



Factor investing and ESG scores: Risk-return when industry bias is corrected

Paolo Matteucci ^{*} , Daniela Venanzi 

Roma Tre University, Dept. of Economics, Rome, Italy

ARTICLE INFO

JEL classification:

G11
G12
G15
F44

Keywords:

ESG strategies
value
momentum
size
macroeconomic risk
asset management

ABSTRACT

This paper examines whether correcting ESG scores for industry affiliation alters the risk–return profile of factor-based investment strategies in international equity markets. Value, size, and momentum portfolios are constructed for six equity regions (the United States, the United Kingdom, Continental Europe, Japan, Canada, and Emerging Markets) over the period June 2001–June 2023, and portfolios based on conventional factor rankings are compared with portfolios that combine these rankings with an industry-relative ESG score designed to mitigate the sectoral component embedded in raw ESG ratings. The contribution of the study is to isolate the ESG signal from industry tilts and to assess its effect on portfolio allocation, volatility, and exposure to global macroeconomic risk – an interaction that the literature on ESG pricing and on factor investing has so far examined only separately. Using descriptive portfolio evidence and two-step cross-sectional asset-pricing tests, the analysis finds that industry-adjusted ESG strategies do not systematically improve average returns relative to their non-ESG counterparts, but are frequently associated with lower return volatility, particularly in developed markets. Industrial production growth and the term spread are priced sources of systematic risk in both samples, whereas the pricing of unexpected inflation, the default spread, and the Environmental Performance Index differs across the two designs. Overall, once industry effects are neutralized, ESG integration does not generate a distinct return premium but instead reshapes portfolio composition and reduces risk, with practical implications for the design of sustainable factor strategies and for the interpretation of ESG-based performance evidence.

1. Introduction

The rapid expansion of environmental, social, and governance (ESG) investing has intensified a long-standing debate on whether sustainability information adds an economically distinct dimension to portfolio construction or merely re-labels exposures already captured by conventional investment styles. The empirical literature is far from a consensus: some studies find no robust relation between ESG investments and returns (Halbritter and Dorfleitner, 2015), others attribute the lower expected returns of highly sustainable stocks to investor preferences and demand effects (Pastor et al., 2022; Stotz, 2021), and a parallel strand documents a return premium precisely on the firms that responsible investors tend to avoid (Hong and Kacperczyk, 2009; Blitz and Swinkels, 2021). The question becomes especially relevant when ESG scores are embedded into canonical factor strategies such as value, size, and momentum, because any observed performance difference may reflect either genuine sustainability effects or changes in the composition

^{*} Corresponding author.

E-mail addresses: paolo.matteucci@uniroma3.it (P. Matteucci), daniela.venanzi@uniroma3.it (D. Venanzi).

of the underlying portfolios.

A central complication is that ESG ratings are not purely firm specific indicators. Providers aggregate heterogeneous indicators through vendor-specific rules, so that the same firm can receive materially different assessments across rating agencies, and the materiality of environmental and social issues varies systematically across sectors. As a result, portfolio sorts based on raw ESG scores may partly capture sector-allocation effects rather than sustainability-related differences across comparable firms, making it difficult to establish whether ESG-based portfolios differ from conventional strategies because of sustainability screening per se or because of the industries that such screening tends to favor. Addressing this concern requires shifting the empirical focus from raw ESG levels to within-industry positioning, in the spirit of the industry-relative approach of [Kaiser \(2020\)](#).

These measurement issues are particularly important in an international setting and in the presence of macroeconomic and climate-related risk. A growing body of evidence indicates that environmental and transition risks are not fully spanned by traditional pricing factors ([In et al., 2017](#); [Jiang and Weng, 2019](#)), that exposure to climate-related shocks helps explain part of the variation usually attributed to style premia ([Balvers et al., 2017](#)), and that climate sensitivity is highly heterogeneous across portfolios ([Nagar and Schoenfeld, 2022](#)). A strategy that incorporates ESG information may therefore alter not only average returns and volatility, but also the way in which portfolios load on global sources of risk such as real activity, inflation surprises, term structure conditions, and environmental policy variables. Assessing whether an ESG overlay changes the macroeconomic pricing of factor portfolios thus calls for a portfolio design that isolates the ESG signal, as far as possible, from mechanical industry effects.

Against this background, this paper investigates whether correcting ESG scores for industry affiliation changes the properties of factor-based strategies in international equity markets. Standard value, size, and momentum portfolios are compared with portfolios formed by jointly considering the conventional factor ranking and an industry-adjusted ESG score derived from LSEG Refinitiv data. While previous work has examined ESG tilts within broad benchmarks ([Nagy et al., 2016](#)) and the role of ESG dynamics such as rating momentum ([Magnani et al., 2024](#)), the literature has largely treated ESG either as a stand-alone sorting dimension or as a conditioning variable in return regressions and has studied ESG pricing and macroeconomic-risk pricing in isolation. The contribution of this study is to bring these strands together: it evaluates whether an industry-neutralized sustainability signal materially affects portfolio returns, risk, and the cross-sectional pricing of global macroeconomic factors, building on the global macro-risk framework recently applied to style strategies by [Matteucci and Venanzi \(2025\)](#). The objective is therefore to identify the impact of ESG investing (with respect to conventional factor strategies) – if anything – once the sectoral component of raw ESG ratings is removed.

Methodologically, the analysis constructs, for each strategy and each of six equity regions, a conventional portfolio and an ESG-adjusted portfolio drawn from the same investment universe, the latter ranked on a composite signal that combines the factor characteristic with an industry-relative ESG score. The cross-sectional pricing of risk is estimated through the two-step procedure of [Black, Jensen, and Scholes \(1972\)](#), using the macroeconomic factors of [Chen, Roll, and Ross \(1986\)](#) augmented with an Environmental Performance Index factor. The results indicate that: *i*) industry-adjusted ESG strategies do not systematically improve average returns relative to their non-ESG counterparts, but are frequently associated with lower volatility, particularly in developed markets; *ii*) industrial production growth and the term spread are priced in both samples; *iii*) the pricing of unexpected inflation, the default spread, and the environmental factor differs across the two designs. These findings suggest that, once industry effects are neutralized, ESG integration operates primarily as a portfolio-reallocation and risk-management device rather than as an independent source of abnormal return, with implications both for the interpretation of ESG-based performance evidence and for the practical design of sustainable factor strategies.

The remainder of the paper is organized as follows. [Section 2](#) reviews and organizes the literature on ESG measurement, factor investing, and macroeconomic risk pricing. [Section 3](#) develops the empirical framework and the testable implications. [Section 4](#) describes the data, the construction of the industry-adjusted ESG portfolios, and the preliminary portfolio evidence. [Section 5](#) reports the macroeconomic risk pricing results and robustness checks. [Section 6](#) discusses the findings and [Section 7](#) concludes.

2. ESG measurement and portfolio investing in literature

Research at the intersection of ESG and asset pricing has expanded rapidly, yet it has not converged on whether sustainability is rewarded, penalized, or simply uncorrelated with expected returns; a useful way to read this body of work is to recognize that much of the disagreement is methodological rather than substantive. A first stream links the absence of a robust ESG premium to investor preferences: when sustainability-conscious investors are marginal, the prices of green assets are bid up and their expected returns compressed, generating a "greenium" ([Pastor et al., 2022](#); [Stotz, 2021](#)). A mirror-image stream studies the firms that responsible investors avoid and documents the opposite pattern, namely an excess return on sin or otherwise excluded stocks ([Hong and Kacperczyk, 2009](#); [Blitz and Swinkels, 2021](#); [Rezaeeian and Racine, 2024](#)). A third, more agnostic stream finds a weak or absent unconditional relation once standard risk controls are imposed ([Halbritter and Dorfleitner, 2015](#); [Bannier et al., 2023](#)); this conclusion has been reinforced by recent out-of-sample evidence that ESG information adds little measurable portfolio value once realistic implementation constraints are imposed ([Bruno et al., 2025](#)), and by S&P 500 evidence that low-rated portfolios outperform higher-rated ones in raw terms but become statistically indistinguishable once returns are risk-adjusted ([Carvalho et al., 2026](#)). Read together, these strands imply that whether ESG "matters" depends heavily on the dimension examined – price level versus expected return, screening versus tilt, raw versus adjusted scores – which is precisely the ambiguity this paper tries to reduce in terms of portfolio-construction.

A closely related question is whether the principal effect of ESG operates on risk rather than on average return. A substantial body of evidence associates stronger ESG profiles with lower risk along several dimensions: lower systematic and firm-specific risk ([Albuquerque et al., 2019](#)), more stable return distributions and reduced exposure to large drawdowns ([Giese et al., 2019](#)), and greater resilience during market-wide stress, particularly for industry-neutral high-ESG portfolios ([Broadstock et al., 2021](#)). The link extends to

downside and tail risk: [Ilhan et al. \(2021\)](#) show that the option-implied cost of protecting against downside tail risk is higher for carbon-intensive firms and varies with climate-policy uncertainty, indicating that environmental exposure is compensated through the tails rather than only through the mean. These findings motivate a clear taxonomy of the three interpretations that this paper seeks to discriminate among. Under the return-enhancement view, ESG conveys value-relevant information not yet impounded in prices and therefore predicts higher risk-adjusted returns; under the risk-mitigation view, ESG leaves average returns largely unchanged but lowers volatility, idiosyncratic risk, and downside exposure; and under the preference view, ESG simply relocates investors along the risk–return trade-off according to their non-pecuniary tastes. [Pedersen et al. \(2021\)](#) formalize the latter two channels in an ESG-efficient frontier, in which each ESG score is at once a signal about fundamentals and a determinant of preferences, and which traces the highest attainable Sharpe ratio for each ESG level. The evidence reported below speaks directly to this taxonomy: the industry-adjusted strategies examined here display the volatility-reducing signature of the risk-mitigation and preference channels rather than the return premium implied by the enhancement view.

A second body of studies traces this ambiguity back to measurement aspects, and it is the starting point for the present study. ESG ratings are noisy and provider-dependent: [Berg et al. \(2022\)](#) show that ratings from major agencies correlate only weakly and that most of the divergence stems from measurement rather than from differences in scope or weighting. A distinct but related problem is that raw scores are not purely firm-specific. Because the materiality of environmental and social issues varies across sectors, and because capital-intensive industries tend to score lower by construction, a raw ESG score partly captures the sector a firm operates in rather than the firm itself. As [Kaiser \(2020\)](#) documents, sorting portfolios on unadjusted ESG levels therefore embeds an implicit sector and size tilt: capital-intensive and larger firms tend to receive systematically different scores, so a portfolio built on raw ESG ends up loading on those characteristics rather than on sustainability as such. The response in the literature has been to neutralize these structural components, for instance by standardizing scores within industry and region or by recalculating ratings relative to the investable universe. Evidence that high-ESG portfolios constructed on an industry-neutral basis exhibit lower risk and greater resilience in stressed markets ([Broadstock et al., 2021](#)) supports the view that the informative content of ESG emerges more clearly once sectoral effects are removed. This paper adopts the same logic. The latter question connects with a fourth, and until recently largely separate, literature on the macroeconomic and climate-related pricing of equities. The cross-section of returns has long been related to global macro factors such as industrial production growth, inflation surprises, and term-structure and default-risk conditions ([Chen, Roll, and Ross, 1986](#); [Ferson and Harvey, 1991](#)), an approach extended to international factor strategies by [Cooper et al. \(2022\)](#) and [Matteucci and Venanzi \(2025\)](#). In parallel, a fast-growing climate-finance literature shows that environmental and transition risks are priced and are not fully spanned by traditional factors: temperature and decarbonization risks carry premia ([Balvers et al., 2017](#); [In et al., 2017](#); [Jiang and Weng, 2019](#)), climate sensitivity is highly heterogeneous across firms and portfolios ([Nagar and Schoenfeld, 2022](#)), and risks arising from the climate-policy debate are reflected in stock prices ([Faccini et al., 2023](#); [Chiang, 2025](#)). These two literatures rarely meet: macro-pricing studies seldom incorporate sustainability, while climate-finance studies rarely ask whether an ESG overlay changes the macroeconomic prices of risk borne by canonical factor portfolios.

Bringing these streams together motivates the contribution of this paper. The measurement literature implies that any credible ESG portfolio comparison must first remove the industry component of raw scores; the integration literature provides a transparent way to do so within factor strategies but stops short of including the macroeconomic dimension; and the macro- and climate-pricing literature shows that real-activity, credit, inflation, and environmental risks are priced but has not examined how they interact with an industry-neutralized ESG overlay. This paper sits at their intersection: it asks whether combining a conventional value, size, or momentum signal with an industry-relative ESG score, on the same international universe, changes portfolio returns, volatility, and – distinctively – the cross-sectional prices of global macroeconomic and environmental risks. In doing so it speaks both to the ESG-pricing debate, by showing where, if anywhere, an adjusted ESG factor adds or removes a premium, and to the climate-finance debate, by tracing how the overlay reshapes exposure to macro and environmental sources of risk.

3. Empirical framework and testable hypotheses

The empirical strategy is built around a simple question: does an industry-adjusted ESG overlay modify the economic profile of traditional factor portfolios? We address this question by comparing standard value, size, and momentum portfolios with alternative portfolios formed from a composite ranking that combines the relevant factor signal and an industry-relative ESG metric.

The first implication concerns portfolio performance. If the inclusion of an ESG screen excludes firms with high expected returns or shifts weight toward stocks with more defensive characteristics, the ESG-adjusted strategies may display lower mean returns than the corresponding unconstrained portfolios, a possibility consistent with the preference-driven greenium under which more sustainable assets command lower expected returns ([Pastor et al., 2022](#)). At the same time, the same reallocation may reduce return volatility and improve some dimensions of downside resilience. The paper therefore treats the effect of ESG integration as an empirical issue rather than presuming either a performance gain or a performance penalty.

A second implication concerns portfolio composition and comparability. Because the ESG overlay is applied to the same underlying investment universe used for the conventional factor portfolios, any observed difference between the two sets of strategies is driven by the ranking mechanism rather than by changes in the eligible asset pool. Holding the eligible pool fixed is especially valuable given the well-documented noise and divergence in ESG ratings ([Berg et al., 2022](#)), as it isolates the effect of the sustainability ranking from differences that would otherwise stem from the choice of rating provider. This feature makes it possible to attribute differences in returns and risk more directly to the interaction between factor characteristics and the ESG adjustment.

The third implication concerns risk pricing. If ESG-adjusted portfolios systematically tilt toward firms with different exposure to business-cycle conditions, credit conditions, inflation surprises, or environmental policy variables, then the estimated prices of

macroeconomic risk may differ from those obtained for the standard factor portfolios. This hypothesis connects the factor-pricing tradition (Chen, Roll, and Ross, 1986; Ferson and Harvey, 1991; Cooper et al., 2022; Matteucci and Venanzi, 2025) with the evidence that environmental and climate-policy risks are priced in the cross-section returns (Faccini et al., 2023; Chiang, 2025). The cross-sectional tests conducted in this paper aim at assessing whether this change occurs and, if so, which sources of risk are most affected.

The analysis is therefore organized around three testable implications:

1. When the industry-relative 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 and Kacperczyk, 2009; Bebchuk and 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 et al., 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 long demanded by national/regional institutional and regulatory setting.

4. Data and portfolio construction

The dataset employed in this study aims to examine the performance of value, momentum, and size strategies on a globally diversified sample. Specifically, for each of the three strategies, two distinct portfolios have been constructed: one that incorporates firms' ESG rankings and one that does not. To this end, the paper analyzes the performance of these strategies across a sample of 26 countries from six geographic areas around the world: Canada, Continental Europe, Emerging Markets, Japan, the United Kingdom, and the United States, covering the period from June 2001 – when ESG rankings first became available on LSEG Workspace – to June 2023.

The ESG measure used in this study is the LSEG Refinitiv ESG score. ESG ratings are known to embody substantial methodological discretion in the choice, weighting, and aggregation of indicators, and to disagree markedly across providers: Berg et al. (2022) report average pairwise correlations across major raters of only 0.38–0.71 and attribute most of the divergence to measurement rather than to scope or weighting. Two implications for the present empirical design follow. First, because raw scores conflate firm-level sustainability with sectoral composition, the analysis works with industry-relative scores. Second, the results should be read as limited on the rating framework utilized and not generalized; using one provider throughout removes cross-vendor noise from the comparison but makes the findings not necessarily portable to other rating contexts.

4.1. Sample and variables

We construct value, size, and momentum portfolios of individual equities traded globally across six equity markets: Canada, Continental Europe, Emerging Markets, Japan, the United Kingdom, and the United States. Securities are included in the sample if they exhibit: *i*) a positive price-to-book ratio; *ii*) available market capitalization data; *iii*) an ESG score, and *iv*) at least twelve months of total return history (including dividends). The sample spans the period from June 2001 to June 2023, on a monthly basis. Excluding firms with non-positive price-to-book ratios may introduce survivorship bias and affect parameter estimates (Heckman, 1979). Nevertheless, this restriction is consistent with the empirical asset pricing literature (Fama and French, 1993; Asness et al., 2013; Cooper et al., 2022; Matteucci and Venanzi, 2025) and is justified by the research objective to assess macroeconomic risk exposures in value-oriented strategies. As argued by Fama and French (1993), firms with negative price-to-book ratios typically exhibit negative equity due to accumulated losses, making them implausible components of investable value portfolios. Accordingly, a realistic value strategy excludes such firms.

The sample is open, allowing firms to enter or exit the eligible universe over time as they satisfy or fail to meet the selection criteria (e.g., firms with negative price-to-book ratios may be temporarily excluded and later reintroduced upon recovery). Potential survivorship bias is mitigated by the primary goal of developing a robust cross-sectional return model grounded in the price-to-book ratio, for which these exclusions are methodologically appropriate.

Data are obtained from the LSEG Workspace database. The sample includes all firms active during the observation period, irrespective of subsequent delisting. Following standard conventions, we exclude ADRs, REITs, financials, closed-end funds, foreign shares, and merged entities. Consistently with Asness et al. (2013) and Matteucci and Venanzi (2025), stocks are sorted each month by market capitalization, and those constituting the top 90% of cumulative market capitalization within each market are retained. This procedure ensures a sufficiently liquid investment universe and provides conservative, implementable estimates for real-world trading applications.

The Canadian sample includes common equities listed on the Toronto Stock Exchange, increasing from 8 firms in June 2001–254 by

June 2023. The Continental European sample comprises equities traded on the primary exchanges of Austria, Belgium, Denmark, Finland, France, Germany, Italy, the Netherlands, Norway, Portugal, Spain, and Sweden, expanding from 171 to 640 firms over the same period. The Emerging Markets sample includes firms listed in Australia, Brazil, China, Hong Kong, India, Russia, Singapore, South Africa, South Korea, and Taiwan. New Zealand is excluded due to missing macroeconomic data required for model construction. This subsample expands from 8 to 1634 firms. Given their size and development, Japan and Canada are treated as separate markets. The Japanese sample grows from 21 firms to 450 over the sample period. The United Kingdom sample expands from 73 to 311 firms, while the U.S. sample – comprising common equities listed on the NYSE and NASDAQ – increases from 261 to 1937 firms.

In total, the global dataset covers a maximum of 5226 and a minimum of 542 individual stocks across 26 countries over 22 years (264 monthly observations).

4.2. Construction of industry-adjusted ESG portfolios

The portfolio construction methodology differs between the two samples (with and without ESG-filters). However, the definitions of value, momentum, and size factors remain consistent within both. Specifically, the value strategy is based on the stock's price-to-book ratio recorded at the end of the previous year. For the size strategy, we use firm's market capitalization, measured in US dollars, as of June 30 of the year preceding the portfolio formation period. Regarding the momentum strategy, we follow the approach proposed by [Asness et al. \(2013\)](#), that employs the standard measure of cumulative raw returns over the prior 12 months, excluding the most recent month (commonly referred to as MOM2–12).

For the non-ESG-filtered portfolios, securities within each asset class are ranked according to their respective value, size, or momentum characteristics and subsequently assigned to one of three equally weighted terciles. This procedure yields three portfolios – low, middle, and high – within which all constituent stocks receive equal weights. Consequently, for each of the three factors (value, size, and momentum) and across the six equity markets, we construct a total of 54 test portfolios.

The performance of each factor strategy is measured as the return spread between the high and low portfolios based on the corresponding characteristic. To prevent potential underestimation of returns for value firms – which typically distribute higher dividends – and to maintain comparability across factor portfolios, all returns are expressed as shareholder total returns, including dividends.

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 et al. \(2016\)](#) 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 et al. \(2024\)](#) 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.

The construction of the ESG-adjusted portfolios follows a composite-ranking procedure in the spirit of [Asness et al. \(2013\)](#) and, more directly, of [Kaiser \(2020\)](#), who integrates style and ESG information by combining their ranks rather than by sorting on raw scores. For each market and each formation year, every eligible stock receives two ranks. The first, r_i^F , is its rank on the conventional factor signal $F \in \{\text{value, size, momentum}\}$, defined exactly as in the non-ESG portfolios. The second, r_i^{ESG} , is its rank on an industry-relative ESG score. To obtain the latter, the raw LSEG Refinitiv ESG score of firm i operating in industry j is normalized by the median ESG score of its industry:

$$ESG_i^{adj} = \frac{ESG_i}{\overline{ESG_j}} \quad (1)$$

so that the adjusted measure captures within-industry positioning rather than the absolute ESG level, thereby attenuating the sectoral component embedded in raw ratings ([Kaiser, 2020; Berg et al., 2022](#)). The composite ranking on which the ESG-adjusted portfolios are sorted is the simple average of the two ranks:

$$r_i^{comp} = 0.5 \ r_i^F + 0.5 \ r_i^{ESG} \quad (2)$$

Stocks are then assigned to equally weighted terciles on r_i^{comp} , exactly as the conventional portfolios are assigned on r_i^F . The high-minus-low strategy return is computed in the same way in both designs. The equal weighting of the two ranks is a deliberate, neutral benchmark: it lets the sustainability signal materially influence selection without subordinating either dimension to the other, and it avoids the discretion that any asymmetric weighting would introduce in the absence of a theoretical or empirical prior on the relative importance of the two components. This choice mirrors the 0.5/0.5 rank combination adopted by [Kaiser \(2020\)](#). However, this equal weighting in building portfolios could be criticized since it might weaken the relevance of the factor strategy.

A different weighting approach could be used. A double (independent or sequential) sort on the factor and the ESG dimension would partition the cross-section into a grid of bins; in an international setting with several regional samples that are thinly populated in the early part of the period (for instance, Canada and Japan contain few firms in the first years), such a grid would produce sparsely filled and unstable portfolios.

However, to address the concern that the equal weighting of the factor and ESG ranks might weaken the underlying factor strategy, we performed an additional robustness check.¹ First, for the value strategy, we verified that the ESG filter strengthens rather than

¹ Data are available upon request.

weakens the value effect. As for the momentum strategy, the spread in past returns is smaller for the ESG portfolios, but this is consistent with the characteristics of ESG investing. For the size strategy, the factor effect is strengthened or unchanged in Canada, the United Kingdom, Japan, and Continental Europe. Only in the United States and Emerging Markets the size effect is weaker for the ESG portfolios. However, in the United States this reduction does not translate into a statistically significant difference in returns between the ESG and non-ESG portfolios; it affects the return differences of the size strategy only in Emerging Markets.

It is important to make explicit what does and does not change between the two designs. The eligible universe is identical: the conventional and the ESG-adjusted portfolios are drawn from the same set of securities, screened with the same criteria, in every market and every year. The two designs do not differ in the weighting scheme either, since within each tercile constituents are equally weighted in both cases. What differs is the composition of the sorted portfolios – that is, which stocks populate the high, middle, and low terciles – because the composite ranking reorders the cross-section relative to the pure factor ranking. A stock with a strong factor score but a weak within-industry ESG score is pushed down by the averaging and may therefore enter the short (low) leg of the ESG-adjusted strategy even though it belongs to the long (high) leg of the conventional one, and conversely for stocks with weak factor but strong ESG positioning. Because the eligible pool and the weighting rule are held fixed, any difference in returns, volatility, or macroeconomic exposure between the two sets of strategies can be attributed to this reordering – the interaction between the factor characteristic and the industry-relative ESG signal – rather than to changes in the asset menu or to a mechanical re-weighting of identical holdings.

4.3. Portfolio characteristics and preliminary evidence

To assess whether the application of the industry-relative ESG filter enhances our analysis without introducing distortions, we compare the performance and risk of strategies based on the industry-adjusted ESG score with those relying on non-ESG portfolios. 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 mean returns of the industry relative-ESG and non-ESG strategies differ in a statistically significant manner. 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.

Table 1 shows the differences in mean returns and volatilities between the industry-relative ESG and non-ESG portfolios. Starting with the value strategy, the findings indicate that the integration of ESG considerations reduces both the average returns and volatility across all markets (except for the Japanese stock market returns). However, it is worth noting that the differences in returns between the two strategies are not statistically significant. On the other hand, volatility differences in Canada, Continental Europe, United States² and Global stock market are statistically significant, as indicated by Levene's test, suggesting that ESG screening affects the distribution of returns.

The impact of ESG filtering on size strategy is similar to that of value strategy. For Canada and Emerging Markets stocks the difference in average returns between ESG and non-ESG portfolios is statistically significant, suggesting that ESG integration materially affects performance in these markets. In the other markets, the non-ESG size strategy delivers a slightly higher average return than its ESG-filtered counterpart, although this difference is not statistically significant. However, the ESG portfolios exhibit significantly lower return volatility in Continental Europe and UK stock markets. This suggests that the performance enhancement is risk-driven rather than return-driven, consistent with the findings of Albuquerque et al. (2019), who document lower downside risk for high-ESG firms. In contrast, other markets show marginal or no statistically significant differences: Canada, Emerging Markets, Japan, and the US display p-values above 0.1. 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 countries.

Performance differences in momentum strategies are not statistically significant. Once again, Levene's test shows consistent volatility effects across all markets except for Emerging Markets. These results suggest that, while no clear pattern emerges in terms of returns, the addition of an ESG filter leads to significant reductions in portfolio volatility. Such findings echo those of Giese et al. (2019), who propose that ESG integration can stabilize return distributions and enhance risk-adjusted returns.

² The U.S. stance on the Paris Agreement shifted during the sample period – the withdrawal announced in 2017 and the re-entry in 2021 – and shifted again with the withdrawal ordered in January 2025, which lies outside our analysis window. For the two in-sample episodes we inspected the behavior of the strategy returns around these dates and found no departure from the general pattern documented in the paper. This is consistent with two mechanisms: the long-horizon investor base in these strategies tends to look through temporary policy reversals (Ramelli et al., 2021), and firms adjust their ESG-compliance posture over multi-year horizons rather than in response to individual political events, so any effect is unlikely to surface in short-horizon returns.

Table 1

Performance comparison between industry-adjusted ESG and conventional factor strategies.

		Value Strategy		Size Strategy		Momentum Strategy				Value Strategy		Size Strategy		Momentum Strategy	
		IR ESG	NON ESG	IR ESG	NON ESG	IR ESG	NON ESG			IR ESG	NON ESG	IR ESG	NON ESG	IR ESG	NON ESG
Canada stocks	Mean	0.19%	0.24%	0.67%	1.02%	0.04%	-0.04%	U.K. stocks	Mean	0.24%	0.35%	0.35%	0.52%	0.13%	0.25%
	(t-stat)	(0.750)	(0.775)	(2.054)	(2.639)	(1.022)	(-0.075)		(t-stat)	(1.686)	(2.001)	(2.517)	(2.802)	(0.781)	(1.047)
	p-value	0.972		0.030		0.508			p-value	0.419		0.247		0.464	
	Stdev	4.16%	4.85%	5.31%	6.00%	5.80%	8.19%		Stdev	2.29%	2.74%	2.25%	2.85%	2.65%	3.70%
	p-value	0.035		0.403		0.018			p-value	0.065		0.001		0.002	
	Sharpe ratio	0.046	0.050	0.126	0.170	0.063	-0.005		Sharpe ratio	0.104	0.129	0.155	0.181	0.048	0.068
Continental Europe stocks	Mean	0.12%	0.19%	0.32%	0.57%	0.28%	0.55%	U.S. stocks	Mean	0.18%	0.36%	0.47%	0.58%	0.04%	0.00%
	(t-stat)	(0.896)	(1.149)	(3.188)	(4.023)	(1.744)	(2.353)		(t-stat)	(1.416)	(2.048)	(4.353)	(3.271)	(0.261)	(0.005)
	p-value	0.677		0.293		0.180			p-value	0.281		0.937		0.936	
	Stdev	2.09%	2.62%	1.64%	2.20%	2.61%	3.59%		Stdev	2.03%	2.71%	1.76%	2.72%	2.54%	3.21%
	p-value	0.001		0.001		0.001			p-value	0.001		0.567		0.002	
	Sharpe ratio	0.055	0.074	0.196	0.260	0.107	0.152		Sharpe ratio	0.087	0.132	0.268	0.211	0.016	0.000
Emerging Markets stocks	Mean	-0.09%	0.27%	0.40%	1.10%	-0.26%	-0.03%	Global stocks	Mean	0.16%	0.36%	0.43%	0.63%	0.08%	0.09%
	(t-stat)	(-0.417)	(0.963)	(1.863)	(3.573)	(-0.944)	(-0.075)		(t-stat)	(1.443)	(2.573)	(4.511)	(5.282)	(0.605)	(0.499)
	p-value	0.523		0.0246		0.462			p-value	0.362		0.347		0.513	
	Stdev	3.49%	4.34%	3.50%	4.78%	4.40%	4.76%		Stdev	1.77%	2.25%	1.56%	1.94%	2.13%	2.99%
	p-value	0.701		0.809		0.428			p-value	0.008		0.106		0.005	
	Sharpe ratio	-0.026	0.062	0.115	0.231	-0.058	-0.006		Sharpe ratio	0.089	0.001	0.278	0.001	0.037	0.002
Japan stocks	Mean	0.31%	0.29%	0.39%	0.48%	-0.08%	-0.21%								
	(t-stat)	(1.774)	(1.369)	(2.720)	(3.380)	(-0.508)	(-0.895)								
	p-value	0.971		0.999		0.983									
	Stdev	2.85%	3.28%	2.32%	2.18%	2.61%	3.72%								
	p-value	0.073		0.723		0.001									
	Sharpe ratio	0.109	0.088	0.167	0.218	-0.031	-0.058								

Taken together, the findings show that across all three strategies the common pattern is a statistically significant reduction in volatility when the ESG filter is applied. Only in a few cases – mainly for strategies involving Emerging Markets, where firms could be less responsive to ESG issues – does this pattern not hold. By contrast, statistically significant excess returns are observed only in very limited circumstances (e.g., the size strategy in Canada and in Emerging Markets). This nuanced evidence challenges the view of ESG integration as uniformly costly or neutral: it suggests, on the contrary, to position it in a factor-aware approach, whose implications vary across markets and volatility drivers.

Two features of this evidence deserve emphasis. First, because the volatility reduction comes at no statistically significant cost in average return, it translates into an at-least-preserved, and frequently improved, risk-adjusted profile (Sharpe ratio) for the ESG-filtered strategies in the markets where it occurs. Second, those markets are systematically the more developed ones – the United States, the United Kingdom, Continental Europe, Canada, and Japan – which tend to rank higher on the Environmental Performance Index and to exhibit longer-standing regulatory pressure and stronger investor orientation toward sustainability, whereas Emerging Markets, where firms may be less responsive to ESG considerations, display the weakest and least significant effects. This regional gradient is consistent with cross-country differences in the role of sustainability that are documented at the institutional level (Liang and Renneboog, 2017) and that the EPI ranking of our regions captures in observable form.

Table 2 extends the single-strategy comparison of Table 1 to multi-factor portfolios, which more closely reflect how investors actually allocate. For each market we form the three pairwise combinations of the value, size, and momentum strategies – value-size (HML-SMB), value-momentum (HML-MOM), and momentum-size (MOM-SMB) – as equally weighted (50/50) blends, in both their industry-relative ESG and conventional versions, and report the monthly mean returns standard deviations, and Sharpe ratios of each combination together with the Mann-Whitney and Levene p-values (introduced in Table 1).

For the value–size combination, the ESG-adjusted blend earns a slightly lower mean return than its conventional counterpart in every market, but the difference is never statistically significant (Mann-Whitney p-values all above 0.10). Volatility, by contrast, is lower for the ESG blend in all markets and statistically significant in the United States, Continental Europe, Canada, and the Global market – and marginally in the United Kingdom and Japan – as indicated by Levene's test; only in Emerging Markets the volatility difference is not significant. The pattern reproduces, at the two-factor level, the value- and size-strategy results of Table 1.

The value–momentum combination shows the clearest return effect: in Continental Europe, Emerging Markets, and the Global market the conventional blend earns a significantly higher mean return than the ESG blend (Mann-Whitney $p = 0.033$, 0.002 , and 0.014 , respectively, and marginally so in the United States), reflecting the cost of tilting away from high-momentum but lower-ESG companies. Volatility is again lower for the ESG blend and more significantly so in the United States, the United Kingdom, and Canada; the exception is Japan, where the ESG blend is significantly more volatile. This is the combination in which the ESG overlay most visibly trades some return for lower risk.

For the momentum–size combination the return differences are uniformly insignificant (all Mann-Whitney p-values above 0.10), while volatility is significantly lower for the ESG blend in the United States, Canada, and the Global market; here the exception is Emerging Markets, where the ESG blend is significantly more volatile. As in Table 1, the dominant effect of the ESG overlay operates on risk rather than on return.

Taken together, Table 2 confirms at the multi-factor level the message of Table 1: combining factors does not overturn the basic pattern. Across the three combinations the ESG overlay leaves average returns statistically unchanged in the large majority of cases, while it lowers volatility – frequently to a statistically significant degree – in all but two market–combination cells (value–momentum in Japan and momentum–size in Emerging Markets), where it raises it. The volatility reduction of the blends is, moreover, larger than a simple average of the corresponding single-factor effects would imply, reflecting the imperfect correlation among the three strategies: because value, size, and momentum are far from perfectly correlated – value and momentum being typically negatively correlated in the conventional versions, consistent with Asness et al. (2013) – combining them already diversifies risk, and the industry-relative ESG filter compounds this through the additional sectoral diversification documented by the Herfindahl–Hirschman index. For an investor who realistically holds several factor exposures jointly rather than a single strategy, the practical implication is therefore the same as for the standalone strategies: an industry-relative ESG overlay reshapes the risk profile of multi-factor portfolios – reducing volatility at no significant cost in return in most markets – rather than delivering a return premium, echoing Giese et al. (2019).

The same regional gradient is, if anything, sharper for the combined strategies and is most visible in the risk dimension: the significant volatility reductions are concentrated in the developed, higher-EPI markets, while in Emerging Markets the volatility differences are insignificant for the value–size and value–momentum blends and, for the momentum–size blend, reverse sign – the ESG-filtered portfolio being significantly more volatile than its conventional counterpart. Read together with Table 1, this reinforces the interpretation that the risk-adjusted benefits of an industry-relative ESG overlay accrue in markets/countries where ESG issue is more targeted from an institutional perspective.

5. Macro-risk pricing results

This section examines whether the cross section of average returns on the test portfolios is explained by global macroeconomic factors and whether the estimated prices of risk differ between industry-adjusted ESG portfolios and traditional portfolios.

5.1. Econometric specification

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),

Table 2

Combo strategies performance comparison between industry-adjusted ESG and conventional factor strategies.

		HML-SMB		SMB-MOM		MOM-HML				HML-SMB		SMB-MOM		MOM-HML	
		IR ESG	NON ESG	IR ESG	NON ESG	IR ESG	NON ESG			IR ESG	NON ESG	IR ESG	NON ESG	IR ESG	NON ESG
Canada stocks	Mean	0.10%	0.17%	0.52%	-0.02%	0.10%	0.41%	U.K. stocks	Mean	0.12%	0.19%	0.24%	0.10%	0.12%	0.24%
	(t-stat)	(0.770)	(1.159)	(3.124)	(-0.079)	(0.770)	(2.303)		(t-stat)	(1.705)	(2.340)	(1.698)	(0.893)	(2.590)	(2.702)
	p-value	0.956		0.136		0.505			p-value	0.420		0.532		0.123	
	Stdev	2.10%	2.39%	2.69%	3.92%	2.07%	2.88%		Stdev	1.15%	1.35%	1.49%	1.80%	1.14%	1.41%
	p-value	0.036		0.023		0.011			p-value	0.063		0.001		0.147	
	Sharpe ratio	0.047	0.071	0.192	-0.005	0.047	0.142		Sharpe ratio	0.105	0.144	0.159	0.055	0.105	0.166
	Correlation	0.612	0.428	-0.533	-0.460	-0.294	-0.521		Correlation	0.335	0.407	-0.267	-0.048	-0.149	-0.306
Continental Europe stocks	Mean	0.06%	0.12%	0.30%	0.26%	0.06%	0.26%	U.S. stocks	Mean	0.09%	0.21%	0.24%	0.02%	0.09%	0.23%
	(t-stat)	(0.918)	(1.509)	(3.191)	(2.433)	(0.920)	(3.894)		(t-stat)	(1.446)	(2.502)	(2.997)	(0.167)	(1.420)	(2.785)
	p-value	0.673		0.888		0.033			p-value	0.280		0.233		0.086	
	Stdev	1.05%	1.31%	1.53%	1.75%	1.04%	1.08%		Stdev	1.02%	1.39%	1.29%	1.59%	1.02%	1.37%
	p-value	0.001		0.220		0.220			p-value	0.001		0.005		0.001	
	Sharpe ratio	0.057	0.093	0.196	0.150	0.057	0.240		Sharpe ratio	0.089	0.154	0.184	0.010	0.087	0.171
	Correlation	0.395	0.316	-0.011	0.013	-0.146	-0.297		Correlation	0.355	0.398	-0.342	-0.385	-0.043	-0.296
Emerging Markets stocks	Mean	-0.04%	0.20%	-0.05%	-0.01%	0.07%	0.52%	Global stocks	Mean	0.07%	0.15%	0.23%	0.05%	0.07%	0.27%
	(t-stat)	(-0.396)	(1.502)	(-0.377)	(-0.092)	(-0.428)	(3.649)		(t-stat)	(1.532)	(2.520)	(3.543)	(0.555)	(1.476)	(4.939)
	p-value	0.527		0.208		0.002			p-value	0.463		0.163		0.014	
	Stdev	1.76%	2.16%	3.18%	2.30%	1.75%	2.31%		Stdev	0.78%	0.97%	1.04%	1.37%	0.82%	0.88%
	p-value	0.718		0.006		0.002			p-value	0.019		0.004		0.630	
	Sharpe ratio	-0.024	0.092	0.023	-0.006	-0.026	0.225		Sharpe ratio	0.094	0.155	0.218	0.034	0.091	0.304
	Correlation	0.710	0.568	0.290	-0.519	0.302	-0.668		Correlation	-0.230	-0.436	-0.356	-0.279	0.647	0.534
Japan stocks	Mean	0.16%	0.19%	0.15%	-0.08%	0.15%	0.23%								
	(t-stat)	(1.786)	(1.851)	(1.381)	(-0.741)	(1.770)	(3.339)								
	p-value	0.971		0.159		0.738									
	Stdev	1.43%	1.65%	1.81%	1.85%	1.42%	1.10%								
	p-value	0.077		0.129		0.009									
	Sharpe ratio	0.110	0.114	0.085	-0.046	0.109	0.206								
	Correlation	0.691	0.447	0.067	-0.101	0.056	-0.222								

assume that an asset 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 and 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). 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 and Mendelson, 1986), or geopolitical risk (Caldara and Iacoviello, 2022) – we prefer to maintain the use of CRR risk factors since equity prices in financial markets are ultimately driven by fundamental forces that at the end affect expectations about 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 ultimately 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.

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. The EPI is a country-level measure of environmental performance produced by the Yale Center for Environmental Law and Policy and Columbia University's Center for International Earth Science Information Network, in collaboration with the World Economic Forum. It scores countries on a 0–100 scale – higher values denoting better performance – by aggregating a large set of indicators grouped into eleven issue categories under the three broad objectives of environmental health, ecosystem vitality, and climate change, so that the index captures each country's proximity to internationally recognized environmental-policy targets.³ Consistently with the treatment of the CRR factors, we build a single global EPI factor from the annual changes in the country-level index, aggregated using market-capitalization weights (Matteucci and Venanzi, 2025). The variable is included to assess whether the returns of the three strategies are influenced not only by macroeconomic risk but also by the extent to which countries meet their environmental targets, and hence whether strategies that integrate ESG considerations display distinct return sensitivities to environmental-policy performance – offering new insight into the intersection between financial markets and sustainability-oriented public policy. The model is estimated by using the cross-sectional regression methodology à la Black, Jensen, and 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:

$$r_{i,t} = \alpha_i + \beta_{i,MP}MP_t + \beta_{i,UI}UI_t + \beta_{i,DEI}DEI_t + \beta_{i,UTS}UTS_t + \beta_{i,UPR}UPR_t + \beta_{i,EPI}EPI_t + \varepsilon_{i,t} \quad (3)$$

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.

$$\bar{r}_i = \lambda_0 + \hat{\beta}_{i,MP}\lambda_{MP} + \hat{\beta}_{i,UI}\lambda_{UI} + \hat{\beta}_{i,DEI}\lambda_{DEI} + \hat{\beta}_{i,UTS}\lambda_{UTS} + \hat{\beta}_{i,UPR}\lambda_{UPR} + \hat{\beta}_{i,EPI}\lambda_{EPI} + \eta_i \quad (4)$$

where:

- $\bar{r}_i$ denotes the average excess return on portfolio i .
- $\lambda_{MP}, \lambda_{UI}, \lambda_{DEI}, \lambda_{UTS}, \lambda_{UPR}, \lambda_{EPI}$ 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 EPI 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, with and without the ESG filter. This 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.

³ To illustrate the cross-country dispersion the factor captures, among the regions used to form the test portfolios the United Kingdom (77.7) and the Continental European economies score highest – with the Nordic countries at the top (Denmark 77.9, Finland 76.5, Sweden 72.7), followed by the other economies (Netherlands 62.6, France 62.5, Germany 62.4, Italy 57.7) – while Japan (57.2), the United States (51.1), and Canada (50.0) are intermediate, and the Emerging Markets rank lowest (e.g., Brazil 43.6, Russia 37.5, South Africa 37.2, China 28.4, India 18.9).

5.2. Cross-sectional evidence

Table 3 and 4 report the estimated prices of risk associated with five global macroeconomic factors derived from Chen et al. (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 premium is 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 et al. (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, UI, UTS, and UPR are statistically significant. Analyzing the results, we can state that for each unit of portfolio beta associated with the MP, UI, UTS, and UPR factors, that unit contributes 1.1060, 0.4236, 1.6135, and 0.3281 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 1.1060 monthly.

For the non-ESG subsample, the risk premiums referred to MP, UTS, and EPI are statistically significant. Analyzing these 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.

In both samples, the industrial production growth (MP) and term spread (UTS) factors are significant, consistent with prior literature identifying them as key global sources of priced macroeconomic risk (Chen et al., 1986; Ferson and Harvey, 1991).

The MP factor, however, shows strong pricing power in non-ESG subsample. In both models, the coefficient is positive and 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 could be seen as the joint outcome of two complementary channels. First, by construction, the industry-relative overlay yields more sector-diversified portfolios: because the sustainability signal is measured within industry, it selects within-industry ESG leaders across all sectors instead of tilting toward a few "clean" ones, so the resulting portfolios are less concentrated – as documented by the Herfindahl–Hirschman index, which is lower for the industry-relative ESG portfolios than for

Table 3
Prices of global macroeconomic risk - industry-adjusted ESG portfolios.

	coefficient	std. error	t-stat	p-value	
const	0.3504	0.0042	0.8383	4.1E-01	***
$\hat{\lambda}$ MP	1.1060	0.0095	1.9639	2.5E-01	*
$\hat{\lambda}$ UI	0.4236	0.0007	6.3690	7.4E-08	***
$\hat{\lambda}$ DEI	0.0466	0.0010	0.4687	6.4E-01	
$\hat{\lambda}$ UTS	1.6135	0.0056	2.8964	5.7E-03	***
$\hat{\lambda}$ UPR	0.3281	0.0017	1.9021	6.3E-02	*
$\hat{\lambda}$ EPI	-2.6515	0.0326	-0.8122	4.2E-01	
R-squared	0.7526		Adjusted R-squared	0.7210	
HAC standard errors, bandwidth 5, Kernel of Bartlett					Test for normality of residuals -
White test for heteroscedasticity -					Null hypothesis: error is normally distributed
Null hypothesis: absence of heteroscedasticity					Test statistics: Chi-square (2) = 4.806
Test statistics: LM = 30.8292					with p-value = 0.0904
with p-value = P (Chi-square (27) > 30.8292) = 0.2782					

Table 4
Prices of global macroeconomic risk - conventional portfolios.

	coefficient	std. error	t-stat	p-value	
const	0.3660	0.0027	1.3413	1.9E-01	
$\hat{\lambda}$ MP	2.2528	0.0047	4.8271	1.5E-05	***
$\hat{\lambda}$ UI	0.1014	0.0009	1.1004	2.8E-01	
$\hat{\lambda}$ DEI	0.0795	0.0007	1.2097	2.3E-01	
$\hat{\lambda}$ UTS	1.8180	0.0023	8.0614	2.1E-10	***
$\hat{\lambda}$ UPR	0.0955	0.0010	0.9496	3.5E-01	
$\hat{\lambda}$ EPI	-5.4383	0.0216	-2.5232	1.5E-02	**
R-squared	0.8739		Adjusted R-squared	0.8578	
HAC standard errors, bandwidth 5, Kernel of Bartlett					Test for normality of residuals -
White test for heteroscedasticity -					Null hypothesis: error is normally distributed
Null hypothesis: absence of heteroscedasticity					Test statistics: Chi-square (2) = 1.056
Test statistics: LM = 31.569					with p-value = 0.58988
with p-value = P (Chi-square (27) > 31.569) = 0.248394					

their raw-ESG counterparts, the latter being in turn comparable to the non-ESG portfolios in this respect (Section 5.3) – and hence less exposed to the cyclical, capital-intensive sectors (traditional energy, basic materials, heavy transport and aviation) most tightly linked to real activity. Second, beyond composition, the ESG tilt selects firms with more resilient and less cyclically sensitive business models whose lower systematic risk (Albuquerque et al., 2019) further lowers sensitivity to real-activity shocks – a risk-levelling role of sustainability. This pattern is consistent with Ferson and Harvey (1991) and Petkova and Zhang (2005), who find that production-based macro factors strongly price cross-sections of expected returns, especially in portfolios exposed to industrial cyclicity.

The term spread coefficient is slightly higher in non-ESG portfolios, again suggesting greater cyclical exposure, analogously to MP factor. 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 et al. (2017), who show that term structure factors can differentially impact portfolios depending on their credit and duration sensitivities.

The non-ESG portfolios display a strong negative price of risk for EPI. This result suggests that environmental performance is a priced risk factor for portfolios without any ESG integration. This implies that portfolios without ESG filtering are penalized in case of EPI reduction (i.e., the market asks for a higher price of risk per unit of EPI exposure). 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. Consistent with this interpretation, the risk premium associated with the EPI factor for the industry-relative ESG portfolios is not statistically significant. These portfolios, being more diversified and less exposed to specific sectors, exhibit a lower sensitivity to changes in the EPI factor. Findings are consistent with Pastor et al. (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 et al. (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 may demand a higher risk premium precisely because they are more exposed to environmental risk.

A comparison of the two tables indicates that the risk premium associated with unexpected inflation (UI) is positive and statistically significant for the ESG dataset. A plausible explanation is that firms with stronger ESG profiles face higher compliance and adaptation costs, that might translate into greater leverage and, in turn, heightened sensitivity to unanticipated inflation shocks. While expected inflation is typically incorporated into firms' pricing and thus in their profit expectations, pricing and cost structures are not fully flexible to unforeseen inflationary spikes. As a result, firms that cannot adjust prices promptly may experience earnings pressure, leading investors to demand a higher risk premium for such companies.

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 and 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.

5.3. Robustness tests

To boost the obtained results, a set of robustness tests were carried out.

The first robustness check concerns the ESG score. We construct two ESG samples: one based on the industry-relative ESG score and the other on the raw ESG score provided by LSEG Refinitiv. Accordingly, the first robustness test is conducted using the raw ESG sample. Table 5 shows that the results remain unchanged in terms of the sign of the coefficients. What differs is the statistical significance of some variables: DEI becomes significant (while UI loses significance), and EPI also attains statistical significance, as in the non-ESG sample. This evidence indicates that, with raw ESG scores, portfolio composition depends more on industry affiliation than on firm-level ESG sensitivity: the high- and low-ESG portfolios specialize in different industry groups rather than picking sustainability leaders and laggards within each industry. In this respect the raw-ESG portfolios behave like the non-ESG ones, while the industry-relative adjustment neutralizes the sectoral component and produces more evenly diversified portfolios.

In fact, to assess whether the sector-adjusted ESG filter delivers a diversification benefit, we also measured the Herfindahl–Hirschman concentration index. Across all geographic regions analyzed, the industry-relative ESG portfolios exhibit, on average, higher diversification than their standard ESG counterparts: the Herfindahl–Hirschman Index – computed as the sum of squared sector market-capitalization weights relative to the total portfolio market capitalization – indicates that, for the value, size, and momentum strategies, the index is lower for the industry-relative ESG portfolios by 4.68%, 7.12%, and 5.92%, respectively.⁴

The second robustness check concerns the macroeconomic factors weights. By following Cooper et al. (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). Tables 6 and 7 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 factors (0.827) we chose to run a cross-sectional regression without UI factor, to avoid any doubt of multicollinearity problem. The results indicate no significant differences compared to the main model presented in Table 3 and 4 neither in terms of the signs of the coefficients, nor of the model's R-squared, nor of the statistical significance of the coefficients.⁵

Finally, although Asness et al. (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.⁶

6. Comparison of empirical findings with international literature

The results can be read in comparison with the four literature strands reviewed above. The first finding – that industry-adjusted ESG strategies do not systematically improve average returns relative to conventional factor portfolios – sits squarely within the agnostic strand of the ESG-pricing debate. It is consistent with the weak or absent unconditional ESG premium reported by Halbritter and Dorfleitner (2015) and Bannier et al. (2023), and with recent out-of-sample evidence that ESG information adds little incremental portfolio value (Bruno et al., 2025). Because the scores are industry-adjusted, the comparison is not contaminated by sector allocation, so the absence of a return differential is more plausibly attributable to sustainability positioning itself than to the cyclical or defensive composition of high-ESG sectors – a distinction that raw-score studies cannot cleanly draw.

The second finding – a frequent and, in developed markets, statistically significant reduction in volatility – connects the results to the risk-mitigation strand. The pattern echoes Albuquerque et al. (2019) on the lower systematic risk of high-ESG firms, Giese et al. (2019) on the stabilizing effect of ESG integration on return distributions, and the industry-neutral evidence of Broadstock et al. (2021) that adjusted high-ESG portfolios are more resilient in stressed markets. It is also in line with Kaiser (2020), whose size- and

⁴ Data are omitted for brevity but could be provided upon request.

⁵ Data are omitted for brevity but available upon request.

⁶ Data are omitted for brevity but available upon request.

Table 5

Estimates of prices of risk for raw ESG 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	
$\hat{\lambda}$ MP	2.2071	0.0043	5.1775	4.60519E-06	***
$\hat{\lambda}$ UI	0.1821	0.0011	1.6701	0.101537457	
$\hat{\lambda}$ DEI	0.1572	0.0009	1.7365	0.0890267	*
$\hat{\lambda}$ UTS	1.7643	0.0022	7.9087	3.48708E-10	***
$\hat{\lambda}$ UPR	0.2084	0.0007	2.8158	7.09E-03	***
$\hat{\lambda}$ EPI	-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				Test for normality of residuals -	
White test for heteroscedasticity -				Null hypothesis: error is normally distributed	
Null hypothesis: absence of heteroscedasticity				Test statistics: Chi-square (2) = 2.025	
Test statistics: LM = 34.9468				with p-value = 0.36335	
with p-value = P (Chi-square (27) > 34.9468) = 0.1402					

Table 6

Estimates of risk premiums for IR ESG 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	*
$\hat{\lambda}$ MP	1.3264	0.0079	1.6833	0.098942	
$\hat{\lambda}$ UI	0.0183	0.0013	0.1421	0.887601	
$\hat{\lambda}$ DEI	0.1496	0.0014	1.0515	0.298398	
$\hat{\lambda}$ UTS	1.4466	0.0039	3.7466	0.000489	***
$\hat{\lambda}$ UPR	0.8394	0.0025	3.3671	1.52E-03	***
$\hat{\lambda}$ EPI	-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				Test for normality of residuals -	
White test for heteroscedasticity -				Null hypothesis: error is normally distributed	
Null hypothesis: absence of heteroscedasticity				Test statistics: Chi-square (2) = 4.489	
Test statistics: LM = 34.9468				with p-value = 0.1060	
with p-value = P (Chi-square (27) > 29.8923) = 0.3190					

Table 7

Estimates of prices of risk for non-ESG 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	
$\hat{\lambda}$ MP	0.5787	0.0054	1.0742	0.288215	
$\hat{\lambda}$ UI	-0.0915	0.0013	-0.6827	0.498125	
$\hat{\lambda}$ DEI	0.0581	0.0013	0.4559	0.650555	
$\hat{\lambda}$ UTS	1.6789	0.0040	4.1952	0.00012	***
$\hat{\lambda}$ UPR	0.7090	0.0018	3.9390	2.70E-04	***
$\hat{\lambda}$ EPI	-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				Test for normality of residuals -	
White test for heteroscedasticity -				Null hypothesis: error is normally distributed	
Null hypothesis: absence of heteroscedasticity				Test statistics: Chi-square (2) = 4.056	
Test statistics: LM = 27.5717				with p-value = 0.5780	
with p-value = P (Chi-square (27) > 27.5717) = 0.4333					

industry-adjusted ESG portfolios retain their style exposure while lowering risk. The interpretation that emerges is that, once industry effects are removed, the marginal contribution of ESG operates through the second moment of returns rather than the first.

The third finding – that the cross-sectional prices of macroeconomic risk differ across the two designs – is where the paper joins the ESG and macro-pricing literatures that rarely meet. The evidence that industrial production growth and term spread are priced in both samples is consistent with the global macro-pricing tradition (Chen, Roll, and Ross, 1986; Ferson and Harvey, 1991; Cooper et al., 2022; Matteucci and Venanzi, 2025); the novelty lies in the divergences. The stronger pricing of industrial production growth index and term-structure risk in the conventional portfolios is consistent with their more cyclical, capital-intensive sectoral tilt, while the

weaker exposure of the industry-adjusted ESG portfolios reflects both their greater sectoral diversification and their orientation to sustainability in terms of risk. The significant negative price of the environmental factor for the non-ESG portfolios, and its insignificance once ESG is integrated, are in line with the view that portfolios that miss the environment compliance command a higher risk premium (Pastor et al., 2022; Albuquerque et al., 2019) and are consistent with the climate-pricing evidence that environmental and policy risks are reflected in prices (Faccini et al., 2023; Chiang, 2025). The positive pricing of both unexpected inflation and default spread for the ESG-adjusted portfolios is more tentative and points against a pure resilience story: it is consistent with the argument that the compliance/adaptation costs of sustainability can heighten short-term sensitivity to inflation and to tightening credit when those costs are capital-intensive and not yet offset by cash flows (Cornell and Damodaran, 2020). The evidence therefore does not portray ESG integration as uniformly risk-reducing; rather, it redistributes macroeconomic exposures, lowering cyclical risk while raising sensitivity to specific credit and inflation channels.

Two broader implications follow. Theoretically, the measurement and normalization of ESG information are not innocuous modelling choices: controlling for industry affiliation changes which risks appear priced, so conclusions about ESG and the cross-section are conditional on whether sector effects have been removed. This qualifies the raw-score evidence and supports treating industry adjustment as a default in ESG asset-pricing tests. Practically, the findings reposition ESG integration for factor investors as a portfolio-reallocation and risk-management device rather than a source of abnormal return: an industry-adjusted ESG overlay can lower volatility and diversify cyclical exposure at little cost in mean return, but it does not deliver a free premium and may import particular sensitivities to credit and inflation. That the volatility reduction is concentrated in the U.S., U.K., and Continental Europe – regions with higher Environmental Performance Index scores and longer-standing regulatory pressure – further suggests that the risk benefits of ESG integration are stronger where sustainability is more deeply priced, a pattern consistent with the international heterogeneity in ESG adoption emphasized by Kaiser (2020).

7. Conclusions, practical implications, and further lines of research

This paper has examined whether adjusting ESG scores for industry affiliation affects the properties of factor-based investment strategies. Using value, size, and momentum portfolios for six international equity markets over the period June 2001 to June 2023, we compared standard factor portfolios with portfolios formed by combining traditional factor rankings and an industry-relative ESG measure.

Three conclusions emerge. First, the industry-adjusted ESG filter does not generate a systematic improvement in average returns with respect to the corresponding non-ESG strategies. Second, the ESG-adjusted portfolios often display lower volatility, particularly in developed markets, suggesting that the main effect of ESG integration in this setting regards the risk profile of the strategies. Third, the asset-pricing tests suggest that ESG-adjusted portfolios bear a lower exposure to macroeconomic risks than non-ESG portfolios, especially to business-cycle fluctuations, a pattern consistent with their lower observed volatility, while additional differences emerge for environmental and credit-related variables.

These findings have implications for both research and practice. From a research perspective, they suggest that the way ESG information is measured and normalized matters for the interpretation of portfolio evidence. Controlling industry affiliation helps separate the role of sustainability information from simple sector composition effects. From an asset-management perspective, the results indicate that incorporating an industry-adjusted ESG signal may alter portfolio selection and reduce risk without necessarily improving returns.

The study is subject to limitations. The evidence depends on the LSEG Refinitiv ESG framework and therefore cannot be assumed to hold under alternative ESG ratings. In addition, the equal weighting assigned to the financial factor ranking and the ESG ranking, while reasonable and balanced, is only one among different specifications. Further research could consider alternative ESG providers, different weighting rules, and additional controls for sectoral and country-level heterogeneity. Overall, the evidence points to a cautious conclusion: once industry effects are taken seriously, ESG integration appears to matter more as a portfolio reallocation device and a risk-management tool than as an independent source of abnormal return.

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 and 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:

$$\text{cost of capital} = r_f + \beta_{Mkt} (E[R_{Mkt}] - r_f) + \beta_{MOM}^{ESG} (E[R_{MOM}^{ESG}] - r_f) + \beta_{VAL}^{ESG} (E[R_{VAL}^{ESG}] - r_f) + \beta_{SIZE}^{ESG} (E[R_{SIZE}^{ESG}] - r_f) \quad (5)$$

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.

- $E[R_{Mkt}]$, $E[R_{MOM}^{ESG}]$, $E[R_{VAL}^{ESG}]$, $E[R_{SIZE}^{ESG}]$ 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 assessing building retrofit interventions, for example, thereby enhancing decision-making quality and aligning financial evaluation practices with advances in asset pricing theory.

CRediT authorship contribution statement

Paolo Matteucci: Writing – review & editing, Writing – original draft, Software, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Daniela Venanzi:** Writing – review & editing, Visualization, Validation, Supervision, Methodology, Formal analysis, Conceptualization.

Declaration of Competing Interest

The authors declare that no financial or non-financial support was provided by any organization or institution for the work submitted. Additionally, no competing financial or non-financial interests exist that could influence the content or conclusions of this publication.

This research has been conducted in full compliance with ethical standards and relevant approval protocols.

All data and materials used in this study have been independently sourced by the authors and are appropriately cited within the manuscript. The data supporting the findings of this study are available from the corresponding author upon reasonable request.

This paper is result of the research project “ESG Portfolio strategy returns and global macroeconomic risk factors” (P.I. Daniela Venanzi) funded through a research fellowship grant by Rome Technopole (2024–2026).

Data availability

Data will be made available on request.

References

- Albuquerque, R., Koskinen, Y., Zhang, C., 2019. Corporate social responsibility and firm risk: Theory and empirical evidence. *Manag. Sci.* 65 (10), 4451–4469. <https://doi.org/10.1287/mnsc.2018.3043>.
- Amihud, Y., Mendelson, H., 1986. Liquidity and stock returns. *Financ. Anal. J.* 42 (3), 43–48. [https://doi.org/10.1016/0304-405X\(86\)90065-6](https://doi.org/10.1016/0304-405X(86)90065-6).
- Asness, C.S., Moskowitz, T.J., Pedersen, L.H., 2013. Value and momentum everywhere. *J. Financ.* 68, 929–985. <https://doi.org/10.1111/jofi.12021>.
- Balvers, R., Du, D., Zhao, X., 2017. Temperature shocks and the cost of equity capital: implications for climate change perceptions. *J. Bank. Financ.* 77, 18–34. <https://doi.org/10.1016/j.jbankfin.2016.12.013>.
- Bannier, E.C., Bonfiger, Y., Rock, B., 2023. The risk-return tradeoff: are sustainable investors compensated adequately? *J. Asset Manag.* 24, 165–172. <https://doi.org/10.1057/s41260-023-00303-6>.
- Bebchuk, L.A., Tallarita, R., 2020. The illusory promise of stakeholder governance. *Cornell Law Rev.* 106, 91. <https://doi.org/10.2139/ssrn.3544978>.
- Belsley, D.A., Kuh, E., Welsch, R.E., 1980. *Regression diagnostic: identifying influential data and sources of collinearity*. Wiley Series in Probability and Statistics.
- Berg, F., Kölbel, J.F., Rigobon, R., 2022. Aggregate confusion: the divergence of ESG ratings. *Rev. Financ.* 26 (6), 1315–1344. <https://doi.org/10.1093/rof/rfac033>.
- Black, F., Jensen, M.C., Scholes, M.S., 1972. The capital asset pricing model: some empirical tests. *Stud. Theory Capital. Mark.* 79–121.
- Blitz, D., Swinkels, L., 2021. Does excluding sin stocks cost performance? *J. Sustain. Financ. & Invest.* 13 (4), 1693–1710. <https://doi.org/10.1080/20430795.2021.1972789>.
- 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. *Financ. Res. Lett.* 38. <https://doi.org/10.1016/j.frl.2020.101716>.
- Bruno, G., Goltz, F., Naly, A., 2025. Does ESG Information Deliver Investment Value? A High-Dimensional Portfolio Perspective (May 30, 2025). Available at SSRN: <https://ssrn.com/abstract=5280378> or <https://doi.org/10.2139/ssrn.5280378>.
- Caldara, D., Iacoviello, M., 2022. Measuring geopolitical risk. *Am. Econ. Rev.* 112 (4), 1194–1225. <https://doi.org/10.1257/aer.20191823>.
- Carhart, M., 1997. On persistence in mutual fund performance. *J. Finance* 52, 57–82. <https://doi.org/10.1111/j.1540-6261.1997.tb03808.x>.
- 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. *Financ. Res. Lett.* 91.
- Chen, N.F., Roll, R., Ross, S.A., 1986. Economic forces and the stock market. *J. Bus.* 59, 383–403. <https://doi.org/10.1086/296344>.
- Chiang, T.C., 2025. The effect of climate policy uncertainty and induced risks on US aggregate and sectoral stock returns. *Res. Int. Bus. Financ.* 76. <https://doi.org/10.1016/j.ribaf.2025.102797>.
- Cooper, I., Mitache, A., Priestley, R., 2022. A global macroeconomic risk model for value, momentum and other asset classes. *J. Financ. Quant. Anal.* 57 (1), 1–30. <https://doi.org/10.1017/S0022109020000824>.
- Cornell, B., Damodaran, A., 2020. Valuing ESG: doing good or sounding good? *J. Impact ESG Invest.* 1 (1), 76–93. <https://doi.org/10.2139/ssrn.3557432>.
- Faccini, R., Matin, R., Skiadopoulos, G., 2023. Dissecting climate risks: Are they reflected in stock prices? *J. Bank. Financ.* 155. <https://doi.org/10.1016/j.jbankfin.2023.106948>.
- Fama, E.F., French, K.R., 1993. Common risk factors in the returns on stocks and bonds. *J. Financ. Econ.* 33, 3–56. [https://doi.org/10.1016/0304-405X\(93\)90023-5](https://doi.org/10.1016/0304-405X(93)90023-5).
- Ferson, W.E., Harvey, C.R., 1991. The variation of economic risk premiums. *J. Political Econ.* 99 (2), 385–415. <https://doi.org/10.2139/ssrn.3281992>.
- Görge, M., Jacob, A., Nerlinger, M., Riordan, R., Rohleder, M., Wilkens, M., 2020. Carbon risk. Available at SSRN 2930897. [10.2139/ssrn.2930897](https://doi.org/10.2139/ssrn.2930897).
- Giese, G., Lee, L.E., Melas, D., Nagy, Z., Nishikawa, L., 2019. Foundations of ESG investing: How ESG affects equity valuation, risk, and performance. *J. Portf. Manag.* 45 (5), 69–83. <https://doi.org/10.3905/jpm.2019.45.5.069>.
- Halbritter, G., Dorfleitner, G., 2015. The wages of social responsibility – where are they? A critical review of ESG investing. *Rev. Financ. Econ.* 26, 25–35. <https://doi.org/10.1016/j.rfe.2015.03.004>.
- Heckman, J.J., 1979. Sample selection bias as a specification error. *Econometrica* 47 (1). <https://doi.org/10.2307/1912352>.
- Hong, H., Kacperczyk, M., 2009. The price of sin: The effects of social norms on markets. *J. Financ. Econ.* 93 (1), 15–36. <https://doi.org/10.1016/j.jfineco.2008.09.001>.

- Ilhan, E., Sautner, Z., Vilkov, G., 2021. Carbon tail risk. *Rev. Financ. Stud.* 34 (3), 1540–1571. <https://doi.org/10.1093/rfs/hhaa071>.
- In, S.Y., Park, K.Y., Monk, A., 2017. Is ‘being green’ rewarded in the market? An empirical investigation of decarbonization risk and stock returns. Stanford Global Project Center Working Paper. <https://ssrn.com/abstract=3020304>.
- Jiang, R., Weng, C., 2019. Climate change risk and agriculture-related stocks. Available at SSRN 3506311. <https://doi.org/10.2139/ssrn.3506311>.
- Kaiser, L., 2020. ESG Integration: Value, Growth and Momentum. *J. Asset Manag.* 21, 32–51. <https://doi.org/10.1057/s41260-019-00148-y>.
- Koijen, R.S.J., Lustig, H., Van Nieuwerburgh, S., 2017. The cross-section and time series of stock and bond returns. *J. Monet. Econ.* 88, 50–69. <https://doi.org/10.1016/j.jmoneco.2017.05.006>.
- Liang, H., Renneboog, L., 2017. On the foundations of corporate social responsibility. *J. Financ.* 72 (2), 853–910. <https://doi.org/10.1111/jofi.12487>.
- Magnani, M., Guidolin, M., Berk, I., 2024. Strong vs. Stable: the impact of ESG ratings momentum and their volatility on the cost of equity capital. *J. Asset Manag.* 25, 666–699. <https://doi.org/10.1057/s41260-024-00377-w>.
- Matteucci, P., Venanzi, D., 2025. Momentum, Value, and Size Strategy Returns: the explanatory power of global macroeconomic risks. *Rev. Quant. Financ. Account.* <https://doi.org/10.1007/s11156-025-01421-5>.
- Nagar, V., Schoenfeld, J., 2022. Measuring weather exposure with annual reports. *Rev. Account. Stud.* 29 (1). <https://doi.org/10.1007/s11142-022-09711-2>.
- Nagy, Z., Kassam, A., Lee, L., 2016. Can ESG add alpha? An analysis of ESG tilt and momentum strategies. *J. Invest.* 25 (2), 113–124. <https://doi.org/10.3905/joi.2016.25.2.113>.
- Pastor, L., Stambaugh, R., Taylor, L.A., 2022. Dissecting green returns. *J. Financ. Econ.* 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. *J. Financ. Econ.* 142, 572–597. <https://doi.org/10.1016/j.jfineco.2020.11.001>.
- Petersen, M.A., 2009. Estimating standard errors in finance panel data sets: Comparing approaches. *Rev. Financ. Stud.* 22 (1), 435–480. <https://doi.org/10.1093/rfs/hhn053>.
- Petkova, R., Zhang, L., 2005. Is value riskier than growth? *J. Financ. Econ.* 78 (1), 187–202. <https://doi.org/10.1016/j.jfineco.2004.12.001>.
- Ramelli, S., Wagner, A.F., Zeckhauser, R.J., Ziegler, A., 2021. The Rev. Corp. *Financ. Stud.* 10 (4), 748–787. <https://doi.org/10.1093/rcfs/cfab010>.
- Rezaeeian, A., Racine, M., 2024. The risk of SIN or socially irresponsible stocks. *Rev. Quant. Financ. Account.* 62, 755–798. <https://doi.org/10.1007/s11156-023-01220-w>.
- Ross, S.A., 1976. The arbitrage theory of capital asset pricing. *J. Econ. Theory* Dec. 343–362. https://doi.org/10.1142/9789814417358_0001.
- Stotz, O., 2021. Expected and realized returns on stocks with high- and low-ESG exposure. *J. Asset Manag.* 22, 133–150. <https://doi.org/10.1057/s41260-020-00203-z>.