Short-term costs and long-term gains of ESG initiatives in high-risk environments: Evidence from UK firms

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ABSTRACT

This study investigates the dynamic relationship among environmental, social, and governance (ESG) practices, firm-level climate risk exposure, and stock returns using a robust system-generalised method of moments (GMM) estimator. The GMM approach effectively addresses endogeneity concerns, including reverse causality and omitted variable bias, which are prevalent in ESG performance studies. Empirical findings reveal that while ESG investments initially exert negative impacts on stock returns- reflecting substantial upfront costs and operational disruptions- these negative effects diminish over time, transitioning into significant long-term benefits through improved firm resilience and enhanced market valuation. Furthermore, our analysis reveals a strategic interplay between ESG initiatives and climate risk exposure, indicating that effective ESG integration can mitigate adverse climate impacts. The study also examines how market concentration and firm size impact ESG effectiveness, highlighting differential biases across various firm categories. Additionally, we emphasise the crucial role of regulatory frameworks, particularly the Paris Agreement, in amplifying the positive outcomes of ESG commitments. Overall, this research underscores the nuanced complexity of ESG investments, highlighting their potential to deliver substantial long-term advantages in risk management and financial performance despite initial implementation challenges.

1. Introduction

The role of business in society has become a prominent issue in recent years. Firms are increasingly expected to address social and environmental issues ahead of just financial performance. This has led to a growing emphasis on environmental, social, and governance (ESG) factors in business strategy and investment decisions. In 2022, 98 % of S&P 500 and 90 % of Russell 1000 companies released sustainability reports, a significant rise from around 20 % in 2011.[4] Additionally, the Governance & Accountability Institute reported a 10 % annual growth in new signatories of the Principles for Responsible Investment (PRI) in 2023, representing over $121 trillion in assets under management. The UK and Ireland recorded a 12 % year-on-year increase in new PRI signatories in 2023.[5] These signatories commit to integrating ESG data into investment decisions. At the same time, issues such as climate change

are posing new risks and opportunities for firms across various industries. This complex landscape has made understanding the implications of ESG performance and climate risk exposure for financial outcomes an important research priority.

Amid growing stakeholder pressure, firms are increasingly disclosing information on their ESG performance to signal long-term value creation and attract committed investors (Ahmad et al., 2021; Alodat et al., 2024; Li et al., 2024; Mbanyele and Muchenje, 2022; Orazalin et al., 2024). The effectiveness of the financial market hinges on the availability of prompt and precise information concerning firms' risk exposures, including an increasingly significant and relevant risk factor: climate risk. Access to high-quality information on firms' climate risk exposures (FCRE) is vital for making well-informed investment decisions, as well as for accurately pricing these risks and their associated opportunities (Krueger et al., 2020). Furthermore, given the growing recognition of

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climate change as a threat to the financial system, comprehensive disclosure of climate risks can be indispensable for regulatory initiatives aimed at safeguarding financial stability, as highlighted by regulators in the United Kingdom, the United States, and the European Union.[6] However, a prevailing view is that investors lack access to sufficient information on corporate climate risks (Ilhan et al., 2023).

However, climate change risk exposure remains an under-reported area, even as extreme weather events and pending carbon regulations pose financial risks across sectors (Mbanyele and Muchenje, 2022; Ozkan et al., 2023). Many companies argue that climate change affects their strategic decisions (TCFD, 2020). While high-emission firms face direct transition costs, even low-emitting firms face physical and systemic climate risks (Ilhan et al., 2023; Krueger et al., 2020). Comprehensive risk disclosure is crucial for efficient capital allocation and financial stability. This paper aims to provide novel evidence on how ESG performance and climate risk management interlink to affect firms' stock performance (FSP). The analysis considers both standalone and interactive effects, recognising that ESG investing must grapple with intensifying climate impacts. Nuanced findings across firm subgroups and policy regimes can inform the discourse on harnessing ESG and climate risk reporting to steer finance toward sustainable outcomes.

Our study contributes to the expanding research on ESG and climate finance by conducting a comprehensive empirical analysis of ESG, FCRE, and their interactive effects on FSP. We extend the current literature in several significant and interconnected ways:

Firstly, we adopt a holistic approach to ESG performance, encompassing social aspects alongside environmental and governance factors. This approach acknowledges the multifaceted nature of corporate sustainability and its growing importance to investors. Building on this comprehensive assessment, our analysis examines the impact of ESG on stock performance, providing a more nuanced view of financial performance compared to studies that focus solely on accounting-based measures.

Secondly, our study explores the hypothesis that FCRE could incentivise firms to adopt more climate-sensitive practices. This proposition assumes that marginal investors incorporate climate-related factors into their decision-making, potentially harming the value of less climate-conscious businesses.[7] As Mark Carney[8] starkly warned in a speech given at Lloyd's of London, "Firms ignoring climate crisis will go bankrupt." Stakeholder theory suggests that firms are motivated to adopt ESG practices to manage relationships with key stakeholders effectively, enhancing their legitimacy and trustworthiness in the process. This is particularly relevant as stakeholders increasingly expect firms to demonstrate responsibility towards both environmental and social issues. On the other hand, risk management theory posits that ESG practices help firms mitigate the financial and operational risks associated with climate change risks (Albuquerque et al., 2019; Lins et al., 2017), which are exacerbated by regulatory and market shifts driven by agreements like the Paris Agreement.

Emerging theory and evidence suggest that firms with high ESG performance are likely to demonstrate higher returns during crises, including those induced by climate change, thereby enhancing their appeal in the capital market.[9] To assess how companies adapt their ESG

initiatives in the face of the risks posed by climate change, we utilise a proactive measure developed by (Sautner et al., 2023). This measure is based on three topic-based standards reflecting exposure to climate-related opportunities, physical risks, and regulatory shocks. It utilises a textual analysis method to capture the proportion of climate change-related discussions in conference calls between managers and financial analysts. This time-varying, firm-level measure enables us to capture within-industry variations in FCRE, which are often challenging to isolate using static or state-level measures. We complement FCRE data with ESG scores extracted from the LSEG ESG database. This comprehensive approach enables us to provide a nuanced analysis of how firms navigate the complex interplay between FCRE, ESG, and financial performance in an increasingly climate-conscious market landscape.

Thirdly, while much of the existing literature centres on the United States (US) and Chinese firms, our study addresses the comparative scarcity of research on UK companies (Ahmad et al., 2021). Studying the UK provides strategic insight into the interplay between ESG performance, FCRE, and FSP thanks to its advanced regulatory framework for climate action and ESG reporting. As a leader in sustainability initiatives, the UK requires comprehensive ESG disclosures that enable detailed analysis of ESG metrics. The maturity of its financial markets and high investor awareness of ESG factors make it an ideal setting to examine how sustainability influences firm valuation in a developed market context. Furthermore, the UK's ambitious climate policies, including its commitment to net-zero emissions by 2050, provide a unique backdrop for exploring how firms adapt to stringent environmental regulations and how these adaptations affect their economic performance. This makes the UK a valuable context for understanding the broader implications of ESG initiatives within a well-regulated, sophisticated market environment. This focus on UK firms fills an important gap in the literature and provides insights specific to the UK market context.

Fourthly, we extend our analysis of the Paris Agreement's influence on investor awareness and corporate behaviour, building on studies by Bolton and Kacperczyk (2021); Monasterolo and de Angelis (2020); Seltzer et al. (2022). Our study makes a significant contribution to the existing literature by specifically examining the impact of the Paris Agreement on the interplay between ESG performance and FSP within the UK context. The Paris Agreement influences firm behaviour through mechanisms that impose direct costs but also confer long-term benefits. By committing to the agreement's targets, firms may incur upfront costs related to implementing sustainable technologies and processes. However, these costs are often offset by benefits such as enhanced brand reputation, operational efficiencies, and alignment with investor preferences towards sustainability, which increasingly influence market valuations. By segmenting the analysis into periods before and after the implementation of the Paris Agreement, we provide empirical evidence on how this landmark global climate policy reshapes corporate valuation strategies related to sustainability. The findings reveal that while the immediate aftermath of the agreement may introduce costs, the long-term effects, facilitated by strategic alignment with the agreement's objectives, are markedly positive. This suggests that the Paris Agreement not only enhances the perceived value of robust ESG practices but also encourages firms to deepen their sustainability efforts, which ultimately yields financial benefits.

Finally, our study integrates firm size and market concentration as pivotal elements in our analytical framework to enhance the understanding of the impact of ESG performance on FSP. By considering firm size, we examine how the scale of a business impacts its ability to implement and reap the benefits of ESG initiatives, acknowledging that larger firms may have different resources and greater public visibility compared to smaller ones. Simultaneously, incorporating market concentration allows us to examine the influence of market concentration on these dynamics. This dual consideration of firm size and market structure provides a more nuanced analysis, revealing how both elements interact with ESG performance to shape financial outcomes.

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[6] See Carney (2015), Davidson (2021) and European Systemic Risk Board (2023).

[7] See Pástor et al. (2021) and Choi (2020).

[8] "Mark Carney is the former Governor of the Bank of England and the UN Special Envoy on Climate Action and Finance."

[9] Pástor et al. (2021) "theoretical model predicts that green stocks outperform brown stocks when there are high climate change concerns". Similarly, Choi (2020) found that carbon-intensive firms' stock performance declines during periods of extremely hot temperatures". Similarly, according to State Street, "ESG is a source of alpha that leads to positive portfolio performance" (Lester et al., 2018).

Section 2 reviews pertinent literature, synthesising key insights into how ESG performance intersects with FSP, climate risk, and regulatory changes. Building on this foundation develops specific, testable hypotheses that bridge theoretical perspectives with empirical inquiry. In Section 3, we detail our methodology, describing the data sources, variable construction, and the GMM approach used to address potential endogeneity issues. The Section 4 presents our empirical findings, offering a nuanced view of how ESG performance impacts firm stock performance in the short and long term. We conclude the study in Section 5 with a discussion on the implications of our findings for policymakers, investors, and corporate managers, emphasising the strategic importance of integrating ESG practices into core business strategies.

2. Theoretical background and hypothesis

The association between ESG performance and firm financial outcomes is complex, influenced by diverging views on the economic implications of corporate social responsibility (CSR) activities. Neoclassical economists like Friedman (1970) argue that CSR investments, by diverting resources from profit maximisation, might impair a firm's financial performance. This perspective suggests that CSR incurs higher operational costs and potential conflicts among stakeholders, leading to competitive disadvantages (Barnett, 2007; Greening and Turban, 2000; Shen and Chang, 2009).

Stakeholder theory suggests that firms that effectively engage their stakeholders through responsible practices may achieve superior financial performance due to enhanced reputational benefits and stakeholder support (Freeman, 1984; Hillman and Keim, 2001). Risk management theory further supports this by proposing that firms that proactively address potential risks, including environmental and social risks, can reduce potential losses and stabilise their operations (Froot et al., 1993). The effective management of stakeholder relationships through CSR activities enhances a firm's reputation, strengthens its legitimacy, and ultimately improves financial outcomes (Alodat et al., 2023; Bitektine and Haack, 2014; Russo and Perrini, 2010). Similarly, the resource-based view contends that CSR activities leverage a firm's unique capabilities and resources to build a competitive advantage through improved brand image, employee satisfaction, and customer loyalty, which contribute to superior financial performance (Alodat et al., 2025; Ashraf et al., 2025; Bird et al., 2007; Orlitzky et al., 2003). Adding to this, the concept of informational effects suggests that high ESG ratings can reduce a firm's residual risks by acting as a form of reputational insurance against external shocks (Bagh et al., 2024b; Godfrey et al., 2009). The size of the firm also influences the extent of its CSR activities, with larger firms typically engaging more in ESG due to their greater resources and capabilities, which can positively impact financial performance (Chen and Metcalf, 1980; Gooding and Wagner, 1985).

Recent studies highlight a complex interaction between firm-level ESG initiatives and market performance, suggesting that while initial ESG investments might burden firm resources, they often lead to long-term financial benefits through enhanced reputational capital and operational efficiencies (Li et al., 2024; Mbanyele and Muchenje, 2022). Robust ESG practices enhance firms' financial performance (Ahmad et al., 2021; Alodat and Hao, 2025; Bagh et al., 2024; Bagh, et al., 2024a, 2024b), environmental innovation (Alodat et al., 2025), reduce the cost of debt (Li et al., 2024), and firm risk (Albuquerque et al., 2019). Significantly, the integration of ESG practices appears to mitigate the adverse effects of climate risks (Ben-Amar et al., 2025; Hossain and Masum, 2022; Khalfaoui et al., 2022; Yin et al., 2025). Given the theoretical and empirical landscape, this research formulates the following hypothesis.

Hypothesis 1. *Initially, ESG performance may negatively impact FSP, reflecting immediate costs and strategic disruptions. However, over time, these practices potentially enhance FSP.*

The emergence of climate change has introduced new risks for firms, categorised by the Task Force on Climate-related Financial Disclosures (TCFD) into physical risks, such as floods and rising sea levels, and transition risks associated with transitioning towards a lower-carbon economy. These changes necessitate adaptive corporate strategies and can have a significant impact on financial stability (Roston, 2019; World Economic Forum, 2019). Climate change introduces a dual set of risks, physical challenges and transition risks associated with the shift towards a lower-carbon economy. These risks can disrupt global supply chains, contribute to political instability, and increase operational costs, potentially leading to significant financial losses for firms (Bagh et al., 2024b; Hong et al., 2019; Liesen et al., 2017; Naseer et al., 2025; Naseer et al., 2024; Ozkan et al., 2023; Sautner et al., 2023; Zhao et al., 2024). While some argue that climate policies may not significantly harm certain industries Okereke and McDaniels (2012); Sudhakara and Assenza (2009), others suggest that the costs associated with enhancing environmental performance can outweigh the financial benefits (Dixon-Fowler et al., 2013; Freedman and Jaggi, 1988; Friedman, 2007; Ruggiero and Lehkonen, 2017). However, investments in environmental protection can also enhance operational efficiency by reducing waste, supporting the notion that environmentally conscious practices can be financially beneficial (Porter and Van der Linde, 1995; Yu et al., 2016). Given the theoretical and empirical landscape, this research formulates the following hypothesis.

Hypothesis 2. *Climate change risks negatively impact FSP.*

The interaction between ESG performance and FCRE forms a multifaceted landscape with profound implications for corporate strategy. Firms confronting elevated climate risks are increasingly perceiving ESG performance not merely as a regulatory obligation but as integral to comprehensive risk management and long-term sustainability agendas. This view is substantiated by Albuquerque et al. (2019); Flammer (2013); Fuente et al. (2022), who demonstrate that proactive ESG practices mitigate climate-related risks, enhance corporate reputation, and ultimately contribute to reduced risk exposure and financial resilience. Grounded in the philosophy of sustainable development, strong ESG commitments are associated with enhanced standardisation, credibility, and stakeholder trust, helping firms to attract clients, secure partnerships, and minimise operational vulnerabilities (Avramov et al., 2022; Bagh, Bouri et al., 2024). Stakeholder theory further supports this notion, positing that firms' accountability to a broad array of stakeholders enhances both reputational capital and risk management, thereby fostering financial sustainability (Chen et al., 2023). Additionally, heightened ESG disclosures reflect a shift towards ethical investing paradigms, appealing to investors seeking to balance societal impact with financial returns (Godfrey, 2005; Godfrey et al., 2009; Lins et al., 2017). Empirical evidence suggests that firms with robust ESG performance exhibit superior governance, more engaged stakeholders, and greater proactivity towards environmental and social risks, often resulting in higher returns (Alodat and Hao, 2025; Naseer et al., 2023; Yin et al., 2025; Zhang et al., 2023).

Given the theoretical support for a positive interaction between ESG and climate risks, we anticipate a nuanced scenario in actual corporate practice. While theoretical models often predict beneficial outcomes from integrating ESG practices, particularly in high-risk environments, the reality might be more complex. Initial investments in ESG initiatives might incur significant costs and introduce operational challenges, which could overshadow their risk mitigation benefits in the short term. However, as firms gradually optimise and integrate these ESG strategies into their core operations, we expect the long-term benefits to become more apparent, in line with the theoretical advantages of improved risk management and reputation enhancement. Based on these considerations, we propose the following hypothesis to guide our empirical investigation:

Hypothesis 3. *In the short term, climate risk may exacerbate the negative*

impacts of ESG performance on FSP; over the longer term, it is likely to amplify the positive impacts of ESG performance on FSP.

In light of these complex dynamics, it is crucial to study the interplay between ESG practices, FCRE, and firm stock performance. The potential for FCRE to both incentivise and hinder ESG investments, coupled with the evolving regulatory landscape and shifting investor preferences, creates a complex environment for corporate decision-making. Understanding these relationships is vital for firms seeking to navigate the challenges posed by climate change, meet stakeholder expectations, and maintain financial performance. Moreover, this research is essential for investors and policymakers aiming to accurately assess and promote sustainable business practices in an increasingly climate-conscious world. By examining these interconnections, we can gain valuable insights into how firms can effectively manage climate risks, enhance their ESG performance, and achieve long-term financial sustainability in the face of global environmental challenges.

3. Methods

3.1. Data

Our empirical analysis utilises an unbalanced panel dataset comprising 226 UK-listed firms over the period 2002–2023. The dataset integrates information from multiple sources, including firms' financial data and ESG data, which were obtained from the London Stock Exchange Group (LSEG). Firm-specific Climate Change Risk Exposure (FCRE) data provided by (Sautner et al., 2023).[10] To ensure data quality and consistency, we apply the following restrictions: A) Firms must provide complete financial information necessary for calculating all dependent, independent, and control variables. B) We exclude firms with negative total assets, sales, or common equity. C) The availability of earnings conference call data is crucial for assessing firm-specific climate change risks. Hence, only firms with such data are included in the analysis.

3.2. Variables

3.2.1. Firm stock performance

Our dependent variable is firm stock performance (FSP), which we assess using stock returns. This measure captures the immediate market response to firm activities, including ESG practices and exposure to climate risks, providing a direct reflection of investor sentiment and market conditions. Stock returns provide a dynamic and current assessment of a firm's value, reflecting real-time changes in the market's perception of a firm's financial health and strategic positioning. This approach aligns with methodologies that focus on stock performance as a primary indicator of corporate success and investor confidence.

The use of FSP as a measure in our study is grounded in its ability to provide an immediate and tangible reflection of a firm's market valuation, particularly in relation to its strategies and performance, including ESG practices and FCRE. FSP, typically evaluated through stock returns, is widely recognised in the literature for its efficacy in reflecting investor sentiment and market response in real-time. For example, studies such as Edmans (2011); Lins et al. (2017) demonstrate that superior ESG/CSR practices correlate positively with enhanced stock returns, suggesting that investors reward companies that effectively manage sustainability and climate-related risks. This measure is particularly adept at capturing the market's rapid response to regulatory changes, such as those imposed by the Paris Agreement, providing valuable insights into the immediate financial impacts of such policies. We use the following equation to calculate FSP:

$$\text{Firm stock performance}(FSP) = \text{LN}\left(\text{Closing price}_{i,t} \middle/ \text{Closing price}_{i,t-1}\right) \tag{1}$$

3.2.2. ESG metrics

We employ ESG as an independent variable. Our analysis employs ESG scores from the London Stock Exchange Group (LSEG) ESG database,[11] a leading industry resource that assesses over 630 factors spanning economic, environmental, social, governance, and additional domains. The factors assessed are organised into ten categories and are grouped under three primary pillars: environmental, social, and corporate governance. Each ESG score is normalised and ranges from 0 (poorest performance) to 100 (best performance), with scores being equally weighted and compared across the global universe of companies. Environmental and social categories are benchmarked against the LSEG Business Classifications, while governance scores are compared to standards set within the country of incorporation. This scoring system enables a comparative analysis of ESG performance across firms and over time. LSEG's ESG database stands out for its comprehensive coverage, encompassing more than 90 % of global market capitalisation. This extensive dataset provides historical information dating back to 2002, allowing for robust long-term analysis (LSEG, 2023). Despite its extensive coverage, the LSEG ESG database has limitations. Potential reporting biases and variability in disclosure practices across different regions and industries may affect the accuracy and consistency of the ESG scores. To mitigate these issues, we implement robustness checks and sensitivity analyses.

3.2.3. Firm climate risk exposure

We employ FCRE as an independent and moderating variable. Our study employs the FCRE measure, developed by Sautner et al. (2023), using bigram analysis of quarterly earnings conference calls.[12] FCRE captures climate risks stemming from regulatory, physical, and transitional climate change shocks. Over the past two decades, earnings conference calls have become a crucial communication channel between firms, stakeholders, investors, and analysts. The climate risk index quantifies FCRE based on these communications, offering robust firm-time variation. The FCRE measure is constructed using bigram analyses, focusing on the frequency of keywords (e.g., "climate risk" and "climate uncertainty") that convey information about potential climate risks. Its construction follows a multidimensional approach, considering physical, regulatory, and transitional firm climate issues. According to Sautner et al. (2023), this measure is positively correlated with other established metrics, such as the CO2 emissions index by Engle et al. (2020), validating its relevance and accuracy. This measure has gained recognition and adoption in recent literature, including studies by (Agoraki et al., 2024; Bagh et al., 2024b; Cook and Luo, 2022; Feng et al., 2024; Hossain and Masum, 2022; Mbanyele and Muchenje, 2022; Naseer et al., 2024).

3.2.4. Control variables

In our analysis, we control for several key variables to isolate the effects of ESG practices and climate risk exposure on firm performance, ensuring other influential factors are accounted for. Financial Leverage (LEV) gauges the extent of borrowed funds used in operations, affecting risk and investment capacity in ESG initiatives. Sales Growth (SG) indicates economic health and market performance, influencing resource allocation towards ESG practices. Cash Flows (CF) are crucial for assessing a firm's liquidity and its ability to fund ESG projects. Working Capital (WC) reflects a company's short-term financial health and its

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[10] Data available at https://doi.org/10.17605/OSF.IO/FD6JQ

[11] The detail methodology available at https://thesource.lseg.com/thesource/getfile/index/4933f0a6–476e-4a30-adbb-df8043d2c33f

[12] Detail methodology of construction of the measure provided by Sautner et al. (2023).

ability to sustain ESG investments. Lastly, Property, Plant, and Equipment (PPE) measures the firm's physical assets, which are significant for evaluating the implementation of sustainability efforts. These controls are crucial for providing a nuanced understanding of how ESG and climate risks directly impact a firm's financial performance while accounting for potential confounding factors. The measurement of variables is provided in Table 1.

Table 1 presents the measurement and summary statistics of study variables.

3.3. Econometric models and empirical strategy

Our empirical investigation into the relationships between ESG performance, FCRE, and FSP employs a multi-stage econometric approach. We begin with baseline regression models and progressively address potential statistical issues to ensure robust and unbiased estimates.

We start with the following Eq. 2 for baseline analysis:

$$FSP_{i,t} = \beta_0 + \beta_1 ESG_{i,t} + \beta_2 FCRE_{i,t} + \beta_3 X_{i,t} + \varepsilon_{i,t} \quad (2)$$

Where $FSP_{i,t}$ is the firm's stock performance for firm i at time t, respectively. $ESG_{i,t}$ represents the ESG performance score. $FCRE_{i,t}$ denotes the firm's climate change exposure. $X_{i,t}$ is a vector of control variables. $\varepsilon_{i,t}$ is the error terms.

To address potential endogeneity issues and dynamic panel bias, we utilise the GMM approach. GMM is particularly useful in this context as it can handle potential simultaneity between FSP and the explanatory variables (such as ESG and FCRE). Additionally, GMM can account for unobserved heterogeneity and the persistence in financial performance measures by incorporating lagged dependent variables as instruments. The dynamic panel GMM model is specified in Eq. 3.

$$Y_{i,t} = \rho Y_{i,t-1} + \beta X_{i,t} + \eta_i + \varepsilon_{i,t} \quad (3)$$

Where $Y_{i,t-1}$ is the lagged dependent variable, η_i represents firm-specific fixed effects, and $\varepsilon_{i,t}$ is the idiosyncratic error term. We implemented a two-step GMM strategy, which includes a finite sample adjustment to the covariance matrix as suggested by (Windmeijer, 2005). This refined method, presented by Roodman (2009), utilises lagged differences in the dependent variable as instruments for equations in levels and employs the lagged levels of the series as instruments for equations in the first differences. The robustness and validity of these instruments were evaluated using diagnostic tests such as the autoregressive (AR) 1, AR2, and Sargan tests for overidentifying restrictions.

To assess the moderating role of climate change exposure on the ESG-FSP relationship, we introduce an interaction term using Eq. 4.

$$Y_{i,t} = \alpha + \beta_1 ESG_{i,t} + \beta_2 FCRE_{i,t} + \beta_3 X_{i,t} + \beta_3 ESG_{i,t} \times FCRE_{i,t} + \beta_4 X_{i,t} + \varepsilon_{i,t} \quad (4)$$

Where ($ESG_{i,t} \times FCRE_{i,t}$) represents the interaction between ESG performance and firm climate change exposure.

4. Results

4.1. Descriptive summary

Fig. 1 illustrates the temporal evolution of average ESG performance among sample UK firms from 2002 to 2023, highlighting a clear upward trajectory over the period, indicative of increased adoption and improvement in sustainability practices. This steady improvement likely reflects intensified regulatory requirements, heightened investor scrutiny, and broader public awareness of environmental and social challenges. Notably, ESG performance accelerated around 2014, potentially in response to global sustainability initiatives or regulatory shifts. In contrast, post-2020 trends exhibit slight fluctuations, suggesting possible maturation or temporary stabilisation of ESG efforts. The overall positive linear trend highlights a sustained corporate shift toward integrating ESG into strategic business practices, with significant implications for risk management, investor decision-making, and policymaking aimed at promoting corporate sustainability.

Fig. 2 presents the temporal distribution of average FCRE among sample UK firms from 2002 to 2023, indicating an overall increasing trajectory in corporate climate risk exposure. Initially, FCRE experienced modest fluctuations, with a relatively stable period between 2008 and 2016. However, starting around 2017, a marked upward trend emerged, sharply accelerating in 2020 and peaking shortly after, suggesting heightened corporate recognition and reporting of climate risks, likely driven by increased regulatory requirements, global climate events, and greater stakeholder pressures. The sharp spike post-2020 could reflect intensified global climate policies, investor demands for transparency, or the direct impacts of climate-related disruptions. Although recent years exhibit a slight decline from this peak, the overall positive linear trend underscores the increasing prominence and importance of managing climate-related risks within corporate strategic planning and financial performance analysis.

Fig. 3 shows pairwise correlations between the variables. The strongest positive correlation (0.34) is observed between CF and WC. There is a correlation of 0.23 between ESG and CF, 0.1 for FCRE, 0.07 for LEV, 0.02 for WC, -0.05 for SG, and −0.05 for PPE. FCRE shows a positive correlation with all variables.

4.2. Baseline analysis

Table 2 presents fixed-effects regressions using stock returns as the dependent variable. The regression analysis indicates that ESG performance has a negative impact on FSP. At the same time, FCRE consistently shows a strong negative impact in our sample firms. Given the variability in the magnitude of ESG's impact across models, further analysis using quantile regression could be particularly insightful. Quantile regression will allow for the examination of how the effects of ESG performance and climate risk exposure might differ across the distribution of stock returns, potentially uncovering nonlinearities or varying impacts at different levels of the return distribution, thereby providing a more detailed picture of the risk-return profile associated with these variables under different market conditions.

4.3. Robustness

Table 3 presents the results from our robustness analysis, which evaluates the impact of ESG and FCRE on financial performance using two models. Model 1 incorporates additional controls, including
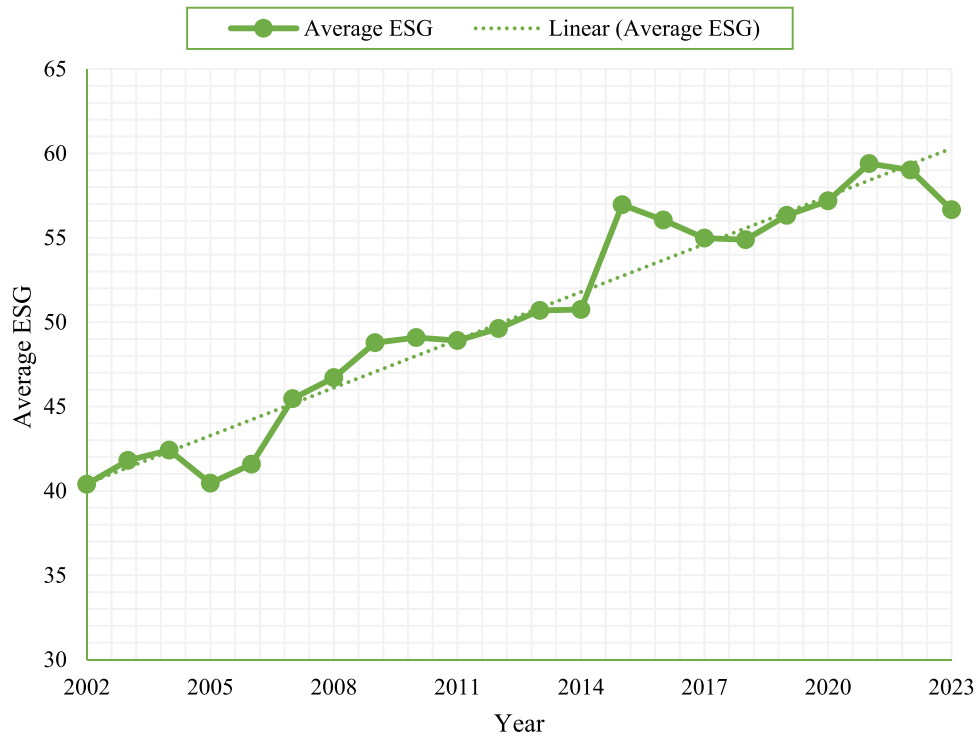
Table 1
Variable measurement and summary statistics.

Variable	Measure	N	Mean	SD	Min	Max
FSP	Eq. 1	2765	0.021	0.386	−2.712	3.583
ESG	LSEG ESG overall score	2765	53.172	16.300	5.170	94.994
FCRE	Sautner et al. (2023)	2765	0.140	0.250	0.005	2.456
LEV	The ratio of long-term borrowings to total assets	2765	0.320	0.213	0.000	0.679
SG	Percentage change in the value of total sales	2765	0.063	0.506	−7.113	6.798
CF	Natural logarithm of net cash flows	2765	5.305	1.690	−1.609	10.444
WC	Natural logarithm of working capital	2765	3.982	3.065	0.000	10.131
PPE	Natural logarithm of property, plant and equipment	2765	0.222	0.236	0.000	2.543

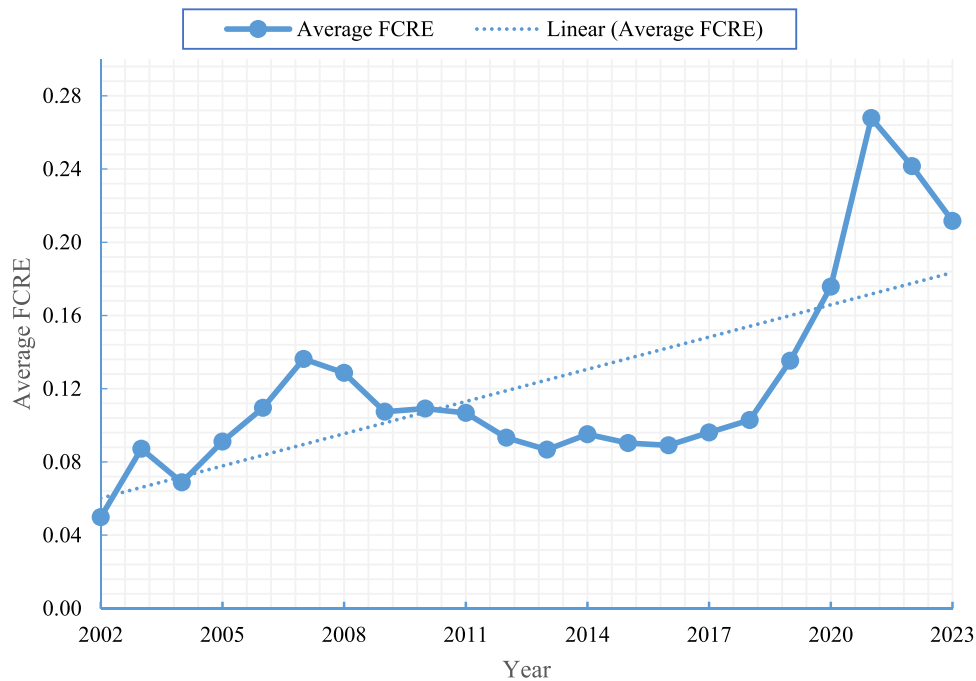**Fig. 1.** Average ESG over the sample period.

Fig. 2. Average FCRE over the sample period.

Earnings Volatility (EARV), Cash Flow Volatility (CFV), and Return on Assets (ROA), to assess their impact on FSP. Model 2 utilises an alternative dependent variable, Tobin's Q, providing a broader measure of financial performance compared to FSP. The analysis reveals that both ESG and FCRE consistently exhibit a negative impact on financial performance across both models.

4.4. Quantile regression estimations

The quantile regression analysis in Table 4 vividly demonstrates that the impacts of ESG scores and FCRE on FSP exhibit distinct patterns across different performance levels, suggesting that their effects are not uniform but vary significantly with the firm's financial performance spectrum. Notably, ESG performance has a positive impact at lower quantiles and a negative impact at higher quantiles, indicating that ESG performance might buffer against downside risks but potentially curtail

Correlation Matrix
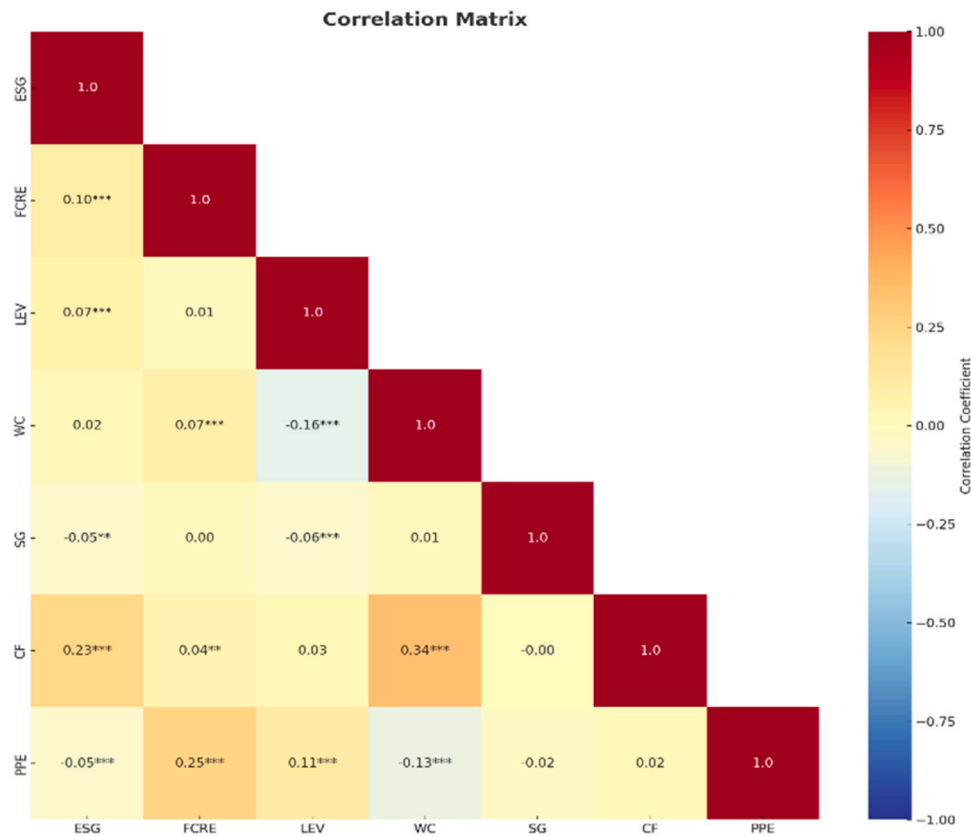
Fig. 3. Correlation matrix plot.

Table 2
Baseline regression analysis.

	The dependent variable is FSP	
VARIABLES	(1)	(2)
ESG	−0.009*	−0.010*
	(0.006)	(0.006)
FCRE	−0.231***	−0.231***
	(0.055)	(0.055)
LEV	−0.022***	−0.012***
	(0.001)	(0.001)
SG	0.069***	0.069***
	(0.019)	(0.019)
CF	−0.028**	−0.028**
	(0.011)	(0.011)
WCAP	0.080*	0.018*
	(0.050)	(0.005)
PPE	−0.011	−0.011
	(0.097)	(0.097)
Constant	0.286***	0.286***
	(0.071)	(0.071)
Observations	*2765*	*2765*
R-squared	*0.104*	*0.158*
Firm/Year FE	*Yes*	*Yes*
Industry FE		*Yes*

The table presents the results of baseline regression models using fixed effect regression. Standard errors in parentheses "()" and asterisks indicate significance level at *** $p < 0.01$, ** $p < 0.05$ and * $p < 0.1$.

Table 3
Robustness analysis.

	(1)	(2)
VARIABLES	FSP	Tobin's Q
ESG	−0.001*	−0.007***
	(0.001)	(0.002)
FCRE	−0.094**	−0.417***
	(0.045)	(0.109)
EARV	−0.114	
	(0.427)	
CFV	−0.701	
	(0.602)	
ROA	1.601***	
	(0.210)	
Controls	*Yes*	*Yes*
Observations	*2765*	*2765*
R-squared	*0.133*	*0.086*
Firm/Year FE	*Yes*	*Yes*
Industry FE	*Yes*	*Yes*

The table presents the robustness analysis of the impact of ESG and FCRE on firm Financial performance. Model 1 includes additional control variables (Earnings Volatility (EARV), Cash Flow Volatility (CFV), and Return on Assets (ROA)) to assess their impact on FSP. Model 2 uses Tobin's Q as an alternative measure for firm financial performance. Standard errors in parentheses "()" and asterisks indicate significance level at *** $p < 0.01$, ** $p < 0.05$ and * $p < 0.1$.

upside potential in higher performance scenarios. Similarly, FCRE exhibits an increasingly negative impact as performance improves, highlighting the heightened vulnerability or increased costs associated with climate risks in more successful firms. Given these complex dynamics, further investigation using system GMM would be advantageous to address potential endogeneity issues between these variables and stock returns. System GMM would allow for a more robust examination of the

dynamic relationships and potential reverse causality, ensuring that the observed effects are not biased by omitted variable bias or the autoregressive nature of financial data. This approach would provide a deeper understanding of how ESG and climate risks influence firm value over time, helping to clarify the conditions under which these factors are either beneficial or detrimental.

Table 4
Quantile regression estimations.

	The dependent variable is FSP.				
	(1)	(2)	(3)	(4)	(5)
VARIABLES	Q_10	Q_25	Q_50	Q_75	Q_95
ESG	0.030***	0.010*	−0.010	−0.011***	−0.032***
	(0.001)	(0.052)	(0.011)	(0.001)	(0.011)
FCRE	0.056	−0.002	−0.054**	−0.095***	−0.157***
	(0.045)	(0.032)	(0.024)	(0.024)	(0.034)
Controls	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*
Observations	*2765*	*2765*	*2765*	*2765*	*2765*

The table presents the quantile regression results at 10, 25, 50, 75 and 95 percentiles. Standard errors in parentheses ("()") and asterisks indicate significance levels at *** $p < 0.01$, ** $p < 0.05$, and * $p < 0.1$.

4.5. GMM estimations

The System GMM results in Table 5 provide compelling insights into the dynamic interactions between ESG performance, FCRE, and FSP. Both models consistently show that current ESG performance has a negative impact on FSP, with coefficients indicating a modest but persistent adverse effect across all lags of ESG included in Model 2. Interestingly, the impact of ESG performance on FSP becomes less negative with additional lags in Model 2, turning positive at the second and third lags (L2. ESG and L3. ESG). This suggests a nuanced relationship where the immediate impact of ESG initiatives may be costly or perceived negatively by investors. However, benefits appear to accrue over a longer horizon, reflecting potentially delayed market recognition or the realisation of ESG-related improvements.

FCRE's negative impact on stock returns is consistent in both models, though the magnitude of its effect is reduced when additional ESG lags are included. This may indicate that the negative implications of climate risk are somewhat mitigated when considering the evolving nature of ESG performance. This observation could reflect a complex interaction where firms with proactive ESG engagements may better manage or mitigate climate-related risks over time.

The diagnostic tests (AR2 and Sargan) validate the model specifications: AR2 confirms the absence of second-order autocorrelation, ensuring that the model's dynamic components are correctly specified without over-differencing. The Sargan test confirms the instruments'

Table 5
GMM estimation with lags structure.

	The dependent variable is FSP	
	(1)	(2)
VARIABLES	Without Lags	With Lags
L.SR	−0.160***	−0.153***
	(0.005)	(0.001)
ESG	−0.041***	−0.040***
	(0.002)	(0.002)
L.ESG		−0.022***
		(0.008)
L2. ESG		0.021***
		(0.004)
L3. ESG		0.011***
		(0.004)
FCRE	−0.111***	−0.058***
	(0.005)	(0.002)
Controls	*Yes*	*Yes*
Observations	*2765*	*2373*
AR2 - P value	*0.977*	*0.608*
Sargan - P value	*0.823*	*0.870*

The table presents the dynamic panel data estimation results using the two-step system GMM. "L." indicates the lagged value in the model. In the 1st and 2nd models, we examine the impact of ESG and FCRE on stock returns, incorporating different lags of ESG scores. Standard errors in parentheses ("()") and asterisks indicate significance levels at *** $p < 0.01$, ** $p < 0.05$, and * $p < 0.1$.

validity, indicating that they are appropriately uncorrelated with the error terms, hence providing reliable estimates.

4.6. Cross-Sectional Analysis

4.6.1. Financial Constraints

The cross-sectional analysis results in Table 6 provide compelling insights into the dynamic interactions between ESG performance, FCRE, and FSP. The regression analysis demonstrates distinct impacts of ESG performance and FCRE on FSP, differentiated by financial constraints. In financially unconstrained firms, ESG practices slightly negatively impact stock performance, while the impact is more pronounced in financially constrained firms, suggesting that limited financial flexibility exacerbates the challenges and costs associated with implementing ESG initiatives. Interestingly, while FCRE negatively affects stock performance in unconstrained firms, indicating concern over potential costs and liabilities from climate risks, it positively impacts constrained firms, possibly reflecting investor approval of proactive risk management in these more vulnerable entities. These results highlight how financial flexibility influences corporate sustainability efforts and their reception by the market.

4.6.2. Firm size

Li et al. (2024) identified "*size discrimination*" in the firm's value analysis. We test this relationship by dividing our sample by mean size in small and big sizes. The results in Table 7, segmented by firm size and incorporating lags of ESG performance, reveal distinct dynamics in how ESG initiatives and FCRE impact FSP. The regression analysis reveals that ESG performance negatively impacts FSP in the short term for both small (−0.030) and big firms (−0.044), with a more pronounced effect in larger organisations, likely due to higher expectations and greater scrutiny from stakeholders. Interestingly, the influence of lagged ESG performance varies over time; initial negative impacts are observed in big firms (L1. ESG at −0.020), whereas positive effects emerge in subsequent years (L2. ESG at 0.011 for big firms and 0.006 for small firms), suggesting that the financial benefits of ESG investments may materialise after overcoming initial implementation challenges. Moreover, FCRE consistently shows a strong negative impact on FSP across all firm sizes (−0.086 for small firms and −0.114 for big firms), indicating that higher climate risks are viewed unfavourably by the market, potentially due to associated mitigation costs or investor concerns about exposure to environmental risks. This pattern underscores the complex dynamics of ESG integration, where strategic management and timing of initiatives play critical roles in realising potential long-term gains while managing

Table 6
GMM estimation for financial constraints.

	The dependent variable is FSP	
	(1)	(2)
VARIABLES	Financial Unconstrained	Financial Constrained
L.SR	−0.174***	−0.212***
	(0.002)	(0.001)
ESG	−0.002***	−0.005***
	(0.001)	(0.001)
FCRE	−0.067***	0.032***
	(0.005)	(0.011)
Controls	*Yes*	*Yes*
Observations	*1322*	*1271*
AR2 - P value	*0.359*	*0.727*
Sargan - P value	*0.992*	*0.997*

The table presents the dynamic panel data estimation results using the two-step system GMM. "L." indicates the lagged value in the model and financial constraints measured using the Whited-Wu (WW) index; firms above the median are classified as constrained, and those below as unconstrained. Standard errors in parentheses ("()") and asterisks indicate significance levels at *** $p < 0.01$, ** $p < 0.05$, and * $p < 0.1$.

Table 7
GMM estimation for small and big firms.

	The dependent variable is FSP	
	(1)	(2)
VARIABLES	Small Firms	Big Firms
L.SR	−0.123***	−0.219***
	(0.004)	(0.003)
ESG	−0.030***	−0.044***
	(0.011)	(0.004)
L.ESG	0.036	−0.020***
	(0.022)	(0.006)
L2. ESG	0.006***	0.011***
	(0.001)	(0.006)
L3. ESG	−0.033***	0.040***
	(0.002)	(0.008)
FCRE	−0.086***	−0.114***
	(0.020)	(0.007)
Controls	Yes	Yes
Observations	1230	1493
AR2 - P value	0.399	0.662
Sargan - P value	0.723	0.665

The table presents the dynamic panel data estimation results using the two-step system GMM. "L." indicates the lagged value in the model. In Models 1 and 2, we divide the sample based on the mean value of firm size in big and small firms. Standard errors in parentheses "()" and asterisks indicate significance level at *** $p < 0.01$, ** $p < 0.05$ and * $p < 0.1$.

immediate financial impacts.

4.7. Mechanism Analysis

4.7.1. The role of climate risk

The results from the GMM analyses in Table 8 highlight the dynamic nature of the relationship between ESG scores, FCRE, and FSP, with lagged stock returns demonstrating a significant negative relationship. The persistent negative effects of ESG scores across models can be theoretically linked to the initial costs and potential short-term financial sacrifices firms may endure when implementing sustainable practices, consistent with the view from neo-classical economics that emphasises

cost efficiency and immediate returns to shareholders. However, the moderation of these effects over time, particularly through interaction with FCRE, suggests a gradual realisation of ESG benefits, aligning with the resource-based view, which posits that strategic investments in sustainability could enhance long-term competitive advantage by mitigating risks associated with climate change.

4.7.2. The role of market concentration

The interaction between ESG performance and market concentration (HHI) (see Table 9) introduces an additional layer of complexity, suggesting that the effectiveness of ESG initiatives can depend significantly on market structure. HHI negatively affects FSP, indicating potential inefficiencies or reduced competitive pressures in concentrated markets (Zhang and Guo, 2021). The interaction terms between ESG and HHI further reveal that the negative impact of ESG on stock returns is more pronounced in highly concentrated markets, a finding supported by research indicating that the effectiveness of ESG can vary significantly depending on industry characteristics (Borghesi et al., 2014). High market concentration can lead to inefficiencies and reduced innovation, as seen in the Indonesian banking sector (Pahlevi and Ruslan, 2019). However, positive coefficients of lagged interaction terms suggest that the market may eventually recognise the value of ESG performance, especially in concentrated industries, supporting the notion that the strategic integration of ESG can yield positive returns over time (Servaes and Tamayo, 2013). This complex interplay highlights the nuanced impact of ESG performance on FSP, influenced by both the temporal aspect of ESG integration and the specific market structure.

4.7.3. The role of the Paris agreement

To investigate the effect of the Paris Agreement, we divided our sample into two groups based on the years. The first group is data from 2009 to 2015, while the second group is from 2017 to 2023. Table 10 presents the results of this analysis. The influence of the Paris Agreement on the dynamics between ESG scores and stock returns presents a compelling insight into how regulatory frameworks can reshape corporate valuation in the context of sustainability. The regression analysis examines the impact of the Paris Agreement on FSP, revealing a

Table 8
Moderation analysis of FCRE with GMM.

	The dependent variable is FSP	
Variables	(1)	(2)
L.SR	−0.160***	−0.154***
	(0.001)	(0.001)
ESG*FCRE	0.011***	0.011**
	(0.003)	(0.004)
L1_ESG*FCRE		0.017***
		(0.006)
L2_ESG*FCRE		−0.080***
		(0.013)
ESG	−0.040***	−0.040***
	(0.011)	(0.009)
FCRE	−0.159***	−0.067*
	(0.012)	(0.036)
L.ESG		−0.030***
		(0.011)
L2. ESG		0.044***
		(0.008)
L3. ESG		0.011***
		(0.001)
Controls	Yes	Yes
AR2 P Value	0.956	0.609
Sargan P value	0.841	0.875

The table presents the dynamic panel data estimation results using the two-step system GMM. "L." indicates the lagged value in the model. In the 1st and 2nd models, we examine the interaction impact of ESG and FCRE on stock returns. Standard errors in parentheses "()" and asterisks indicate significance level at *** $p < 0.01$, ** $p < 0.05$ and * $p < 0.1$.

Table 9
Moderation analysis of HHI with GMM.

	The dependent variable is FSP	
Variables	(1)	(2)
L.SR	−0.163***	−0.173***
	(0.001)	(0.001)
ESG	−0.040***	−0.040***
	(0.010)	(0.010)
L.ESG		−0.030***
		(0.007)
L2. ESG		0.003***
		(0.001)
FCRE	−0.101***	−0.077***
	(0.005)	(0.008)
HHI	−0.241***	−0.898***
	(0.029)	(0.040)
ESG*HHI	−0.022***	−0.017***
	(0.006)	(0.002)
L1_ESG*HHI		0.015***
		(0.002)
L2_ESG*HHI		0.021
		(0.017)
Controls	Yes	Yes
AR2 P Value	0.998	0.598
Sargan P value	0.830	0.807

The table presents the dynamic panel data estimation results using the two-step system GMM. "L." indicates the lagged value in the model. In models 1 and 2, we examine market concentration (HHI) as a moderator of ESG. Standard errors in parentheses "()" and asterisks indicate significance level at *** $p < 0.01$, ** $p < 0.05$ and * $p < 0.1$.

Table 10
Moderation analysis of Paris agreement with GMM.

	The dependent variable is FSP	
Variables	(1)	(2)
L.SR	−0.162***	−0.167***
	(0.001)	(0.001)
ESG	−0.040***	−0.040***
	(0.010)	(0.011)
L.ESG		−0.011***
		(0.002)
L2. ESG		0.033***
		(0.009)
FCRE	−0.090***	−0.031***
	(0.009)	(0.005)
A_Paris	−0.194***	−0.092***
	(0.011)	(0.006)
ESG*Paris	0.012***	0.080***
	(0.001)	(0.014)
L1_ESG*Paris		−0.020***
		(0.004)
L2_ESG*Paris		−0.060***
		(0.005)
Controls	Yes	Yes
AR2 P Value	*0.924*	*0.612*
Sargan P value	*0.857*	*0.822*

The table presents the dynamic panel data estimation results using the two-step system GMM. "L." indicates the lagged value in the model. In Models 1 and 2, we examine the impact of ESG and FCRE on stock returns by dividing the sample before and after the Paris Agreement. Standard errors in parentheses "()" and asterisks indicate significance level at *** $p < 0.01$, ** $p < 0.05$ and * $p < 0.1$.

negative correlation with stock returns immediately following its implementation, as indicated by coefficients of −0.194 and −0.092 in the two models. However, the interaction terms between ESG performance and the Paris Agreement reveal that higher ESG performance initially mitigates this negative impact, with coefficients of 0.012 in the first model and a more pronounced 0.080 in the second. This suggests that firms with robust ESG frameworks are better equipped to withstand the initial negative reactions to the Paris Agreement. The diminishing effect of ESG scores in subsequent years, indicated by the negative coefficients of −0.020 and −0.060 for the first and second-year lags in model 2, reflects the challenges firms face in sustaining the initial benefits of their ESG efforts. While firms may initially mitigate some of the negative impacts of the Paris Agreement, maintaining these advantages could be challenging as ongoing compliance costs accrue and the initial adjustments become less impactful. Over time, the continuous investment required to meet or exceed the evolving regulatory standards might strain financial resources, or the benefits may plateau, leading to reduced mitigation effects on stock performance. Chang et al. (2024) highlight that the Paris Agreement has increased consumer awareness of sustainability, leading to a shift away from "brown firms," those with poor environmental practices. This shift results in decreased demand for their products and services, subsequently reducing their financial performance. This trend highlights the growing economic pressure on firms to adopt sustainable practices or risk declining market share and financial performance due to shifting consumer preferences. This consumer behavior reinforces the importance of integrating robust environmental strategies to maintain competitiveness in a rapidly evolving marketplace.

4.8. Propensity Score Matching Analysis

In this study, we examine the complexities of evaluating the impact of ESG performance and FCRE on FSP, primarily employing fixed effects and System GMM methodologies to address potential endogeneity and non-linear relationships. While these methods robustly account for unobserved heterogeneity and the dynamic nature of financial data, we further enhance our analysis by employing Propensity Score Matching

(PSM) to mitigate issues of non-linearity and potential model misspecification that fixed effects and GMM might not fully resolve. PSM offers a methodologically distinct approach by not imposing a functional form on the relationships between dependent and independent variables, thereby providing a complementary perspective on the causal effects between ESG performance and FSP (Hossain et al., 2023; Jha and Cox, 2015).

To implement PSM, we categorise our sample based on the median ESG performance, forming a control group of firms with scores below the median and a treated group with scores above the median. Using a logit model incorporating all control variables from our primary analyses, we calculate the propensity scores to estimate the likelihood of firms belonging to higher climate risk exposure categories. Each firm in the treated group is then matched to a counterpart in the control group using a calliper of 0.0001, without replacement, culminating in a carefully curated sample of 1544 firm-year observations. By re-estimating the relationship using these matched samples and following the recommendations of Hossain et al. (2023); Shipman et al. (2017). Our results (see Table 11) consistently indicate a negative and significant association between ESG, FCRE, and stock returns. This reinforced finding through PSM not only corroborates our earlier results obtained via fixed effects and GMM but also underscores the robustness and reliability of our conclusions regarding the economic implications of ESG performance and climate risks.

4.9. Discussion

Our study offers comprehensive insights into the complex relationships between ESG, FCRE, and FSP, with a focus on varying firm sizes and the temporal impact of regulatory changes, such as the Paris Agreement. Our findings illuminate the complex dynamics that are crucial for both theoretical understanding and practical application in corporate strategy and policy formulation.

We observe a consistently negative impact of ESG performance on FSP across all firm sizes, which becomes less pronounced with the

Table 11
Propensity score matching analysis.

	The dependent variable is FSP			
Variables	(1)	(2)	(3)	(4)
L.SR	−0.165***	−0.163***	−0.166***	−0.169***
	(0.001)	(0.001)	(0.001)	(0.001)
ESG	−0.040***	−0.040***	−0.040***	−0.033***
	(0.009)	(0.011)	(0.008)	(0.008)
FCRE	−0.156***	−0.297***	−0.154***	−0.107***
	(0.002)	(0.025)	(0.004)	(0.003)
ESG_FCRE		0.003***		
		(0.001)		
HHI			−0.191***	
			(0.027)	
ESG_HHI			0.018	
			(0.017)	
A_Paris				−0.330***
				(0.010)
ESG_Paris				0.004***
				(0.001)
Controls	Yes	Yes	Yes	Yes
Observations	*1544*	*1544*	*1544*	*1544*
AR2 P Value	*0.304*	*0.328*	*0.303*	*0.316*
Sargan P value	*0.950*	*0.963*	*0.951*	*0.969*

This table displays the PSM sample results, which are estimated using dynamic panel data estimation with the two-step system GMM. "L." indicates the lagged value in the model. In 1st, examine the impact of ESG and FCRE on stock returns. In 2nd model, we examine the interaction impact of ESG and FCRE on stock returns. In the 3rd and 4th models, we examine market concentration (HHI) and the Paris Agreement as moderators of ESG. The sample spans from 2002 to 2023 and includes 226 firms from the UK. Standard errors in parentheses "()" and asterisks indicate significance level at *** $p < 0.01$, ** $p < 0.05$ and * $p < 0.1$.

inclusion of additional time lags. This pattern suggests that initial market reactions to ESG initiatives might be unfavourable due to the perceived costs or operational disruptions they entail. However, over time, these perceptions shift as the benefits of ESG performance begin to manifest, aligning with the Resource-Based View (RBV) that internal capabilities, like ESG practices, can evolve into strategic assets providing long-term value (Barney, 1991). The economic significance of this delayed positive impact suggests that firms endure an ESG integration learning curve, which gradually leads to enhanced operational efficiencies and improved market standing factors that positively influence stock performance.

The adverse effects of FCRE on FSP underscore the tangible financial risks posed by climate change, particularly affecting higher-performing firms where the impact of climate risks is more pronounced. This observation aligns with the risk management literature's perspective that exposure to external risks, such as climate change, can significantly erode firm value (Monasterolo and de Angelis, 2020). Our findings extend this perspective by showing that ESG practices can act as a moderating factor, with our data indicating that the negative impact of FCRE on stock performance diminishes when considering the influence of ESG performance over time. This modulation suggests that robust ESG strategies not only enhance firm resilience against climate-related risks but also support the stakeholder theory's assertion that managing broader stakeholder expectations through strong ESG performance is vital for sustained corporate success.

Our moderation analysis offers profound insights into the regulatory impact on the efficacy of ESG initiatives. Our analysis suggests that the Paris Agreement initially has a negative impact on firm stock performance, reflecting market concerns about the costs associated with new compliance requirements. However, firms with robust ESG frameworks are more effective in mitigating these initial negative effects, demonstrating the protective power of strong sustainability practices. Over time, the challenge becomes sustaining these benefits as the novelty of initial adjustments wanes and ongoing compliance costs accumulate, leading to a diminution of the positive impacts of ESG efforts. These dynamics underscore the importance for firms not only to adopt but also to continually enhance their ESG strategies to maintain competitiveness in a rapidly evolving regulatory and market landscape.

These findings underscore the importance of a nuanced understanding of how ESG performance, climate risks, and regulatory environments interact to impact FSP. This suggests that firms should not only implement ESG practices but also strategically manage these initiatives to align with both market expectations and regulatory frameworks. Overall, this research contributes to the empirical literature by providing evidence of the complex, time-sensitive interplay between internal corporate strategies (ESG performance), external risks (climate exposure), and regulatory changes (the Paris Agreement), thereby enriching the dialogue on strategic management and corporate finance in the context of global sustainability challenges.

5. Conclusion

The findings from this study highlight the complex interplay between ESG performance, FCRE, and FSP, providing valuable insights into the role of corporate sustainability practices within the broader context of financial performance and regulatory influence. The investigation has revealed that the immediate financial impacts of ESG initiatives are often negative due to their associated costs and investment shifts. However, the long-term perspective shifts dramatically, with ESG performance showing a positive impact on FSP as firms adjust and capitalise on their sustainability investments. This nuanced relationship between ESG performance and FSP is significantly conditioned by the firm's exposure to climate risks. Our study confirms that higher levels of FCRE have a negative impact on FSP, underscoring the tangible financial risks associated with climate change. However, the mitigating effect of ESG performance over time suggests that strategic ESG integration can serve

as a crucial risk management tool, enhancing a firm's resilience against environmental uncertainties. Our moderation analysis reveals that while the Paris Agreement initially reduces FSP due to compliance costs, firms with robust ESG frameworks effectively mitigate these impacts. Over time, maintaining these benefits becomes increasingly challenging as compliance costs rise, underscoring the critical need for ongoing enhancements to ESG strategies to remain competitive in a dynamic regulatory environment.

Our study makes significant theoretical contributions by integrating Stakeholder Theory and Resource-Based Theory to analyse the impact of ESG performance in high-risk environments. From the perspective of Stakeholder Theory, we demonstrate how enhanced stakeholder management through ESG initiatives can mitigate immediate risks and foster long-term trust and corporate legitimacy. This finding enriches the theory by underscoring the importance of transparent and ethical practices in maintaining stakeholder relationships, especially in sectors where risk perception is heightened. Simultaneously, through the Resource-Based Theory, our research demonstrates that ESG performance is not merely a matter of ethical imperatives but also a strategic resource that enhances competitive advantage and firm resilience. By treating ESG initiatives as integral components of a firm's strategic assets, we highlight their role in driving sustainable competitive benefits over time, thereby extending the theory to incorporate sustainability as a core element in resource-based competitive strategy.

On the practical front, the implications of our findings are manifold and extend across a diverse set of stakeholders, reflecting the broad relevance of our research. For company executives, the insights from our study provide a robust basis for advocating the initial costs associated with implementing ESG practices, demonstrating their role in securing long-term profitability and stability. Lawmakers and regulators can leverage our findings to refine policies and develop frameworks that encourage ESG adoption, aligning corporate actions with broader environmental and social objectives. Sustainability advocates and stakeholders can use the evidence from our research to push for more robust and genuine ESG commitments from firms, ensuring that corporate practices align with societal values. Additionally, our findings equip politicians and regulators with empirical evidence to support the enactment of policies that facilitate sustainable development, promoting a transition towards more resilient and environmentally conscious business practices.

Future research could extend this work by exploring the specific mechanisms through which ESG practices create value, investigating industry-specific effects, and examining how these relationships evolve over longer time horizons. Additionally, as climate-related disclosures and ESG reporting standards continue to evolve, future studies could assess how improvements in data quality and comparability affect these relationships. In conclusion, our study provides robust evidence for the financial materiality of ESG performance and climate risk exposure while revealing the complex and nuanced nature of these relationships across different firm characteristics and market conditions. As sustainability continues to gain prominence in corporate strategy and investment decision-making, understanding these dynamics will be crucial for creating long-term value and managing risks in an increasingly complex business environment.

CRediT authorship contribution statement

Xiaoxian Zhu: Project administration, Formal analysis, Writing – review & editing, Supervision. **Yongsheng Guo:** Supervision, Writing – review & editing, Software, Data curation. **Mirza Muhammad Naseer:** Formal analysis, Methodology, Writing – original draft, Conceptualization.

Declaration of Generative AI and AI-assisted technologies in the writing process

During the preparation of this work, the author(s) used ChatGPT (OpenAI) to enhance readability, refine the language, and improve clarity of the manuscript. After using this tool, the author(s) thoroughly reviewed, edited, and revised the content as necessary, and take(s) full responsibility for the content of the publication.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

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