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Does ESG compliance lower the sensitivity of portfolio strategies to global macroeconomic risk factors?

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Abstract

This paper investigates whether ESG-integrated portfolio strategies provide superior risk-return trade-offs and distinct exposures to global macroeconomic risk factors compared to their non-ESG counterparts. Using a sample of 54 value, size, and momentum portfolios constructed across six major equity markets from June 2001 to June 2023, we evaluate performance and risk pricing through both descriptive statistics and a two-step cross-sectional asset pricing model à la Black, Jensen, & Scholes (1972). Empirical results show that ESG integration tends to modestly reduce average returns and Sharpe ratios, particularly for value and momentum strategies, though these effects are rarely statistically significant. More consistently, ESG strategies exhibit lower volatility, especially in developed markets such as the U.S., U.K., and Continental Europe, suggesting a potential shift toward a greater portfolio resilience. In the asset pricing tests, industrial production growth and term spread are significantly priced in both ESG and non-ESG portfolios, albeit with slightly lower estimated prices in ESG strategies. Notably, the Environmental Performance Index (EPI) factor is priced negatively and significantly in both samples with a stronger effect in non-ESG portfolios, indicating that weak environmental performance constitutes a priced source of systematic risk. Furthermore, the default spread is significant only in the ESG sample, possibly reflecting greater vulnerability to credit conditions due to the operational costs associated with sustainability compliance. Overall, our findings suggest that ESG integration reshapes the exposure of factor-based portfolios to global macroeconomic risks, not necessarily by enhancing returns, but by reprioritizing risk control and sustainability alignment. These results contribute to the ongoing debate on the financial relevance of ESG investing and highlight the importance of macroeconomic context in evaluating ESG performance.

1. Introduction

Over the past decade, the integration of Environmental, Social, and Governance (ESG) principles into investment processes has evolved from a niche activity to a mainstream practice among institutional investors. ESG investing is now perceived not only as a response to social and regulatory pressure but also as a potential source of portfolio resilience and long-term value preservation. However, despite its rapid diffusion, the empirical evidence on the performance of ESG-integrated strategies remains mixed and sometimes contradictory.

A central concern for investors is whether the incorporation of ESG considerations necessarily entails a sacrifice in risk-adjusted performance. While some studies argue that stronger ESG performance may lead to lower returns due to reduced risk or investor preference channels, others suggest that ESG integration enhances financial performance or, at minimum, leaves it unaffected. This divergence in findings is largely attributable to methodological differences, inconsistent ESG scoring methodologies, and variation in sampling periods and regions. As emphasized by Bruno, Esakia, & Goltz (2022), a more granular, factor-based perspective is essential to clarify these ambiguities.

This debate becomes even more salient when examined through the lens of macroeconomic risk exposure. Although recent literature has explored the relationship between ESG characteristics and market returns, few studies have explicitly investigated how ESG-integrated factor strategies – particularly those based on value, size, and momentum – respond to unexpected shifts in global macroeconomic conditions. Understanding whether ESG integration reshapes the sensitivity of portfolios to macroeconomic risk premium such as changes in inflation, industrial production, or credit spreads is crucial for asset managers and policymakers aiming to align financial and sustainability objectives. Papers by Bolton & Kacperczyk (2021, 2023), among others, have illuminated the pricing of climate-related risk, particularly in relation to macroeconomic policy shifts, but a comprehensive cross-sectional asset pricing assessment of ESG-integrated portfolios remains largely unexplored.

This study seeks to bridge that gap. We systematically examine whether ESG integration modifies the performance and macro risk exposures of traditional value, size, and momentum strategies across six global equity markets (U.S., U.K., Japan, Continental Europe, Canada, and Emerging Markets) over the period June 2001 to June 2023. Specifically, we ask whether the ESG-integrated portfolios deliver superior risk-adjusted returns, and whether any observed performance differentials stem from structural changes in their sensitivity to global sources of systematic risk.

This paper extends the global macro-risk framework developed in Matteucci and Venanzi (2025) by incorporating ESG criteria into the construction of traditional factor-based portfolios. Specifically, we explore whether the inclusion of ESG metrics alters the exposure of value, size, and momentum strategies to global macroeconomic risk factors. The research question is twofold: i) does ESG integration improve the risk–return trade-off of classical factor strategies? and ii) does it modify their sensitivity to systematic sources of macroeconomic risk such as industrial production growth, credit and term spreads, and inflation dynamics?

Our findings indicate that while ESG integration tends to lower average returns and Sharpe ratios – particularly for value and momentum strategies – these reductions are rarely statistically significant. In contrast, the return volatility declines more consistently across markets, particularly in the U.S., U.K., and Continental Europe. This risk reduction suggests potential diversification or stability benefits associated with ESG screening, particularly in regions where ESG awareness and regulatory frameworks are more developed. In terms of macroeconomic risk pricing, factors such as industrial production growth (MP) and term spread (UTS) are significantly priced in both ESG and non-ESG portfolios, though the risk prices are slightly lower in ESG portfolios, suggesting weaker exposure to cyclical macro shocks. Notably, the Environmental Performance Index (EPI) factor exhibits a negative and statistically significant risk price in both samples, stronger in non-ESG portfolios, suggesting that poor environmental performance is perceived as a priced source of risk. This counterintuitive result implies that ESG strategies may not underperform due to inefficiency, but rather due to a reprioritization of portfolio objectives toward resilience and sustainability alignment, particularly under conditions of tightening macro-financial constraints.

The remainder of the paper is structured as follows. Section 2 reviews the relevant literature on ESG integration and its intersection with factor investing and macro risk pricing. Section 3 describes research questions and testable hypotheses. Section 4 presents data, portfolio construction methodology, descriptive statistics, and comparative performance metrics for ESG versus non-ESG strategies. Section 5 reports the results from the cross-sectional pricing tests and interprets the estimated risk premium. Section 6 concludes by summarizing the contributions and outlining avenues for future research.

2. Literature Review

In recent years, research at the intersection of environmental, social, and governance (ESG) factors and asset pricing has expanded considerably. This growing body of literature seeks to understand whether, and how, ESG characteristics of firms are reflected in their stock returns and risk profiles, often within the framework of established asset pricing models. A widely used approach involves sorting stocks into portfolios based on their ESG ratings – either overall or by individual E, S, and G pillars – and analyzing their performance through multi-factor models. Several studies have applied this methodology, typically constructing High-minus-Low (or Green-minus-Brown) portfolios by going long on stocks with high ESG ratings and short on those with low ratings. For example, Halbritter & Dorfleitner (2015) created value-weighted ESG quintile portfolios for U.S. firms and assessed their performance using both the Carhart (1997) four-factor model and Fama & MacBeth (1973) cross-sectional regressions. Similarly, Bannier, Bonfinger, & Rock (2023) applied the Carhart model to U.S. ESG portfolios, including robustness checks with the Fama & French (2015) five-factor model. Extending the geographical scope, Kaiser (2020) analyzed ESG-sorted portfolios for European and U.S. firms, while Nagy, Kassam, & Lee (2016) proposed an "ESG tilt strategy" based on MSCI ESG ratings within the MSCI World Index, aiming to overweight companies with superior ESG scores.

Beyond static ESG ratings, the literature has also examined ESG momentum strategies, focusing on changes in ESG performance over time. Notably, Magnani, Guidolin, & Berk (2024) evaluated the effectiveness of ESG momentum and ESG volatility strategies for European equities, sorting stocks into quintiles based on rank-neutralized changes in ESG scores over different time horizons, and analyzing long-short portfolios using a seven-factor model that includes the Fama-French (2015) five factors, the Carhart (1997) momentum factor, and a low volatility factor. While these studies provide valuable insights into ESG scores and momentum effects, fewer works have directly investigated strategies that jointly sort stocks by ESG characteristics and traditional factors such as size or value in the manner proposed by the present research. Some papers, such as Kaiser (2020), introduce size- and industry-adjusted ESG ratings and sort by style factors like value/growth, suggesting possible interactions, though comprehensive joint-sorting methodologies remain relatively underexplored. Most existing works treat size and value factors as control variables within ESG-based portfolio regressions, rather than as integrated sorting criteria.

Empirical results from this literature are mixed. Some early studies documented positive abnormal returns for high ESG-rated firms, while more recent analyses – covering extended periods or different markets – produced conflicting evidence. For example, Halbritter & Dorfleitner (2015) reported no significant return differences between high and low ESG-rated firms in their U.S. sample, noting a decline in explanatory power during the final decade of their study. Bannier et al. (2023) even found that portfolios with lower corporate social responsibility (CSR) ratings outperformed higher-rated ones in terms of factor-adjusted returns and return-to-risk ratios, concluding that a low-CSR strategy offered the most favorable return profile. Similarly, Kaiser (2020) observed largely insignificant or negative ESG premiums in U.S. and European markets. Several explanations have been proposed for these results. A prevalent view is that strong ESG performance reduces firm-specific and systematic risks, which should be reflected in lower expected returns. Indeed, ESG integration is often associated with risk mitigation, especially during adverse events or periods of high volatility. However, as noted by Bannier, Bonfinger, & Rock (2023), the reduction in risk may not always compensate for lower returns, leading to suboptimal return-to-risk profiles. Pastor, Stambaugh, & Taylor (2022) found no evidence that stocks with good ESG scores carry higher risk, while Magnani, Guidolin, & Berk (2023) showed that ESG rating stability is linked to a lower ex-ante cost of capital, implying a premium for predictability. Another widely discussed explanation relates to investor preferences, particularly among ESG-conscious institutional investors, which can drive up the prices of high ESG-rated stocks and compressed expected returns. This aligns with the "sin stock" phenomenon described by Hong & Kacperczyk (2009), who documented outperformance among firms excluded by socially responsible investors. Pastor, Stambaugh, & Taylor (2022) and Stotz (2021) further argued that shifts in investor preferences and demand, often unrelated to financial risk, explain variations in expected returns and contribute to the so-called "greenium" – i.e., the trend of green stocks to deliver lower expected returns due to excess demand.

On the other hand, the literature debate focuses on whether climate risk constitutes a market anomaly, an additional source of systematic risk priced in financial markets, or merely a firm-specific characteristic that can be mitigated through diversification. For instance, In, Park, & Monk (2017) and Jiang & Weng (2019) demonstrate that climate change constitutes an additional source of market risk not adequately captured by traditional asset pricing factors, such as market, size, value, and momentum. Similarly, Balvers, Du, & Zhao (2017) regress size and value premiums on a temperature risk factor, revealing that part of the explanatory power of the Fama & French (1993) factors may be attributed to stocks' sensitivity to temperature risks. Conversely, Nagar & Schoenfeld (2021) identify significant heterogeneity in market capitalization across their weather-sorted portfolios, suggesting that the climate change risk is distinct from the size effect. This raises a pivotal question: is the stock market inefficient in pricing the climate change risk? Our study contributes to the literature by addressing this question through a focused analysis of the sensitivity of ESG investment strategies to macroeconomic risk factors.

Although these studies provide valuable insights into how macro-level conditions influence ESG risk pricing, relatively few have explicitly examined how ESG-integrated factor strategies respond to unexpected macroeconomic shocks like inflation expectations or industrial production growth. Most existing works emphasize how macroeconomic environments shape ESG premiums, rather than investigating the sensitivity of multi-factor ESG portfolios to traditional economic risks. Taken together, the literature offers a rich but fragmented understanding of the relationship between ESG factors and asset pricing, covering a range of portfolio construction techniques, markets, and theoretical frameworks. However, findings often diverge, reflecting the complexity of isolating the mechanisms through which ESG influences returns, the heterogeneity of available data, and the evolving nature of investor preferences and regulatory contexts. Moreover, while the significance of traditional factors like momentum, size, and value is widely recognized, there remains a notable gap in systematically integrating these factors with ESG metrics in portfolio construction – particularly across global markets.

The present research seeks to address this gap by systematically building and evaluating ESG-integrated momentum, size, and value strategies relative to their traditional counterparts on a global scale. By analyzing their performance, risk profiles, and sensitivity to macroeconomic shocks, this study aims to offer new evidence on how ESG characteristics interact with established factor premiums within a unified framework and across different market environments.

3. Research questions and testable hypotheses

In recent years, the integration of ESG criteria into investment strategies has transitioned from being a niche issue to a central focus in both academic research and financial practice. With growing global awareness of sustainability issues and increasing demand for responsible investing, the following question arises: can the integration of ESG metrics into the traditional factor-based portfolio strategy enhance financial performance or reduce systematic risk? Our paper addresses this issue by building a bridge between the classical portfolio theory and the emerging paradigm of ESG-focused investing. In particular, the purpose of this paper is firstly to investigate whether integrating ESG metrics into the asset pricing strategies – e.g. value, size, and momentum as proposed by Fama-French (1992), and Carhart (1997) – can enhance portfolio returns compared with the same strategies without ESG consideration. The study begins by presenting the value, size, and momentum strategies returns as applied to global equity markets. By using a comprehensive and original database, the analysis provides a detailed overview of the effectiveness of these strategies across various financial markets in the world. Following this baseline analysis, the paper delves into an innovative integration of ESG scores into the Fama-French (1992) and Carhart (1997) factor models. By recalibrating the factor strategies to include ESG scores, the research examines how this integration impacts portfolio returns and risk-adjusted performance. The comparative analysis highlights whether ESG-enhanced strategies offer statistically significant improvements over their traditional counterparts. In this regard, this study contributes to the academic and practitioner debate by providing empirical insights into the potential benefits of ESG integration in factor-based investing. It aims to guide asset managers and policy makers in understanding the role of the ESG considerations in building resilient and high-performing investment portfolios.

The second objective of this paper is to investigate whether any observed differences in the performance of ESG-integrated and non-ESG-integrated strategies can be attributed to different sensitivities of these strategies to macroeconomic risk factors, as proposed by Chen, Ross, & Roll (CRR) (1986) in the empirical testing of the Arbitrage Pricing Theory (APT). By incorporating CRR's macroeconomic risk factors into the analysis, this study tries to understand the extent to which the ESG perspective influences the portfolio exposure to systematic risk factors, i.e. industrial production growth, changes in expected inflation, unexpected inflation, credit spread, and term structure. This approach aims at contributing to the scholar-practitioner debate by providing empirical insights into the effects of the ESG screening on the impact of macroeconomic risks on portfolio strategy. The findings aim to guide asset managers and policymakers in designing investment strategies that align financial performance with sustainability objectives while accounting for systematic risk exposure.

The analysis is driven by three main hypotheses:

1. When the ESG scores are integrated into traditional factor-based strategies such as value, size, and momentum, the resulting ESG-enhanced strategies may underperform their non-ESG counterparts. This hypothesis is based on the prevailing belief in financial literature that non-ESG companies tend to outperform ESG-aligned firms in financial markets due to the potential higher costs associated with sustainability initiatives and compliance with ESG requirements (Hong & Kacperczyk, 2009; Bebchuk & Tallarita, 2020).
2. The ESG-integrated strategies show less sensitivity to macroeconomic risk factors than their non-ESG counterparts. This hypothesis is based on studies that suggest that the ESG-aligned companies are less vulnerable to macroeconomic shocks due to their emphasis on sustainability, robust governance, and long-term resilience (Albuquerque, Koskinen, & Zhang, 2019; Görgen et al., 2020). This lower sensitivity may contribute to explain any observed underperformance, since ESG strategies prioritize risk mitigation and stability over maximizing short-term returns.
3. As a result of the two previous hypotheses, we expect that the second effect (less macroeconomic risk) overtakes the first one (less performance) and therefore the ESG-enhanced strategies defeat their non-ESG counterparts from a risk-return perspective. In addition, we expect that this winning trade-off is more evident in countries/geographical regions where the environmental issues have been more strongly and for a longer time demanded by national/regional institutional and regulatory setting.

4. Dataset and Methodology

The dataset developed for this study represents a unique contribution to the empirical literature on sustainable asset pricing. While previous research has often analyzed either traditional factor portfolios (Fama and French, 1993; Asness et al., 2013) or ESG performance in isolation (Albuquerque et al., 2019; Pastor et al., 2022), few datasets combine firm-level financial and sustainability data with global macroeconomic variables in a unified, cross-country framework. Our dataset fills this gap by integrating montlhy return data with ESG scores across multiple geographic regions. This comprehensive structure enables us to assess whether ESG integration alters the exposure of canonical factor strategies – value, size, and momentum – to systematic macroeconomic risks at the global level.

4.1 Data sources and sample construction

The core financial and accounting data are obtained from LSEG Workspace (Refinitiv Datastream), which provides consistent global coverage of listed firms. Monthly total returns (including dividends), market capitalization, and book value of equity are used to construct the conventional value, size, and momentum factors. ESG scores are sourced from Refinitiv ESG Scores, which aggregate over 400 environmental, social, and governance indicators based on publicly available disclosures. For macroeconomic variables, we rely on IMF International Financial Statistics, OECD Main Economic Indicators, and World Bank Global Economic Monitor datasets, from which we compute the global macro factors following the Chen, Ross, and Roll (1986) framework.

The sample covers six global regions: the United States, United Kingdom, Continental Europe, Japan, Canada, and Emerging Markets. These areas collectively represent more than 95% of global market capitalization. Within each region, securities are included if they satisfy the following criteria: i) positive book-to-market ratio and available market capitalization; ii) at least twelve consecutive months of return data; iii) availability of ESG scores.

We exclude financials, REITs, closed-end funds, and ADRs to maintain comparability with standard cross-sectional factor models. The resulting sample contains approximately 18,500 firm-month observations per year, with coverage expanding over time as ESG reporting becomes more widespread. This makes it one of the most extensive datasets combining ESG and factor information currently available in the literature.

4.2 Portfolio formation

The construction of the factor and ESG-integrated portfolios follows a systematic multi-step procedure designed to ensure both cross-market comparability and economic consistency. Portfolios are formed at a monthly frequency over the sample period June 2001 to June 2023, resulting in 264 rebalancing dates. This horizon is selected to capture the full availability of ESG data across regions and to encompass distinct macroeconomic regimes – including periods of expansion, recession, and financial turmoil – thus enabling an assessment of how sustainability integration behaves under varying global conditions.

At the end of each month t, all firms within each of the six geographic regions (United States, United Kingdom, Continental Europe, Japan, Canada, and Emerging Markets) are ranked according to three core financial characteristics: i) book-to-market ratio for the value strategy; ii) market capitalization for the size strategy; iii) cumulative total return over the past 12 months, excluding the most recent month (t-12 to t-2) for the momentum strategy.

The ranking approach follows standard practice in cross-sectional asset pricing but differs from earlier implementations (Asness et al., 2013; Fama and French, 2015) by combining financial and non-financial dimensions in a consistent global framework.

To avoid survivorship bias, the sample is open: firms may enter or exit the universe depending on data availability and listing status. Stocks with negative book equity, missing ESG scores, or market capitalization below the 10th percentile of their domestic market are excluded to minimize micro-cap distortions and illiquidity effects.

For each factor, firms are sorted into three terciles (Low, Medium, High) based on the ranking variable. The traditional factor return is computed as the difference between the equal-weighted average return of the top tercile (High) and the bottom tercile (Low). This produces monthly time series for the classical value (HML), size (SMB), and momentum (MOM) factors in each regional market. These conventional portfolios serve as the baseline to evaluate the effect of ESG integration. To create ESG-adjusted portfolios, we integrate the sustainability dimension directly into the sorting mechanism.
Each firm's standardized ESG score $ESG_{i,t}$ is combined with its corresponding financial ranking $Rank_{i,t}^{Factor}$ through an equally weighted average:

$$Rank_{i,t}^{ESG-Factor} = 0.5 \times Rank_{i,t}^{Factor} + 0.5 \times Rank_{i,t}^{ESG} \quad (1)$$

This procedure effectively shifts portfolio composition toward firms that are simultaneously attractive on the financial factor and well-aligned with ESG principles. The equal weighting ensures that sustainability does not dominate the financial signal, preserving comparability with traditional factor construction.

After ranking firms based on the combined score, we again form terciles and compute the return differential between the top and bottom groups, generating monthly ESG-adjusted factor returns for each region. Thus, for every month and region, we obtain six time series: the conventional and ESG-integrated versions of the value, size, and momentum factors.

A substantial body of research has investigated ESG-based investment strategies and has tried to define this strategy in an alternative way than value, momentum, and size strategies. For instance, Nagy, Kassam, & Lee (2016) proposed an ESG tilt strategy within the MSCI World Index framework, systematically overweighting firms with stronger ESG profiles based on MSCI ESG ratings. Beyond the use of static ESG scores, the literature has also explored ESG momentum strategies, which capitalize on changes in ESG performance over time. Notably, Magnani, Guidolin, & Berk (2023) examined the profitability of ESG momentum and ESG volatility strategies in the European equity market, sorting stocks into quintiles based on rank-neutralized changes in ESG ratings over varying time horizons. In this study, we adopt a dual-ranking approach for the construction of ESG portfolios. Specifically, each stock in our sample two distinct rankings are assigned: the first based on traditional style factors – value, momentum, and size – and the second based on its ESG score as provided by LSEG Workspace. The final composite ranking for each stock is then computed as the simple average of these two ranks. It is important to note that both the ESG and non-ESG portfolios are composed of the same set of securities; what differentiates them depends on the average ranking assumed by each asset and therefore its respective position in portfolio construction. For example, a stock might exhibit a high ranking based on its value, momentum, or size characteristics but simultaneously receive a poor ESG score. Since the overall ranking is determined by averaging these two dimensions, it is entirely possible for such a stock to be assigned to a short position in the ESG portfolio, despite its strong financial factor attributes.

4.3 ESG vs non-ESG strategy returns: descriptive statistics

Table 1 reports the monthly mean returns, corresponding t-statistics, and standard deviations for the 21 high-minus-low (HML) portfolios within each equity market. These portfolios correspond to the value, size, and momentum strategies constructed as described earlier. The table also presents statistics for the Global Stock Market, computed as the average of the monthly returns of the respective strategies across all six regional markets. For each portfolio, the Sharpe ratio is reported, calculated as the ratio of the portfolio's excess return to its standard deviation. To ensure cross-market comparability and maintain consistency between the dependent variables (portfolio returns) and the macroeconomic factors used as independent variables, excess returns are measured relative to a global risk-free rate. The global short-term risk-free rate is computed as the market-capitalization-weighted average of the individual countries' short-term interest rates. For the United States, we employ the 1-month Treasury bill rate from Ibbotson Associates, while for all other markets, we use short-term rates obtained from the LSEG Workspace database. The table also reports the p-values from the Mann-Whitney test, used to assess whether the differences in mean returns between the ESG-filtered and non-ESG-filtered strategies are statistically significant. In addition, we report the p-values from Levene's test to evaluate whether the differences in return volatilities between the two strategies are statistically significant.

The results point to a heterogeneous impact of ESG integration, with varying significance depending on market and strategy.

Starting with the value strategy, the results consistently indicate that the integration of ESG considerations reduces both the average returns and Sharpe ratios across many markets. These differences are statistically significant in Continental Europe, the United Kingdom, the United States, and Emerging Markets, as confirmed by the Mann–Whitney test. Volatility differences in Continental Europe and in the United States are also significant, as indicated by Levene's test, suggesting that ESG screening affects not only expected returns but also the distribution of returns. These findings align with those of Blitz & Fabozzi (2017), who document that the exclusion of sin stocks and low-ESG-rated firms from value portfolios can materially dilute value premia, especially when the excluded firms are those that exhibit characteristics typical of deep value opportunities. Moreover, Pedersen, Fitzgibbons, & Pomorski (2021) argue that ESG-imposed constraints tend to shift portfolios away from less ESG-compliant (often undervalued) stocks, potentially eroding the contrarian mechanism underpinning value investing. The significant underperformance of ESG value strategies at the global level further supports the argument that ESG integration introduces a systematic tilt away from traditional value exposures.

The impact of ESG filtering on size strategy is mixed and country dependent. At the global level, the difference in average returns between ESG and non-ESG portfolios is statistically significant, suggesting that ESG integration materially affects performance in aggregate. In the U.S. and Continental Europe markets, the ESG-filtered size strategy delivers a slightly higher average return than its non-ESG counterpart, although this difference is not statistically significant. However, the ESG portfolios exhibit significantly lower return volatility, resulting in a higher Sharpe ratio. This suggests that the performance enhancement is risk-driven rather than return-driven, consistent with the findings of Albuquerque, Koskinen, & Zhang (2019), who document lower downside risk for high-ESG firms. In contrast, other markets show marginal or no statistically significant differences:

Japan hints at potential effects, while Canada, the U.K., and Emerging Markets display p-values above 0.1, with broadly similar Sharpe ratios across ESG and non-ESG portfolios. This pattern highlights that ESG integration in size-based strategies may primarily contribute to volatility reduction rather than uniformly altering returns. Moreover, this heterogeneity across regions implies that the effect of ESG screening on size-based strategies is not uniform and may reflect differences in ESG disclosure standards, market structure, or investor preferences across geographies.

Performance differences in momentum strategies reflect a heterogeneous, context-dependent impact of ESG filters. In Continental Europe, ESG portfolios underperform both in average return and risk adjustment, supporting findings by Nagy, Kassam, & Lee (2016), who demonstrate that ESG filters may exclude recent winners with lower ESG scores, thereby impairing momentum performance. In Emerging Markets, returns are lower for ESG, but the difference lacks statistical significance. Conversely, in Canada, the U.S., and Japan, ESG-filtered momentum portfolios deliver comparable or slightly improved Sharpe ratios, although differences in mean returns are not statistically significant. Levene's test does not show consistent volatility effects across these markets. This suggests that while ESG integration can dampen momentum returns in some regions, it does not uniformly degrade performance across all markets and may even support tail-risk management in certain contexts. Such findings echo those of Giese et al. (2019), who propose that ESG integration can stabilize return distributions and enhance risk-adjusted returns.

Taken together, the empirical evidence underscores a strategic and market-sensitive impact of ESG filtering on factor premium. ESG integration significantly penalizes value strategies, particularly in regions that are rich in undervalued and low-ESG firms. For size strategies, the main benefit appears to be the volatility reduction, notably in the U.S., whereas other markets show limited effects. For momentum, the impact is variable: negative in regions where ESG and recent winners diverge, but neutral or even mildly positive in others. Crucially, the combined use of Mann–Whitney and Levene's tests is essential for distinguishing statistically robust ESG effects from random variation. This nuanced understanding challenges the view of ESG integration as uniformly costly or neutral, instead positioning it as a factor-aware approach whose implications vary across markets and return drivers.

Table 1

Performance and risk of value, size, and momentum strategies across markets with and without ESG-filters.

		Value Strategy		Size Strategy		Momentum Strategy	
		ESG	NON ESG	ESG	NON ESG	ESG	NON ESG
Canada stocks	Mean	0.48%	0.24%	0.73%	1.02%	0.04%	-0.04%
	(*t*-stat)	(1.244)	(0.775)	(2.318)	(2.639)	(0.142)	(-0.075)
	p-value	0.639		0.768		0.835	
	Stdev	6.25%	4.85%	5.11%	6.00%	4.32%	8.19%
	p-value	0.777		0.210		0.001	
	Sharpe ratio	0.077	0.050	0.143	0.170	0.009	-0.005
Continental Europe stocks	Mean	-0.01%	0.19%	0.29%	0.57%	0.22%	0.55%
	(*t*-stat)	(-0.041)	(1.149)	(2.584)	(4.023)	(1.416)	(2.353)
	p-value	0.002		0.058		0.002	
	Stdev	2.27%	2.62%	1.85%	2.20%	2.50%	3.59%
	p-value	0.02		0.005		0.001	
	Sharpe ratio	-0.003	0.074	0.159	0.260	0.087	0.152
Emerging Markets stocks	Mean	-0.34%	0.27%	0.43%	1.12%	-0.24%	0.02%
	(*t*-stat)	(-1.151)	(0.957)	(2.056)	(2.639)	(-0.859)	(0.080)
	p-value	0.034		0.027		0.631	
	Stdev	4.80%	4.35%	3.43%	4.77%	4.60%	4.77%
	p-value	0.285		0.053		0.389	
	Sharpe ratio	-0.071	0.062	0.127	0.235	-0.053	0.005
Japan stocks	Mean	0.17%	0.29%	0.25%	0.48%	-0.11%	-0.21%
	(*t*-stat)	(0.859)	(1.369)	(1.417)	(3.380)	(-0.594)	(-0.895)
	p-value	0.637		0.827		0.963	
	Stdev	3.14%	3.28%	2.93%	2.18%	2.94%	3.72%
	p-value	0.705		0.158		0.008	
	Sharpe ratio	0.053	0.088	0.087	0.218	-0.037	-0.058

		Value Strategy		Size Strategy		Momentum Strategy	
		ESG	NON ESG	ESG	NON ESG	ESG	NON ESG
U.K. stocks	Mean	0.17%	0.35%	0.35%	0.52%	0.13%	0.25%
	(*t*-stat)	(1.170)	(2.001)	(2.973)	(2.802)	(0.696)	(1.047)
	p-value	0.008		0.227		0.09	
	Stdev	2.40%	2.74%	1.94%	2.85%	2.98%	3.70%
	p-value	0.270		0.036		0.089	
	Sharpe	0.072	0.129	0.183	0.181	0.043	0.068
U.S. stocks	Mean	0.21%	0.36%	0.47%	0.58%	0.06%	0.00%
	(*t*-stat)	(1.503)	(2.048)	(4.353)	(3.271)	(0,082)	(0.005)
	p-value	0.045		0.983		0.951	
	Stdev	2.09%	2.71%	1.76%	2.72%	2.73%	3.21%
	p-value	0.020		0.001		0.016	
	Sharpe	0.055	0.132	0.289	0.211	0.005	0.000
Global stocks	Mean	0.11%	0.36%	0.42%	0.63%	0.02%	0.09%
	(*t*-stat)	(0.908)	(2.573)	(4.345)	(5.282)	(0.131)	(0.499)
	p-value	0.006		0.002		0.310	
	Stdev	2.04%	2.25%	1.58%	1.94%	1.94%	2.99%
	p-value	0.339		0.107		0.001	
	Sharpe	0.056	0.001	0.267	0.001	0.008	0.002

4.4 Global Macroeconomic Risk Factors

This study aims to establish a common factor structure across markets linked to underlying global macroeconomic risk sources. A noteworthy aspect of the presented factor model is to measure risk as exposure to macroeconomic conditions impacting cash flows and discount rates, as discussed in CRR. While we acknowledge that the subsequent literature has introduced and used a wide range of alternative macroeconomic risk factors – such as liquidity risk (Amihud & Mendelson, 1986), or geopolitical risk (Caldara & Iacoviello, 2018) – we continue to use CRR risk factors since equity prices in financial markets are ultimately driven by those fundamental forces that directly affect expectations regarding economic growth or inflation dynamics. For instance, while geopolitical risk may indeed exert an influence on asset prices, its effects materialize primarily when such events alter market expectations about future economic growth or inflationary pressures. A pertinent example is the different market impact observed between the Russia-Ukraine conflict, which had substantial implications for global growth and inflation expectations, and the Israel-Palestine conflict, which did not materially affect those macroeconomic variables. For these reasons, we argue that the original macroeconomic factors identified by CRR remain highly effective in capturing the key drivers of equity returns in global financial markets. Their framework continues to offer a comprehensive and parsimonious representation of the macroeconomic risks that ultimately shape asset pricing.

Given that the primary objective of this paper is to investigate whether the returns of value, momentum, and size strategies exhibit differential sensitivity to macroeconomic risk factors depending on the application of an ESG filter, we extend the original Chen, Roll, & Ross (1986) model by introducing an additional explanatory variable: the Environmental Performance Index (EPI). This variable is included to assess whether the returns of the three strategies are not only influenced by macroeconomic risks, but also by the extent to which countries achieve their targets related to climate change mitigation, environmental health, and ecosystem vitality. The EPI, developed by Yale University and Columbia University in collaboration with the World Economic Forum, was designed to support the environmental objectives set by the United Nations. It leverages 58 performance indicators across 11 categories to rank 180 countries according to their environmental outcomes in areas such as climate policy, ecosystem vitality, and environmental health. The EPI thus provides a comprehensive, country-level measure of proximity to internationally recognized environmental policy goals. Incorporating the EPI into the model allows us to explore whether investment strategies integrating ESG considerations display distinct return sensitivities to environmental policy performance, thereby offering new insights into the intersection between financial markets and sustainability-oriented public policy.

As in Matteucci & Venanzi (2025), the macroeconomic factors in our model are computed as market capitalization-weighted averages of the CRR factors and EPI factor across the 26 countries included in the sample.

The macroeconomic factors included in the Chen, Roll, and Ross (1986) framework comprise five variables: the growth rate of industrial production (MP), unexpected inflation (UI), the change in expected inflation (DEI), shifts in the yield curve (UTS), and changes in the default risk premium (UPR). Each factor is constructed following standard definitions in the multifactor asset pricing literature.

The industrial production growth rate is measured as the monthly logarithmic change in the global index of industrial production, with data obtained from the OECD statistics database. Unexpected and expected inflation components are computed in line with Chen, Roll, and Ross (1986). Inflation is defined as the logarithmic change in the seasonally adjusted Consumer Price Index (CPI), sourced from the U.S. Bureau of Labor Statistics for the United States and from LSEG Workspace for the other countries. The expected inflation component is estimated following Fama and Gibbons (1984), as the difference between the short-term nominal interest rate and the expected real rate. The short-term nominal rate is calculated as a market capitalization–weighted average of individual country short-term rates. For the United States, the one-month Treasury bill rate from Ibbotson Associates is used, while for the remaining countries the corresponding short-term rates are taken from LSEG Workspace, consistent with Cooper, Mitrache, and Priestley (2022). The expected real interest rate is estimated using the Fama and Gibbons (1984) approach, which models changes in the real rate as a first-order moving average process, following the Box and Jenkins (1976) methodology. This procedure allows the identification of an ARIMA (0,0,1) model for the dynamics of the real rate. The global term structure factor (UTS) is computed as the market capitalization–weighted spread between long-term and short-term government bond yields. Long-term rates for the United States are obtained from the Federal Reserve Bank of St. Louis, while rates for all other markets are collected from LSEG Workspace. Due to the limited international coverage of corporate bond yield data, the default risk factor (UPR) is proxied by the U.S. default spread, defined as the difference between Moody's Baa and Aaa corporate bond yields, with data sourced from LSEG Workspace. Finally, the Environmental Performance Index (EPI) is measured as the market capitalization–weighted annual variation in the index, also obtained from LSEG Workspace.

5. The empirical test: design and results

This section's objective is to test whether global macroeconomic factors along with EPI factor affect the risk and return of both investment strategies. The objective is first to test whether there is a statistically significant effect and then to try to understand whether this effect could explain the lower return and risk yielded by ESG strategies. The aim of this section is to test if the ESG-integrated strategies show less sensitivity to macroeconomic risk factors than their non-ESG counterparts and hence whether the ESG-aligned companies are less vulnerable to macroeconomic shocks due to their emphasis on sustainability, robust governance, and long-term resilience.

5.1 The tested model

Factor models, grounded in a solid academic background, offer a comprehensive framework for analyzing the systematic drivers underlying the cross-section of asset returns. Linear factor models, as a specific application of Arbitrage Pricing Theory (Ross, 1976), assume that an asset's return can be expressed as a linear combination of the fundamental risk factors. The research in climate finance that uses factor models to examine stock returns in cross-section analyses typically relies on portfolios rather than individual stocks. This preference is often justified by the enhanced stability of beta estimations achieved through portfolio aggregation (Petersen, 2009).

Global macroeconomic variables are utilized to form the global CRR factors, aiming to identify sources of macroeconomic risk on a global scale. Following Matteucci & Venanzi (2025), factors are given by the market capitalization-weighted averages of the CRR factors of the 26 countries in our sample. The factors of the CRR model are the following: *i*) the industrial production growth rate (MP); *ii*) the unexpected inflation (UI); *iii*) the change in expected inflation (DEI); *iv*) the yield curve shifts (UTS); *v*) the changes in default risk premium (UPR).

Since the empirical evidence introduces a degree of ambiguity in understanding how climate change risks influence the specification of asset pricing models and, consequently, the theoretical predictions of macro-financial frameworks, we decided to integrate in the model the EPI index with the five CRR macroeconomic factors.

The model is estimated by using the cross-sectional regression methodology à la Black, Jensen, & Scholes (1972), which follows two steps. The first step involves a time-series regression over the period June 2001 – June 2023 of the value, size, and momentum portfolios' excess returns on the six independent variables using the entire sample period:

$$r_{i,t} = \alpha_i + \beta_{i,MP}MP_t + \beta_{i,UI}UI_t + \beta_{i,DEI}DEI_t + \beta_{i,UTS}UTS_t + \beta_{i,UPR}UPR_t + \beta_{i,EPI}EPI_t + \varepsilon_{i,t} \quad (2)$$

The second step involves the estimation of the risk premium associated with each independent variable through a single cross-sectional regression of the average excess returns of each portfolio on the factor loadings estimated in the time series regressions.

$$\bar{r}_i = \lambda_0 + \hat{\beta}_{i,MP}\lambda_{MP} + \hat{\beta}_{i,UI}\lambda_{UI} + \hat{\beta}_{i,DEI}\lambda_{DEI} + \hat{\beta}_{i,UTS}\lambda_{UTS} + \hat{\beta}_{i,UPR}\lambda_{UPR} + \hat{\beta}_{i,EPI}\lambda_{EPI} + \eta_i \quad (3)$$

where:

- $\bar{r}_i$ denotes the average excess return on portfolio i.
- λ_{MP}, λ_{UI}, λ_{DEI}, λ_{UTS}, λ_{UPR}, λ_{EPI} represent the estimated risk premia associated respectively with global industrial production growth, unexpected inflation, changes in expected inflation, yield curve shifts, the default spread, and the Environmental Performance Index factors.
- $\hat{\beta}_{i,MP}$, $\hat{\beta}_{i,UI}$, $\hat{\beta}_{i,DEI}$, $\hat{\beta}_{i,UTS}$, $\hat{\beta}_{i,UPR}$, $\hat{\beta}_{i,EPI}$ correspond to the portfolio-specific factor loadings obtained from the time-series regressions on the respective macroeconomic factors.
- η_i captures the residual component of the cross-sectional regression, representing the pricing error not explained by the model.

Finally, it is worth noting that both steps of the regression analysis are conducted on two separate samples: one incorporating ESG screening criteria and one without any ESG filter. This dual approach allows us to rigorously assess whether and how the application of ESG filters alters the sensitivity of factor-based strategies to macroeconomic risk factors and overall performance characteristics.

5.2 The empirical results

Tables 2 and 3 report the estimated prices of risk associated with five global macroeconomic factors derived from Chen, Roll, and Ross (1986), along with the Environmental Performance Index (EPI) factor. The estimates are obtained from the second step of the two-step regression methodology proposed by Black, Jensen, and Scholes (1972), applied separately to ESG-integrated and non-ESG strategies. The test assets consist of the average excess returns of 54 long-only portfolios sorted by value, size, and momentum characteristics. In the first stage, portfolio factor loadings are estimated from time-series regressions of portfolio excess returns on the five CRR factors plus the EPI factor, using the full sample period from June 2001 to June 2023. In the second stage, the risk premia are obtained from a cross-sectional regression of the average portfolio returns on the estimated betas from the first stage.

Despite the relatively high correlation between UI and DEI variables – with a pairwise correlation coefficient of 0.83 – we retained both variables in the model, following the original specification of CRR. As discussed in the econometrics literature, such correlation levels do not necessarily induce severe multicollinearity or distort inference. To formally assess this issue, we computed both variance inflation factors (VIFs) and the condition index proposed by Belsley, Kuh, & Welsch (1980). All VIFs were below the commonly accepted threshold of 10, and the maximum condition index was 7.76 – well below the threshold of 30 typically associated with moderate to severe collinearity –

indicating that multicollinearity does not materially affect the estimates. Nonetheless, as a robustness check, we also re-estimated the model excluding the UI factor, obtaining qualitatively similar results.

To further assess the reliability of the cross-sectional regression estimates, we examined two standard assumptions: homoscedasticity and normality of residuals. First, we conducted White's test for heteroscedasticity. The test statistic was 34.95 ($p = 0.1402$) for the ESG sample and 31.57 ($p = 0.2484$) for the non-ESG sample, indicating that the null hypothesis of homoskedasticity could not be rejected. Second, the residuals were tested for normality using a Chi-square test, which yielded a test statistic of 2.03 ($p = 0.363$) for the ESG sample and 1.06 ($p = 0.589$) for the non-ESG sample, again supporting the null hypothesis. Taken together, these diagnostics suggest that the assumptions underpinning linear cross-sectional regression are not violated, reinforcing the robustness of the second-pass estimation.

For the ESG subsample, the prices of risk associated with MP, DEI, UTS, UPR, and EPI are statistically significant. Analyzing the results, we can state that for each unit of portfolio beta associated with the MP, DEI, UTS, UPR, and EPI factors, that unit contributes 2.2071, 0.1572, 1.7643, 0.2084, and -4.0793 monthly, respectively, to the portfolio average excess return. Therefore, in phases of rising industrial production, for example, we expect that on average, for each unit of beta in our portfolio associated with the MP factor, the portfolio will gain 2.2071 monthly, while in phases of rising inflation expectations we expect that for each unit of beta in our portfolio associated with the DEI factor, the portfolio will gain on average 0.1572 monthly.

For the non-ESG subsample, the prices of risk associated with MP, UTS, and EPI are statistically significant. Analyzing the results, we can state that for each unit of portfolio beta associated with the MP, UTS, and EPI factors, that unit contributes 2.2528, 1.8180, and -5.4383 monthly, respectively, to the portfolio average excess return. Therefore, in phases of rising industrial production, for example, we expect that on average, for each unit of beta in our portfolio associated with the MP factor, the portfolio will gain 2.2528 monthly, while in phases of rising of the yield curve we expect that for each unit of beta in our portfolio associated with the UTS factor, the portfolio will gain on average 1.8180 monthly.

Across both tables, the industrial production growth (MP) and term spread (UTS) factors are highly significant, consistent with prior literature identifying them as key global sources of priced macroeconomic risk (Chen, Ross, & Roll, 1986; Ferson & Harvey, 1991).

The MP factor shows strong and highly significant pricing power in both ESG and non-ESG subsamples. In both models, the coefficient is positive and highly significant, indicating that exposure to industrial production growth is rewarded with a risk premium. The magnitude is higher in the non-ESG portfolios, suggesting they are more sensitive to business cycle conditions and benefit more (in expected return terms) from positive economic shocks. This difference may reflect the sectoral composition of non-ESG portfolios, which tend to be more concentrated in cyclical, capital-intensive industries (e.g., traditional energy, basic materials, heavy transport and aviation) that are closely tied to fluctuations in real activity. By contrast, ESG-integrated portfolios may overweight sectors with more stable cash flows (e.g., healthcare, IT and communication), resulting in a somewhat lower – but still significant – exposure to industrial production growth risk.

Table 2

Estimates of prices of risk for ESG-integrated portfolios from the cross-sectional asset pricing test.

	coefficient	std. error	t-stat	p-value	
const	0.3658	0.0023	1.6018	1.16E-01	
λMP	2.2071	0.0043	5.1775	4.60519E-06	***
λUI	0.1821	0.0011	1.6701	0.101537457	
λDEI	0.1572	0.0009	1.7365	0.0890267	*
λUTS	1.7643	0.0022	7.9087	3.48708E-10	***
λUPR	0.2084	0.0007	2.8158	7.09E-03	***
λEPI	-4.0793	0.0187	-2.1799	3.43E-02	**

R-squared 0.8718 Adjusted R-squared 0.8554

HAC standard errors, bandwidth 5, Kernel of Bartlett
White test for heteroscedasticity -
Null hypothesis: absence of heteroscedasticity
Test statistics: LM = 34.9468
with p-value = P (Chi-square (27) > 34.9468) = 0.1402

Test for normality of residuals -
Null hypotesis: error is normally distributed
Test statistics: Chi-square (2) = 2.025
with p-value = 0.36335

This pattern is consistent with Ferson & Harvey (1991) and Petkova & Zhang (2005), who find that production-based macro factors strongly price cross-sections of expected returns, especially in portfolios exposed to industrial cyclicality.

The term spread coefficient is slightly higher in non-ESG portfolios, again suggesting greater cyclical exposure. This reinforces the notion that ESG integration shifts portfolio exposures toward sectors and firms with more stable financing profiles, possibly less reliant on interest rate cycles. These findings also align with Koijen, Lustig, & Van Niewerburgh (2017), who show that term structure factors can differentially impact portfolios depending on their credit and duration sensitivities.

The non-ESG portfolios display an even stronger negative price of risk for EPI than ESG portfolios in both magnitude and statistical strength. This result suggests that environmental performance is a priced risk factor, regardless of ESG integration. However, the stronger (more negative) EPI price in non-ESG portfolios implies that portfolios without ESG filtering are more penalized in case of EPI reduction (i.e., the market asks for a higher price of risk per unit of EPI exposure). In contrast, ESG portfolios appear to be less exposed to this source of risk. Contrary to the common narrative that ESG integration increases exposure to sustainability-related risks and, potentially, to related premia, the results show that non-ESG portfolios carry greater exposure to negative environmental performance shocks. This may reflect the fact that such portfolios overweight sectors or firms with weaker environmental performance, which are more vulnerable to regulatory and reputational risks. This is consistent with Pastor, Stambaugh, & Taylor (2022), who argue that ESG preferences can push up prices (and lower expected returns) for ESG-friendly assets. Moreover, the negative price of EPI aligns with findings by Albuquerque, Koskinen, & Zhang (2019), who show that firms with strong ESG characteristics have lower systematic risk and are more resilient to macro shocks, suggesting that portfolios lacking ESG filters (Table 3) may demand a higher risk premium precisely because they are more exposed to environmental downside risk.

Table 3

Estimates of prices of risk for non-ESG-integrated portfolios from the cross-sectional asset pricing test.

	coefficient	std. error	t-stat	p-value	
const	0.3660	0.0027	1.3413	1.86E-01	
λMP	2.2528	0.0047	4.8271	1.5E-05	***
λUI	0.1014	0.0009	1.1004	0.27678	
λDEI	0.0795	0.0007	1.2097	0.23246	
λUTS	1.8180	0.0023	8.0614	2.1E-10	***
λUPR	0.0955	0.0010	0.9496	3.47E-01	
λEPI	-5.4383	0.0216	-2.5232	1.51E-02	**

R-squared 0.8739 Adjusted R-squared 0.8578

HAC standard errors, bandwidth 5, Kernel of Bartlett
White test for heteroscedasticity -
Null hypothesis: absence of heteroscedasticity
Test statistics: LM = 31.569
with p-value = P (Chi-square (27) > 31.569) = 0.248394

Test for normality of residuals -
Null hypotesis: error is normally distributed
Test statistics: Chi-square (2) = 1.056
with p-value = 0.58988

The UPR factor displays divergent pricing behavior across ESG and non-ESG portfolios. In ESG-integrated portfolios, the price of UPR is positive and statistically significant, indicating that exposure to credit risk is compensated with a return premium. In contrast, in the non-ESG portfolios, the UPR factor is not statistically significant, suggesting that credit risk is not systematically priced in this subset of portfolios. A possible explanation for the significant pricing of the default spread (UPR) factor in ESG-integrated portfolios, but not in their non-ESG counterparts, is that firms adhering to stronger ESG practices may become more vulnerable when credit conditions tighten. These firms often face higher operating costs associated with sustainability investments, compliance, and stakeholder engagement. During periods of rising default risk or constrained financing, these additional burdens may amplify earnings pressure and increase the sensitivity of such firms to credit risk. As a result, ESG-oriented portfolios may exhibit stronger exposure to systemic default risk premia, particularly in environments characterized by deteriorating credit markets. These findings suggest that the heightened sensitivity of ESG portfolios to the UPR factor may reflect not just sectoral tilts, but a deeper structural vulnerability: in periods of tightening credit, the operational and compliance costs associated with strong ESG implementation may exacerbate financial fragility. This interpretation aligns with emerging evidence in the literature that ESG adoption, while beneficial in the long term, may increase firms' short-term sensitivity to macro-financial stress when sustainability efforts are capital intensive and not immediately offset by higher cash flows (Cornell & Damodaran, 2020).

These findings point to a trade-off that characterizes ESG-integrated strategies: lower average returns are often accompanied by lower return volatility. While this pattern may appear suboptimal from a purely return-maximizing perspective, it should not be interpreted as a performance failure. Instead, it may reflect a deliberate investor preference for sustainability-aligned portfolios that prioritize long-term resilience over short-term alpha. The reduction in volatility observed in ESG portfolios, especially in macroeconomically relevant regions such as the U.S., U.K., and Continental Europe, coincides with geographies exhibiting higher Environmental Performance Index (EPI) scores. This suggests that in markets where ESG awareness is more developed, investors may be more willing to accept a lower return premium in exchange for reduced exposure to both idiosyncratic and systematic risk. In this context, the underperformance of ESG strategies relative to their non-ESG counterparts may signal not inefficiency, but rather a reprioritization of objectives: away from return maximization and toward risk containment and sustainability alignment.

6. Robustness tests

To give more robustness to the results obtained, a set of robustness tests were carried out.

The first robustness test involves the macroeconomic factors weights. By following Cooper, Mitrache, & Priestley (2022), it was decided to conduct the same tests, using GDP per capita as weight for the macroeconomic variables (instead of market capitalization used in the main analysis). Table 4 and 5 show how the results do not differ in terms of sign with macroeconomic variables (only the sign associated to UI variable is different from the main model, but the results are not statistically significant) but in terms of statistical significance of some macroeconomic variables. In the case of ESG-integrated portfolios, the MP risk factor loses its statistical significance, as does the DEI factor. At the same time, it is worth noting that the UPR factor becomes statistically significant even within the non-ESG sample. Nonetheless, these findings are consistent with those from the main model: ESG strategies exhibit greater sensitivity to the default spread compared to non-ESG strategies.

Since the high correlation between UI and DEI (0.83) factors we chose to run a cross-sectional regression without UI factor, to avoid any sort of multicollinearity problem. The results indicate no significant differences compared to the main model presented in Table 2 and 3, either in terms of the signs of the coefficients, nor of the model's R-squared, nor of the statistical significance of the coefficients[1].

Table 4

Estimates of prices of risk for ESG-integrated portfolios from the cross-sectional asset pricing test, with macroeconomic variables GDP per capita weighted.

	coefficient	std. error	t-stat	p-value	
const	-0.0036	0.0052	-0.0070	9.94E-01	*
λMP	1.3264	0.0079	1.6833	0.09894	
λUI	0.0183	0.0013	0.1421	0.8876	
λDEI	0.1496	0.0014	1.0515	0.2984	
λUTS	1.4466	0.0039	3.7466	0.00049	***
λUPR	0.8394	0.0025	3.3671	1.52E-03	***
λEPI	-2.9385	0.0211	-1.7948	1.70E-01	*

R-squared 0.7614 Adjusted R-squared 0.7309

HAC standard errors, bandwidth 5, Kernel of Bartlett
White test for heteroscedasticity -
Null hypothesis: absence of heteroscedasticity
Test statistics: LM = 34.9468
with p-value = P (Chi-square (27) > 29.8923) = 0.3190

Test for normality of residuals -
Null hypotesis: error is normally distributed
Test statistics: Chi-square (2) = 4.489
with p-value = 0.1060

[1] Data are omitted for brevity but are available upon request.

Finally, although Asness, Moskowitz, & Pedersen (2013) highlight that averaging across all markets and strategies mitigates much of the noise unrelated to portfolio strategies – such as idiosyncratic regional effects thus allowing for a clearer identification of common factors, and that such patterns become difficult to detect when attention is restricted to individual strategies, we nonetheless opted to run cross-sectional regressions on a strategy-by-strategy basis. Once again, the results obtained by regressing the average returns of each strategy (separately) on the time-series betas associated with each independent variable confirm the empirical findings from the main model[2].

Table 5

Estimates of prices of risk for non-ESG-integrated portfolios from the cross-sectional asset pricing test, with macroeconomic variables GDP per capita weighted.

	coefficient	std. error	t-stat	p-value	
const	0.1789	0.0045	0.3995	6.91E-01	
λMP	0.5787	0.0054	1.0742	0.28822	
λUI	-0.0915	0.0013	-0.6827	0.49812	
λDEI	0.0581	0.0013	0.4559	0.65056	
λUTS	1.6789	0.0040	4.1952	0.00012	***
λUPR	0.7090	0.0018	3.9390	2.70E-04	***
λEPI	-3.2948	0.0275	-1.9961	2.38E-01	*

R-squared 0.6939 Adjusted R-squared 0.6549

HAC standard errors, bandwidth 5, Kernel of Bartlett
White test for heteroscedasticity -
Null hypothesis: absence of heteroscedasticity
Test statistics: LM = 27.5717
with p-value = P (Chi-square (27) > 27.5717) = 0.4333

Test for normality of residuals -
Null hypotesis: error is normally distributed
Test statistics: Chi-square (2) = 4.056
with p-value = 0.5780

Conclusions

Our results indicate that ESG integration modestly reduces average returns and Sharpe ratios, especially in value and momentum strategies. However, these reductions are generally not statistically significant, and volatility often decreases – particularly in the U.S. and global portfolios – suggesting potential diversification benefits rather than outright performance deterioration. Turning to the pricing of macroeconomic risks, we find that several global factors – namely industrial production growth (MP) and term spread (UTS) – are consistently and significantly priced in both ESG and non-ESG portfolios. However, the estimated prices of these factors are slightly lower in the ESG sample, implying that ESG integration may reduce exposure to cyclical macroeconomic risk, potentially due to sectoral shifts toward more stable or intangible-intensive industries. Notably, the Environmental Performance Index (EPI) factor is priced in both portfolio sets, but with greater magnitude and statistical significance in the non-ESG sample. This suggests that portfolios not explicitly screened for ESG characteristics remain more exposed to environmental performance risk, requiring a higher premium to compensate for this vulnerability. Conversely, ESG-integrated portfolios may provide a partial hedge against such risks through intentional exposure to firms with stronger sustainability profiles. An additional insight arises from the differential pricing of the default spread (UPR): this

[2] Data are omitted for brevity but available upon request.

factor is statistically significant only in the ESG sample. One possible interpretation is that firms adhering to ESG standards may face higher operating costs and reduced financial flexibility, making them more sensitive to tightening credit conditions.

In summary, ESG integration does not uniformly enhance or impair performance. Rather, it reshapes the underlying macroeconomic risk exposures of factor-based strategies. Our evidence positions ESG not merely as a values-based screen, but as a structural transformation of portfolio sensitivity to macroeconomic and environmental shocks, a finding with important implications for investors seeking both sustainability alignment and risk-aware portfolio construction.

Finally, the empirical results produced by the current analysis could contribute to the development of a novel approach to the cost of capital estimation for environmental projects. Specifically, the objective would be to enhance the traditional Capital Asset Pricing Model (CAPM) framework by integrating the well-documented asset pricing anomalies identified by Fama & French (1993) and Carhart (1997), namely the value, momentum, and size factors. By incorporating these additional sources of systematic risk – whose pricing dynamics have been shown to vary significantly across ESG and non-ESG portfolios – the resulting cost of capital estimation would better reflect the true risk-adjusted return expectations of investors operating in this space. Formally, the proposed specification of the cost of capital would take the following form:

$$cost\ of\ capital = r_f + \beta_{Mkt}(E[R_{Mkt}] - r_f) + \beta_{MOM}^{ESG}\left(E\left[R_{MOM}^{ESG}\right] - r_f\right) + \beta_{VAL}^{ESG}\left(E\left[R_{VAL}^{ESG}\right] - r_f\right) + + \beta_{SIZE}^{ESG}\left(E\left[R_{SIZE}^{ESG}\right] - r_f\right) \quad (4)$$

where:

- β_{Mkt}, β_{MOM}^{ESG}, β_{VAL}^{ESG}, β_{SIZE}^{ESG} are respectively the sensitivity of the price of the variable under analysis (e.g., natural gas for electricity production) to the return on the market portfolio, to the return on the ESG-filtered momentum portfolio, to the return on the ESG-filtered value portfolio, and to the return on the ESG-filtered size portfolio.
- $E[R_{Mkt}]$, $E\left[R_{MOM}^{ESG}\right]$, $E\left[R_{VAL}^{ESG}\right]$, $E\left[R_{SIZE}^{ESG}\right]$ are respectively the expected return of the market portfolio, and the momentum, value, and size ESG-filtered portfolios.

Such an extension would provide a more theoretically consistent and empirically grounded framework for discounting future cash flows in retrofit investment analyses, thereby enhancing decision-making quality and aligning financial evaluation practices with advances in asset pricing theory.

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