge upon the same dimension constitutes the principal finding of this dissertation.

5. Discussion

This chapter interprets the findings reported in Chapter 4 in relation to the literature reviewed in Chapter 2 and discusses what they imply for theory and for practice.

5.1. Raw returns and risk-adjusted performance

The results show that lower-rated ESG portfolios generated substantially higher absolute returns, but this advantage largely disappeared once risk was considered, as discussed in Section 2.5. This finding may help explain some of the mixed evidence in the existing literature. Studies finding that lower-rated firms outperform and studies finding no significant difference between high- and low-rated firms may not necessarily contradict each other. Instead, they may be measuring performance differently.

The descriptive results support this interpretation. Lower-rated portfolios were more volatile across all four ESG dimensions examined and experienced larger maximum drawdowns in 3 of the 4. Their higher returns were therefore the result of higher levels of risk. This is particularly clear for the Social pillar, where the lower-rated portfolio generated an additional 1.46 p.p. of return, while the difference in Sharpe ratios was only 0.003. In other words, the higher return of the lower-rated portfolio was almost entirely offset by the additional risk required to achieve it.

These findings support a risk-based explanation of the return differences. If the lower returns of highly rated firms were mainly the result of investors being willing to pay a premium for stronger sustainability characteristics (Section 2.2.), the difference would be expected to remain after adjusting for risk. However, this is not observed in the results. Instead, the return advantage of lower-rated portfolios largely disappears on a risk-adjusted basis, suggesting that their higher returns mainly compensate investors for taking greater risk. The findings are also consistent with previous evidence that ESG integration does not necessarily harm financial performance. Although investors selecting higher-rated firms earned lower absolute returns in this sample, they were also exposed to lower risk and did not perform materially worse on a risk-adjusted basis.

5.2. The role of the allocation method

The results show that the choice of weighting scheme can materially affect conclusions about ESG portfolio performance. Mean-variance optimisation changes the relative performance of high- and low-rated portfolios in three of the four ESG dimensions examined. Importantly, the securities included in each portfolio remain the same; only the weights assigned to them change. This suggests that differences in ESG portfolio performance may reflect not only which securities are selected, but also how capital is allocated across them. This finding supports the concern raised in the literature review that relying on a single weighting method may provide only a partial view of ESG investment performance.

One possible explanation for this result is estimation error. The efficient frontier analysis shows that the lower-rated portfolios appeared to offer a better expected risk-return trade-off in most years, with the higher-rated portfolio dominating in only six of the nineteen years. However, this expected advantage did not translate into better realised performance. The higher expected returns estimated for lower-rated securities using the previous year's data were not sustained, while the more moderate estimates for higher-rated securities proved more stable. This highlights a known limitation of mean-variance optimisation: portfolio weights can be highly sensitive to estimates of expected returns and risk, particularly when these are based on relatively short historical periods.

Overall, the results reinforce the importance of the weighting scheme when evaluating ESG investment strategies. The weaker performance of lower-rated portfolios after optimisation does not necessarily result from the ESG selection itself, but from how the characteristics of the selected securities interact with the optimisation process. Therefore, conclusions about whether high- or low-rated ESG portfolios perform better should consider both the sustainability screen used to select securities and the method used to allocate capital across them.

5.3. The heterogeneity of ESG pillars

The different behaviour of the Governance pillar compared with the Environmental and Social pillars is one of the most consistent findings of this dissertation. This pattern appears across different parts of the analysis. Governance records the highest Sharpe ratio

among the equally weighted portfolios, comes closest to statistical significance in the risk-adjusted comparisons, and is the only pillar with a positive coefficient in the firm-level regression.

One possible explanation is that Governance captures different firm characteristics from the other two pillars. Environmental and Social scores are strongly correlated at 0.753, while their correlations with Governance are considerably lower, at 0.422 and 0.400, respectively. This suggests that Governance measures a somewhat different dimension of firm performance. As discussed in the literature review, governance characteristics such as board oversight, managerial incentives, transparency and accountability are also closely related to traditional measures of corporate quality. The positive relationship between Governance and returns may therefore partly reflect these quality characteristics rather than a distinct sustainability effect.

This distinction is important when interpreting aggregate ESG scores. Combining Environmental, Social and Governance into a single measure may hide the fact that the three pillars have different relationships with financial performance. In this study, Governance is positively associated with returns, while Environmental and Social show negative associations. The results therefore support analysing the pillars separately, rather than assuming that an aggregate ESG score captures a single and consistent relationship with financial performance.

5.4. ESG characteristics and behaviour during market stress

The results do not support the view that higher ESG ratings provide greater protection during periods of market stress. In fact, the negative relationship between ESG ratings and excess returns is more than three times stronger during 2008 and 2020 than during normal periods. This differs from some of the evidence discussed in Section 2.6, which generally suggests that firms with stronger ESG characteristics may be more resilient during market downturns.

Several factors may help explain this difference. First, the time period used to measure performance differs across studies. Much of the literature on ESG resilience during Covid-19 focuses on the initial stages of the crisis, while this dissertation evaluates performance over the full calendar year. ESG characteristics may therefore provide some

protection during the initial market shock without necessarily leading to better performance over the entire year.

Second, sector composition may also influence the results. As shown in Appendix A, higher-rated portfolios have greater exposure to Information Technology and lower exposure to Energy than lower-rated portfolios. Differences in sector performance during periods of market stress may therefore contribute to the observed differences between high- and low-rated portfolios. This reinforces the importance of considering sector composition when interpreting ESG performance, as discussed in the literature review.

Finally, the results should be interpreted with caution because the stress-period analysis is based on only two episodes: the 2008 financial crisis and the Covid-19 pandemic in 2020. These crises had very different causes and market effects, and two observations are not sufficient to determine whether the same relationship would hold during other periods of market stress. The limited number of crisis years also restricts the ability to identify how the individual ESG pillars behave during these periods.

Overall, the findings do not provide evidence that higher ESG ratings consistently offer downside protection during periods of market stress. However, given the limited number of crisis episodes considered, the results should not be interpreted as evidence that ESG characteristics can never contribute to resilience. Instead, they suggest that any resilience effect may depend on the nature and duration of the crisis, as well as on the sector composition of the portfolios.

5.5. Theoretical and practical implications

The findings of this dissertation have several implications for the ESG investment literature. First, they reinforce the importance of considering risk when assessing ESG performance. The substantial differences observed in absolute returns largely disappear after adjusting for risk, showing that conclusions about ESG performance can depend significantly on the performance measure used. This supports the view that ESG investment strategies should be evaluated within a risk-adjusted framework rather than based on absolute returns alone.

Second, the results show that portfolio construction is an important part of ESG performance analysis. Changing from equal weighting to mean-variance optimisation alters the relative performance of high- and low-rated portfolios, even though the securities included in each portfolio remain unchanged. This suggests that some differences reported in the literature may reflect the weighting method used rather than ESG-based security selection alone. Portfolio allocation should therefore be treated as an important methodological choice when comparing ESG investment strategies.

Third, the different results across the Environmental, Social and Governance pillars question the use of the aggregate ESG score as a single measure of sustainability performance. In this study, Environmental and Social scores are negatively associated with excess returns, while Governance shows a positive relationship. Combining these dimensions into a single score may therefore hide important differences between them and may partly explain why previous studies have reached different conclusions about ESG performance. These findings reinforce the importance of examining the individual ESG pillars alongside the aggregate score.

From a practical perspective, the findings suggest that asset managers should avoid relying exclusively on aggregate ESG scores when constructing sustainable portfolios. The individual pillars may provide different information about financial performance, with Governance showing the most consistent positive relationship with returns in this study. Portfolio managers should therefore consider the individual ESG dimensions and assess how ESG-based security selection interacts with the chosen weighting method.

For investors seeking to incorporate sustainability considerations into their portfolios, the results are relatively encouraging. Higher-rated portfolios do not perform significantly worse on a risk-adjusted basis and perform better under optimisation in most of the ESG dimensions considered. This suggests that investors may be able to incorporate sustainability preferences without necessarily sacrificing risk-adjusted performance, although this may involve lower absolute returns.

Finally, the findings also have implications for ESG disclosure and rating practices. The differences identified across the three pillars highlight the importance of providing sufficiently detailed Environmental, Social and Governance information rather than relying only on composite ESG scores.

6. Conclusion

This dissertation set out to examine the relative financial performance of portfolios composed of high- and low-rated ESG firms, to identify which sustainability characteristics, if any, are associated with the differences observed, and whether their comparative performance depends on the method of capital allocation. The investigation was framed within the broader academic debate on the financial performance of ESG investing, a debate that has produced extensive but persistently mixed evidence. The literature review set out the principal arguments on both sides: stakeholder theory, resource-based reasoning and risk management perspectives suggest that sustainability practices should enhance firm value and reduce downside exposure, while asset pricing arguments hold that growing investor demand for sustainable assets raises their valuations and thereby lowers their expected returns. A parallel debate concerns whether the performance attributed to higher-rated ESG portfolios reflects sustainability itself or merely exposure to established investment factors such as quality, profitability and conservative investment behaviour.

The empirical results of this study offer several contributions to that debate. Over the period from 2005 to 2024, portfolios composed of the lowest-rated firms in the S&P 500 delivered substantially higher absolute returns than those composed of the highest-rated firms, with cumulative returns of 448.3% against 150.5% for the aggregate ESG score. However, lower-rated portfolios were more volatile in every sustainability dimension examined and suffered deeper losses in most of them, and once returns are measured relative to the risk assumed the two groups become statistically indistinguishable. The superior returns of lower-rated firms therefore represent compensation for risk rather than evidence of outperformance.

The optimisation analysis reveals that this conclusion depends materially on how capital is allocated across the selected securities. Holding the ESG-based selection rule constant and replacing equal weighting with Markowitz mean-variance optimisation, the risk-adjusted performance of higher-rated portfolios improved while that of lower-rated portfolios deteriorated, reversing the ordering in three of the four dimensions examined.

The regression analysis addresses the question of which sustainability characteristics are associated with these differences. After controlling for firm size, the five Fama–French factors and sector effects, the Environmental and Social pillars are both negatively and

significantly associated with subsequent excess returns, while the Governance pillar carries a positive coefficient. Governance also produces the highest Sharpe ratio among the equally weighted portfolios and is the only dimension for which the improvement under optimisation reaches statistical significance.

A further result concerns the negative relationship between ESG ratings and excess returns during periods of market disruption, which is more than three times stronger during periods of market disruption than under normal conditions, and the effect is significant at the 1.0% level under both estimation methods. Higher ESG ratings therefore did not offer downside protection during these episodes.

To conclude, the results indicate that ESG integration might not compromise financial performance. Sustainability considerations can be incorporated into portfolio construction while maintaining competitive risk-adjusted returns, provided that the method of allocation is given explicit attention and that the sustainability dimension is chosen deliberately. ESG screening at the aggregate level, however, is not in itself a driver of superior financial performance; the aggregate score combines dimensions that behave in opposing directions, and its use as a single indicator of prospective performance is difficult to justify on the present research.

However, there are some limitations to these conclusions. The analysis is confined to large-capitalisation United States equities, and its extension to smaller firms or to other geographies remains untested. ESG coverage is incomplete in the earliest years of the sample, and commercial ratings are subject to retrospective revision, so that the scores employed reflect the state of the data at the point of retrieval rather than the information available to investors at the time. The risk-adjusted performance measures rest on twenty annual observations, and the crisis indicator is active in only two years, which prevented the crisis effect from being attributed to any individual pillar. Additionally, transaction costs were not incorporated, and the optimised portfolios generate materially higher turnover than the equally weighted ones in this specific study.

Future research would benefit to focus on the distinctive behaviour of the Governance pillar, particularly as to whether its favourable association with returns reflects governance quality itself or the broader corporate quality with which it is correlated. Finally, the absence of downside protection during market disruption could be studied examination

over a longer sample containing more episodes of stress, which would permit the effect to be attributed to individual sustainability dimensions rather than to the aggregate score alone

7. References

Ademi, B., & Klungseth, N. J. (2022). Does it pay to deliver superior ESG performance? Evidence from US S&P 500 companies. *Journal of Global Responsibility*, *13*(4), 421–449. https://doi.org/10.1108/JGR-01-2022-0006

Ahmed, M. F., Gao, Y., & Satchell, S. (2021). Modeling demand for ESG. *European Journal of Finance*, *27*(16), 1669–1683. https://doi.org/10.1080/1351847X.2021.1924216

Albuquerque, R., Koskinen, Y., Yang, S., & Zhang, C. (2020). Resiliency of environmental and social stocks: An analysis of the exogenous COVID-19 market crash. *Review of Corporate Finance Studies*, *9*(3), 593–621. https://doi.org/10.1093/rcfs/cfaa011

Ardia, D., & Boudt, K. (2015). Testing equality of modified Sharpe ratios. *Finance Research Letters*, *13*, 97–104. https://doi.org/10.1016/j.frl.2015.02.008

Asness, C. S., Frazzini, A., & Pedersen, L. H. (2019). Quality minus junk. *Review of Accounting Studies*, *24*(1), 34–112. https://doi.org/10.1007/s11142-018-9470-2

Barney, J. (1991). Firm resources and sustained competitive advantage. *Journal of Management*, *17*, 99–120. https://doi.org/10.1177/014920639101700010

Blitz, D., & Fabozzi, F. J. (2017). Sin Stocks Revisited: Resolving the Sin Stock Anomaly. *The Journal of Portfolio Management*, *44*(1), 105–111. https://doi.org/10.3905/jpm.2017.44.1.105

Boudt, K., Cornelissen, J., & Croux, C. (2013). The impact of a sustainability constraint on the mean-tracking error efficient frontier. *Economics Letters*, *119*(3), 255–260. https://doi.org/10.1016/j.econlet.2013.03.020

Broadstock, D. C., Chan, K., Cheng, L. T. W., & Wang, X. (2021). The role of ESG performance during times of financial crisis: Evidence from COVID-19 in China. *Finance Research Letters*, *38*, 1–11. https://doi.org/10.1016/j.frl.2020.101716

Carvalho, P. V., Falcão, P. F., Pinheiro, C. M., & Carrão, D. (2026). Revisiting ESG performance: do high scores translate to higher returns? A risk-adjusted analysis of S&P 500 portfolios. *Finance Research Letters*, *91*. https://doi.org/10.1016/j.frl.2025.109467

Cesarone, F., Martino, M. L., & Carleo, A. (2022). Does ESG Impact Really Enhance Portfolio Profitability? *Sustainability*, *14*(4). https://doi.org/10.3390/su14042050

Chen, L., Zhang, L., Huang, J., Xiao, H., & Zhou, Z. (2021). Social responsibility portfolio optimisation incorporating ESG criteria. *Journal of Management Science and Engineering*, *6*(1), 75–85. https://doi.org/10.1016/j.jmse.2021.02.005

Chen, M., Mussalli, G., & Berhen, R. Von. (2021). The Unreasonable Attractiveness of More ESG Data. *Portfolio Management Research*, 3–16. https://doi.org/10.2139/ssrn.3878386

Ding, W., Levine, R., Lin, C., & Xie, W. (2021). Corporate immunity to the COVID-19 pandemic. *Journal of Financial Economics*, *141*(2), 802–830. https://doi.org/10.1016/j.jfineco.2021.03.005

Eccles, R. G., & Serafeim, G. (2013). The Performance Frontier: Innovating for a Sustainable Strategy. *Harvard Business Review*, *91*(5), 50–60.

Edmans, A. (2011). Does the stock market fully value intangibles? Employee satisfaction and equity prices. *Journal of Financial Economics*, *101*(3), 621–640. https://doi.org/10.1016/j.jfineco.2011.03.021

Eling, M. (2008). Does the Measure Matter in the Mutual Fund Industry? *Financial Analysts Journal*, *64*(3), 54–66. https://doi.org/10.2469/faj.v64.n3.6

European Commission. (n.d.). *Overview of sustainable finance*. European Commission. Retrieved https://finance.ec.europa.eu/sustainable-finance/overview-sustainable-finance_en

European Commission. (2018). *Financing a Sustainable European Economy*.

Fama, E. F., & French, K. R. (2015). A five-factor asset pricing model. *Journal of Financial Economics*, *116*(1), 1–22. https://doi.org/10.1016/j.jfineco.2014.10.010

Freeman, R. E. (1984). *Strategic Management: A Stakeholder Approach* (7th ed.).

Friede, G., Busch, T., & Bassen, A. (2015). ESG and financial performance: aggregated evidence from more than 2000 empirical studies. *Journal of Sustainable Finance and Investment*, *5*(4), 210–233. https://doi.org/10.1080/20430795.2015.1118917

Gallagher, D. R., Gardner, P. A., Schmidt, C. H., & Walter, T. S. (2014). Portfolio quality and mutual fund performance. *International Review of Finance*, *14*(4), 485–521. https://doi.org/10.1111/irfi.12031

Giese, G., Lee, L.-E., Melas, D., Nagy, Z., & Nishikawa, L. (2019). Foundations of ESG Investing: How ESG Affects Equity Valuation, Risk, and Performance. *The Journal of Portfolio Management*, *45*(5), 69–83. https://doi.org/10.3905/jpm.2019.45.5.069

Godfrey, P. C., Merrill, C. B., & Hansen, J. M. (2009). The relationship between corporate social responsibility and shareholder value: An empirical test of the risk management hypothesis. *Strategic Management Journal*, *30*(4), 425–445. https://doi.org/10.1002/smj.750

Green, R. C., & Hollifield, B. (1992). When Will Mean-Variance Efficient Portfolios Be Well Diversified? *The Journal of Finance*, *47*(5), 1785–1809. https://doi.org/10.1111/j.1540-6261.1992.tb04683.x

Gregoriou, G. N., & Gueyie, J.-P. (2003). Risk-Adjusted Performance of Funds of Hedge Funds Using a Modified Sharpe Ratio. *The Journal of Wealth Management*, *6*(3), 77–83. https://doi.org/10.3905/jwm.2003.442378

Halbritter, G., & Dorfleitner, G. (2015). The wages of social responsibility - where are they? A critical review of ESG investing. *Review of Financial Economics*, *26*, 25–35. https://doi.org/10.1016/j.rfe.2015.03.004

Jagannathan, R., & Ma, T. (2003). Risk Reduction in Large Portfolios: Why Imposing the Wrong Constraints Helps. *The Journal of Finance*, *58*(4), 1651–1683. https://doi.org/10.1111/1540-6261.00580

Khan, M. A. (2022). ESG disclosure and Firm performance: A bibliometric and meta analysis. In *Research in International Business and Finance* (Vol. 61). Elsevier. https://doi.org/10.1016/j.ribaf.2022.101668

Khan, M., Serafeim, G., & Yoon, A. (2016). Corporate Sustainability: First Evidence on Materiality. *The Accounting Review*, *91*(6), 1697–1724. https://doi.org/10.2308/accr-51383

Markowitz, H. (1952). Portfolio Selection. *The Journal of Finance*, *7*(1), 77–91. https://doi.org/https://doi.org/10.2307/2975974

Michaud, R. O. (1989). The Markowitz Optimisation Enigma: Is "Optimised Optimal"? *Financial Analysts Journal*, *45*(1), 31–42. https://doi.org/10.2469/faj.v45.n1.31

Novy-Marx, R. (2013). The other side of value: The gross profitability premium. *Journal of Financial Economics*, *108*(1), 1–28. https://doi.org/10.1016/j.jfineco.2013.01.003

Oikonomou, I., Platanakis, E., & Sutcliffe, C. (2018). Socially responsible investment portfolios: Does the optimisation process matter? *The British Accounting Review*, *50*(4), 379–401. https://doi.org/10.1016/j.bar.2017.10.003

Oukhouya, H., El Rhiouane, A., Guerbaz, R., Zari, T., & El Himdi, K. (2025). Balancing Returns and Responsibility: Markowitz Optimisation for ESG-Integrated Portfolios in Morocco. *Computational Economics*. https://doi.org/10.1007/s10614-024-10834-8

Pástor, Ľ., Stambaugh, R. F., & Taylor, L. A. (2022). Dissecting green returns. *Journal of Financial Economics*, *146*(2), 403–424. https://doi.org/10.1016/j.jfineco.2022.07.007

Pedersen, L. H., Fitzgibbons, S., & Pomorski, L. (2021). Responsible investing: The ESG-efficient frontier. *Journal of Financial Economics*, *142*(2), 572–597. https://doi.org/10.1016/j.jfineco.2020.11.001

Revelli, C. (2017). Socially responsible investing (SRI): From mainstream to margin? *Research in International Business and Finance*, *39*, 711–717. https://doi.org/10.1016/j.ribaf.2015.11.003

Revelli, C., & Viviani, J. L. (2015). Financial performance of socially responsible investing (SRI): What have we learned? A meta-analysis. *Business Ethics: A European Review*, *24*(2), 158–185. https://doi.org/10.1111/beer.12076

Rojo-Suárez, J., & Alonso-Conde, A. B. (2024). Have shifts in investor tastes led the market portfolio to capture ESG preferences? *International Review of Financial Analysis*, *91*. https://doi.org/10.1016/j.irfa.2023.103019

Sahin, Ö., Bax, K., Paterlini, S., & Czado, C. (2023). The pitfalls of (non-definitive) Environmental, Social, and Governance scoring methodology. *Global Finance Journal*, *56*, 1–14. https://doi.org/10.1016/j.gfj.2022.100780

Sharpe, W. F. (1964). Capital Asset Prices: A Theory of Market Equilibrium under Conditions of Risk. *The Journal of Finance*, *19*(3), 425–442. https://doi.org/10.2307/2977928

Sharpe, W. F. (1994). The Sharpe Ratio. *The Journal of Portfolio Management*, *21*(1), 49–58. https://doi.org/10.3905/jpm.1994.409501

S&P Dow Jones Indices. (2024). *The Growing S&P 500® ESG Index Liquidity Ecosystem*. https://www.spglobal.com/spdji/en/documents/education/education-the-growing-sp-500-esg-index-liquidity-ecosystem.pdf

Wen, L., Li, J., Sheng, J., & Zhang, Y. (2024). Active portfolio management in the face of ESG uncertainty: An agile framework for adaptive investment strategies. *North American Journal of Economics and Finance*, *75*. https://doi.org/10.1016/j.najef.2024.102295

Appendix

Appendix A – Sector composition of the ESG portfolios

Table A - Portfolio allocation by GICS sector, 2005–2024

GICS sector	Top-ESG	Bottom-ESG	Top-Env.	Bottom-Env.	Top-Social	Bottom-Social	Top-Gov.	Bottom-Gov.
Information Technology	16.8%	5.0%	13.2%	11.8%	20.4%	5.2%	13.2%	9.6%
Consumer Staples	15.2%	6.4%	15.2%	6.6%	13.6%	2.6%	9.4%	6.8%
Health Care	12.4%	8.6%	8.4%	9.8%	17.4%	8.6%	9.4%	15.0%
Industrials	10.8%	15.8%	13.0%	16.2%	10.4%	13.2%	7.0%	15.0%
Materials	10.0%	3.4%	4.4%	3.2%	5.6%	4.2%	13.6%	4.8%
Financials	9.4%	13.2%	22.2%	9.4%	6.0%	14.0%	9.6%	12.8%
Consumer Discretionary	9.2%	20.8%	8.8%	19.0%	14.4%	22.2%	6.0%	13.4%
Real Estate	7.2%	3.6%	4.6%	3.6%	4.4%	2.4%	5.0%	4.2%
Energy	5.0%	10.8%	5.0%	7.8%	4.2%	14.2%	8.0%	4.0%
Utilities	3.8%	2.0%	5.0%	3.2%	1.4%	5.0%	18.0%	0.4%
Communication Services	0.2%	10.4%	0.2%	9.4%	2.2%	8.4%	0.8%	14.0%

Appendix B – Performance and descriptive statistics of ESG portfolios

Table B.1. - Performance of top- and bottom-ranked ESG portfolios, 2005–2024

Year	Top-ESG	Bottom-ESG	Top-Env.	Bottom-Env.	Top-Social	Bottom-Social	Top-Gov.	Bottom-Gov.
2005	4.9%	1.4%	0.0%	9.8%	6.3%	8.1%	4.3%	(6.5%)
2006	14.1%	26.1%	11.1%	18.0%	16.3%	7.9%	22.4%	27.3%
2007	11.2%	(13.2%)	(4.1%)	(8.2%)	7.1%	(5.7%)	20.4%	(10.3%)
2008	(41.5%)	(39.0%)	(47.9%)	(55.5%)	(39.4%)	(44.2%)	(33.3%)	(41.5%)
2009	25.7%	41.1%	19.9%	55.8%	31.7%	34.9%	8.3%	44.9%
2010	7.4%	15.0%	10.6%	13.0%	6.3%	24.8%	12.7%	9.2%
2011	0.9%	0.5%	(10.8%)	2.6%	5.2%	8.0%	(3.2%)	0.5%
2012	5.7%	16.0%	14.8%	25.0%	5.4%	15.1%	5.3%	18.1%
2013	29.0%	42.9%	29.8%	39.6%	23.6%	37.7%	27.9%	46.4%
2014	14.3%	18.1%	14.5%	7.0%	15.1%	15.8%	14.1%	19.0%
2015	4.8%	4.3%	(3.8%)	2.8%	2.6%	0.3%	7.9%	23.9%
2016	9.8%	12.6%	14.8%	(2.3%)	7.3%	9.9%	15.9%	0.1%
2017	26.1%	20.5%	19.8%	22.2%	18.5%	22.5%	13.7%	32.6%
2018	(8.4%)	6.0%	(15.5%)	(2.9%)	(1.3%)	2.3%	(1.1%)	4.4%
2019	32.6%	34.8%	21.8%	33.4%	28.6%	28.0%	40.1%	16.8%
2020	13.8%	17.2%	(0.4%)	36.6%	21.8%	14.5%	29.6%	18.6%
2021	38.6%	26.3%	25.8%	28.5%	23.5%	31.5%	48.4%	14.6%
2022	(22.1%)	(7.9%)	(10.9%)	(7.4%)	(15.8%)	(9.3%)	(22.6%)	(7.9%)
2023	31.3%	28.9%	9.1%	25.6%	(0.6%)	19.8%	42.6%	28.5%
2024	10.3%	35.3%	13.3%	33.1%	9.6%	26.5%	16.8%	34.1%
AR	8.6%	12.4%	3.8%	10.7%	7.2%	10.6%	11.7%	11.5%
TR	419.8%	937.5%	110.2%	669.5%	304.4%	648.0%	810.2%	782.6%

Table B.2. - Descriptive statistics of portfolio returns

Portfolio	Mean	Median	Std. Dev	Min	Max	Sharpe ratio	Max. drawdown
Top-ESG	10.4%	10.8%	19.0%	(41.5%)	38.6%	0.464	(57.9%)
Bottom-ESG	14.3%	16.6%	20.0%	(39.0%)	42.9%	0.635	(61.8%)
Top-Env.	5.6%	10.9%	18.0%	(47.9%)	29.8%	0.219	(67.1%)
Bottom-Env.	13.8%	15.5%	23.9%	(55.5%)	55.8%	0.509	(72.2%)
Top-Social	8.6%	7.2%	16.1%	(39.4%)	31.7%	0.425	(56.4%)
Bottom-Social	12.4%	14.8%	18.6%	(44.2%)	37.7%	0.570	(64.9%)
Top-Gov.	13.5%	13.9%	20.0%	(33.3%)	48.4%	0.605	(52.1%)
Bottom-Gov.	12.4%	14.8%	18.6%	(44.2%)	37.7%	0.570	(64.9%)