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ESG UNCERTAINTY AND CORPORATE CAPITAL INVESTMENT BEHAVIOR: THE MEDIATING ROLE OF ENVIRONMENTAL EXPENDITURES

Sisi CHEN[1], Umar FAROOQ[2]✉, Abdulrahman ALOMAIR[3], Abdulaziz S. AL NAIM[4]

[1]*School of Accounting, Guangzhou College of Commerce, Guangzhou 511363, China*
[2]*School of Economics and Finance, Xi'an Jiaotong University, Xi'an, Shaanxi, P. R. China*
[3,4]*Accounting Department, School of Business, King Faisal University, AlAhsa 31982, Saudi Arabia*

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Abstract. This study investigates the impact of SUS on CIN, with a specific focus on the mediating role of ENX. Utilizing a panel dataset of firms spanning the period from 2010 to 2022, the study employs the fixed effects model (FEM), 2SLS, and the system generalized method of moments (GMM) to ensure robust estimation and address potential endogeneity concerns. The findings reveal that SUS harms CIN, suggesting that firms facing heightened ESG uncertainty are more cautious in their capital allocation. Moreover, the results confirm that ENX plays a mediating role, as firms tend to increase environmental expenditures in response to higher ESG uncertainty, which in turn reduces their capital investment. The study provides valuable social and practical implications. From a social perspective, it underscores the importance of stable and transparent ESG policies in mitigating uncertainty and promoting sustainable investment practices. Practically, firms should balance their environmental expenditures and investment strategies to ensure long-term financial stability. The study's novelty lies in integrating ESG-related uncertainty with CIN decisions through the mediating role of environmental expenditures, offering a fresh perspective on how firms respond to ESG-related risks in capital allocation.

Keywords: capital investment, environmental expenditures, ESG-related uncertainty, sustainable finance, BRICS, corporate finance.

JEL Classification: G31, Q56, G32.

✉Corresponding author. E-mail: ***umerrana246@gmail.com***

1. Introduction

Recently, factors related to environmental, social, and governance (ESG) have gained prominence in shaping corporate strategies, risk management, and financial performance (Gao et al., 2025). The mounting demand from regulatory authorities, investors, and stakeholders for transparent ESG performance compels firms to embed sustainability principles across their business practices and investment decisions (Jhunior et al., 2025). However, the evolving nature of ESG regulations and expectations introduces uncertainty which can have profound implications for corporate capital investment (CIN hereafter). Firms operate in a dynamic environment where shifting policy frameworks, stakeholder activism, and changing market conditions contribute to ESG uncertainty, thereby influencing strategic financial decisions. While preceding research has extensively inspected the impact of regulatory uncertainty on firm behavior (Zhang et al., 2024; Khan et al., 2025; Zhao et al., 2026), limited studies have

explored how ESG uncertainty specifically affects corporate capital investment and the mechanisms through which firms respond.

ESG-related uncertainty refers to the unpredictability surrounding ESG regulations, stakeholder expectations, and sustainability disclosure requirements which can significantly impact corporate decision-making. This uncertainty arises from fluctuating policy frameworks, evolving investor preferences, and the increasing amalgamation of ESG norms into financial markets (Ongan et al., 2025). In response, firms often reallocate resources toward environmental expenditures which include investments in pollution control, carbon reduction, renewable energy, and sustainable production processes (Cui & Li, 2025). These expenditures serve as both a compliance mechanism and a strategic tool to mitigate regulatory risks, enhance corporate reputation, and attract green financing. However, ESG uncertainty also affects capital investment, which involves long-term financial commitments to infrastructure, technology, and projects expansion (Yu et al., 2024). When firms face high ESG uncertainty, they may either delay traditional capital investments due to financial risks or integrate sustainability-focused investments to align with future regulatory landscapes. The interaction between these factors suggests that environmental expenditures may act as a bridge, enabling firms to manage ESG uncertainty while maintaining capital investment strategies that support long-term growth and sustainability.

This research examines how uncertainty surrounding ESG (SUS) considerations influences firms' capital investment decisions (CIN), emphasizing the transmission mechanism operating through environmental spending (ENX). The analysis was conducted on BRICS economies over the period 2010 to 2022 by using three econometric techniques: fixed effects (FEM), the instrumental variable approach (IV) i.e., 2SLS, and the system GMM model. The findings reveal that SUS negatively impacts CIN through the channel of increased environmental expenditures, which act as a mediating variable. Specifically, SUS has a positive effect on ENX, indicating that firms facing SUS allocate more financial resources toward environmental initiatives, likely to comply with regulations and manage sustainability risks. However, this increase in ENX limits the flow of funds toward CIN, as ENX shows a negative relationship with CIN. This effect remains consistent in the final channel, where the combined impact of SUS and ENX on CIN confirms the mediating role of environmental expenditures. Additionally, the study uncovers the dynamic impact of key financial variables including bank financing, cash holdings, firm size and firm efficiency. These findings pay to the ongoing discourse on sustainable finance by illustrating how ESG uncertainty influences CIN decisions in emerging economies.

This study makes a substantial theoretical contribution by extending the literature on ESG-related uncertainty and corporate financial decision-making. While previous research has explored the impact of general policy uncertainty on investment behavior (Hu et al., 2023; Zhang et al., 2024; Zhao et al., 2025), limited studies have specifically examined how ESG uncertainty influences capital investment through environmental expenditures. By integrating ESG uncertainty into the CIN framework, this study provides a novel perspective on how firms reallocate financial resources in response to sustainability-related risks. Additionally, the findings donate to the debate on the trade-off between regulatory compliance and growth-oriented investments, highlighting the role of environmental expenditures as a strategic adjustment mechanism. The study also enriches the literature on sustainable finance by linking ESG uncertainty with financial constraints, offering insights into how firms strike a balance between immediate financial results and long-term sustainability objectives. Empirically, this study enhances the understanding by employing a robust econometric approach across BRICS economies from 2010 to 2022. Using three distinct techniques i.e., FEM, 2SLS,

and the system GMM model, the study certifies that the verdicts are not driven by endogeneity concerns or model selection bias.

From a practical angle, the study offers valuable insights for corporate managers, policymakers, and investors. For corporate leaders, the findings emphasize the need to develop strategic approaches that balance environmental expenditures with capital investment to ensure financial stability while meeting sustainability goals. The study suggests that firms proactively managing ESG uncertainty through sustainable investments can enhance their market reputation and long-term financial resilience. For policymakers, the results highlight the importance of designing clear and stable ESG regulations that reduce uncertainty and encourage sustainable CIN.

The remainder of the paper proceeds as follows. Section 2 outlines the conceptual underpinnings, Section 3 synthesizes the empirical literature and formulates the testable hypotheses, Section 4 details the data sources and empirical strategy, Section 5 reports and interprets the results, and Section 6 offers concluding remarks, policy implications, limitations, and avenues for future research.

2. Theoretical background

The linkage between capital investment (CIN), ESG-related uncertainty (SUS), and environmental expenditures (ENX) can be supported by several theoretical frameworks that explore how firms respond to uncertainty and allocate resources towards sustainable practices. Agency theory, introduced by Jensen and Meckling (1976), explores the relationship between managers and shareholders, focusing on conflicts of interest and how these can affect corporate decision-making. In the context of this study, SUS can lead to an increased ENX as firms may allocate more resources to manage ESG-related risks, aiming to align the benefits of numerous stakeholders, including investors, regulators, and the public. However, these increased environmental investments could reduce available capital for other investments, leading to a negative relationship with CIN.

Similarly, signaling theory (Spence, 1973) suggests that companies convey information to the market through their actions, such as investments and expenditures. In the context of SUS and ENX, firms might increase environmental spending as a way to signal their commitment to sustainability and to reduce uncertainty for stakeholders. This is particularly relevant when facing ESG-related uncertainty, as firms use their environmental expenditures to signal to investors, regulators, and consumers that they are addressing sustainability concerns. However, these signaling activities may limit the funds available for direct capital investment (CIN), as resources are diverted towards environmental efforts. Thus, signaling theory supports the notion that increased ENX may mediate the negative relationship between SUS and CIN, as firms attempt to signal their sustainable practices while balancing limited resources.

The resource-based view (RBV) asserts that a firm's distinct resources and competences are the primary causes of its competitive advantage (Barney, 1991). In this framework, SUS can be viewed as a source of external uncertainty that prompts firms to allocate resources towards sustainability initiatives, represented by ENX. Firms that invest in environmental expenditures may be aiming to develop capabilities that differentiate them in the market and comply with regulatory requirements. However, this shift in resource allocation could reduce the capital available for other types of investments, leading to a lower CIN. The RBV suggests that firms are strategically managing their resources in response to external pressures like SUS, leading to a trade-off between sustainability investments and traditional capital expenditures.

The pecking order theory (POT) (Myers & Majluf, 1984) argues that firms prioritize using internal funds, such as retained earnings, for financing investments over exterior financing to minimize the costs and avoid the information disproportionateness that comes with issuing new equity. In the context of CIN and ENX, firms that face higher SUS might prioritize environmental expenditures as part of their internal financing strategy. When facing uncertainty about future ESG regulations or market shifts, firms may allocate more funds to environmental initiatives to reduce risk. However, this could come at the expense of other capital investments, as firms may feel constrained in their capital expenditure decisions.

3. Empirical review of literature and hypotheses

3.1. ESG-uncertainty and corporate investment

The intersection of ESG factors and corporate investment (CIN) decisions has attracted growing scholarly attention, particularly under conditions of uncertainty. Ren et al. (2022) explored the nonlinear and unequal effects of climate policy uncertainty (CPU) on CIN in China's energy sector using a dynamic threshold model and panel data from 128 firms (2007–2019). Their findings revealed that CPU negatively affects investment at lower levels but becomes insignificant at higher levels, with mining firms facing stronger adverse impacts compared to other sectors. Extending this inquiry to developed economies, Zhang et al. (2022) investigated the relationship between autonomous ESG factors and CIN in the UK, finding that strong authority fosters investment, whereas climate and migration policy uncertainty hinders it, highlighting how institutional quality shapes the uncertainty–investment nexus.

Focusing on the Chinese context, Hu et al. (2023) examined environmental policy uncertainty by distinguishing between PCU and PEU. The study found that both forms significantly reduce green investments, while executives' environmental awareness indirectly enhances investment by moderating the effect of PEU. In another dimension, Chasiotis et al. (2024) analyzed how ESG reputational danger influences investment efficiency, showing that higher reputational risk leads to underinvestment and slower adjustment toward optimal investment levels. Similarly, Zhuang and Duan (2025) assessed the influence of environmental uncertainty on CSR, with corporate financial investment acting as a mediating factor. Their results indicated that rising environmental uncertainty discourages CSR engagement, as firms prioritize short-term financial investments—especially among state-owned, nonfamily, and low-risk-taking firms.

Moreover, Zhang et al. (2025) investigated the influence of CPU on corporate investment efficiency (CIE) using annual data of Chinese firms (2009–2020). They found that CPU adversely affects CIE across industries, with a stronger influence on non-SOEs and technology-driven firms, while highly productive firms exhibit greater resilience. Complementing this evidence, Zhao et al. (2025) analyzed Chinese A-share listed companies (2008–2022) and confirmed that CPU reduces CIN, particularly for SOE and high-carbon-emitting firms, whereas supervisory climate attention and robust ESG ratings can mitigate this negative effect.

Collectively, these studies demonstrate that different forms of uncertainty like climate, policy, environmental, and reputational consistently shape firms' investment decisions by altering risk perceptions and strategic priorities. However, despite the growing body of literature on policy and ESG-related uncertainties, there remains a lack of research explicitly investigating sustainability uncertainty (SUS) as an overarching construct that encompasses ESG-related unpredictability. This gap underscores the need to explore how SUS affects CIN. Accordingly, the following hypothesis is proposed:

H1: Uncertainty surrounding ESG factors exerts a statistically significant adverse effect on firms' CIN decisions.

3.2. ESG-uncertainty and environmental expenditures

While no direct studies have discovered the link amongst ESG uncertainty (SUS) and environmental expenditures (ENX), several related works provide important insights into how firms may adjust their environmental spending under conditions of sustainability-related uncertainty. For instance, Apergis et al. (2022) scrutinized the association between ESG scores and the cost of debt for S&P 500 firms (2010–2019) and found that firms with stronger ESG performance benefit from lower bond spreads and higher credit ratings. This suggests that improving ESG standing can reduce perceived financial risk, motivating firms to allocate more resources toward environmental initiatives. Similarly, Cheng and Micale (2022) analyzed the informational role of third-party ESG risk assessments and found that higher ESG menace exposure strengthens the connection between current earnings and firm value, while weakening the relevance of book value, particularly for governance risks. These findings imply that firms emphasizing ESG performance may increase ENX to enhance long-term valuation and stakeholder confidence.

Empirical evidence also connects broader policy and environmental uncertainty to sustainability-related investments. Ilyas et al. (2022) reported that higher economic policy uncertainty (EPU) encourages firms to increase CSR investment across ESG dimensions, with firm size moderating this relationship, larger firms being better positioned to absorb uncertainty through higher CSR engagement. Similarly, Kyaw (2022) found that EPU has a delayed but persistent adverse effect on environmental innovation, as firms postpone R&D investments for 5–6 years under uncertainty before the effect dissipates. Wang et al. (2023) further revealed that environmental ambiguity reduces overall ESG performance through its influence on investor sentiment and green innovation, particularly among mature firms and those in smaller markets with substantial government intervention. These findings collectively suggest that firms may use ENX as a strategic buffer to counter uncertainty and maintain ESG performance.

At the international level, Priem and Gabellone (2024) analyzed 600 companies across 17 countries (2018–2021) and initiate that higher ESG scores lower the cost of capital, especially in countries with feebler legal environments. The environmental and social dimensions were the main contributors to this reduction, implying that firms with lower ESG performance may face higher environmental costs similar to higher financing costs. Lastly, Chen and Meng (2025) examined how sustainable development practices influence corporate tax jeopardy and found that firms with better ESG performance mitigate tax risk by improving green innovation, reputation, and transparency, particularly under high EPU. This suggests that, to pre-empt regulatory and reputational risks, firms may proactively raise environmental expenditures during periods of sustainability uncertainty. Collectively, these studies indicate that ESG uncertainty and related risks encourage firms to enhance environmental investments as a means of mitigating financial, regulatory, and reputational vulnerabilities. This theoretical reasoning supports the following hypothesis:

H2: ESG uncertainty significantly enhances the environmental expenditures.

3.3. Environmental expenditures and corporate investment

The empirical literature provides valuable insights into how environmental expenditures (ENX) and related policies influence CIN. Farooq et al. (2021) examined the role of government green policies in shaping CIN using System GMM estimation and found that carbon taxes reduce corporate investment, whereas renewable energy policies and green growth productivity stimulate investment. Their results support Porter's hypothesis, emphasizing the importance of subsidy-driven green transitions to offset regulatory costs. Similarly, Huang and Lei (2021) analyzed how different types of environmental regulations affect corporate green investment in China, focusing on the moderating effects of regional marketization and ownership structure. They reported that market-based and public participation regulations significantly encourage green investment, with non-state-owned firms demonstrating higher responsiveness.

Li et al. (2021) explored the dual effects of environmental uncertainty and financing constraints on CIN among Chinese A-share firms (2010–2019). Their findings indicate that environmental uncertainty directly reduces investment and indirectly constrains it by tightening financing conditions, especially for smaller firms. While such uncertainty curbs overinvestment and enhances efficiency, it exacerbates inefficiencies in underinvested firms. Hong et al. (2022) further investigated the role of fiscal environmental expenditures and observed a crowding-out effect on corporate green investment, most evident in non-heavily polluting and state-owned firms, suggesting that government environmental spending can reduce private sector investment incentives.

Expanding the analysis to cross-country data, Farooq et al. (2024) studied 10 Asian economies (2010–2019) and found that environmental regulations (ENR) discourage investment but lead firms to increase cash holdings as a precautionary measure, whereas green innovation (GNI) promotes investment and reduces cash reserves. This highlights the moderating role of financial flexibility in responding to environmental policies. Liu et al. (2024) tested the "Porter Hypothesis" by assessing the impact of China's NEPL using a PSM-DID approach. Their findings show that stricter enforcement and disclosure requirements under NEPL significantly enhance green investment, particularly in areas with high industrial concentration and among SMEs with stronger financial performance.

Wang and Zhang (2024) evaluated the productivity effects of environmental investment and found a negative relationship, especially among firms with moderate productivity levels. The effect was stronger in heavily polluting industries and firms located in China's eastern region, reflecting geographic and sectoral heterogeneity. Liu et al. (2025) investigated how the AEC policy affects CIN in air trash control and found that highly polluting firms increased environmental investment after the policy's introduction. This response was largely driven by local government initiatives that strengthened pollution control and expanded green subsidies. State-owned enterprises exhibited a stronger response than private firms, and those facing greater pollution risks or shorter policy assessment cycles increased ENX more significantly. Finally, Sun et al. (2025) demonstrated that government environmental audits stimulate company green investment, particularly in large, non-state-owned firms. This effect is amplified by executives' environmental awareness and CEO overconfidence, highlighting the role of leadership traits in shaping investment outcomes.

Overall, the reviewed literature suggests that while supportive environmental policies and regulatory frameworks can encourage green investment, stringent environmental regulations, fiscal expenditures, and policy uncertainty may divert corporate funds from productive

investments toward compliance and adaptation (Farooq et al., 2021; Hong et al., 2022). Moreover, firms tend to increase environmental spending in response to uncertainty, which can further constrain capital investment (Li et al., 2021; Liu et al., 2024). Despite these insights, no existing study has explicitly examined how ESG uncertainty (SUS) affects CIN through the mediating role of ENX. Addressing this gap, the present study investigates the following hypotheses:

H3: Environmental expenditures have significant negative relationship with corporate investment.

H4: Environmental expenditures significantly mediate the relationship between ESG-uncertainty and corporate investment.

4. Data and methods

4.1. Data and sample description

The data used in this study spans from 2010 to 2022. Initially, the sample consists of 27,157 firm-year observations, representing 2,089 unique firms across a 13-year period. To ensure data reliability and robustness, several data cleaning techniques were applied. These included the removal of firms with missing financial data and the exclusion of extreme outliers that could distort the results. After these adjustments, the final sample comprises 23,647 firm-year observations, covering 1,819 distinct firms over the study period. The distribution of firms across the BRICS economies is as follows: Brazil (131 firms), Russia (88 firms), India (593 firms), China (882 firms), and South Africa (125 firms). This diverse sample from emerging economies provides a comprehensive foundation for inspecting the impact of SUS on CIN within the context of developing markets.

The selection of the 2010–2022 time span and the focus on BRICS economies for this study is motivated by several key factors. The period from 2010 to 2022 captures a significant era of increasing global attention to ESG issues, marked by evolving regulatory frameworks, heightened corporate sustainability efforts, and growing investor demands for transparent ESG disclosures. These developments have made ESG-related uncertainty a critical factor influencing corporate decision-making, particularly in emerging markets. Similarly, the BRICS economies are chosen due to their pivotal roles in the global economy and their diverse economic, political, and regulatory landscapes, making them ideal for examining the impact of ESG uncertainty across different contexts. The data utilized in this study were sourced from DataStream (for firm-specific variables) and Uncertainty website[1].

4.2. Research models and variables

Building on the theoretical framework established by Baron and Kenny (1986), the mediating relationship can be examined through the following four pathways:

Path 1: Effect of ESG-Uncertainty (SUS) on Investment (CIN)

$$CIN_{ijt} = \beta_{\circ} + \alpha_1 SUS_{ijt} + \beta_1 BFN_{ijt} + \beta_2 CHO_{ijt} + \beta_3 FRS_{ijt} + \beta_4 FEF_{ijt} + \varepsilon_{ijt}. \quad (1)$$

[1] https://www.policyuncertainty.com/

Path 2: Effect of ESG-Uncertainty (SUS) on Environmental Expenditures (ENX)

$$ENX_{ijt} = \beta_{\circ} + \alpha_1 SUS_{ijt} + \beta_1 BFN_{ijt} + \beta_2 FRS_{ijt} + \beta_3 FEF_{ijt} + \varepsilon_{ijt}. \quad (2)$$

Path 3: Effect of Environmental Expenditures (ENX) on Investment (CIN)

$$CIN_{ijt} = \beta_{\circ} + \alpha_1 ENX_{ijt} + \beta_1 BFN_{ijt} + \beta_2 CHO_{ijt} + \beta_3 FRS_{ijt} + \beta_4 FEF_{ijt} + \varepsilon_{ijt}. \quad (3)$$

Path 4: Effect of Environmental Expenditures (ENX) on Investment (CIN)

$$CIN_{ijt} = \beta_{\circ} + +\alpha_1 SUS_{ijt} + \alpha_2 ENX_{ijt} + \beta_1 BFN_{ijt} + \beta_2 CHO_{ijt} + \beta_3 FRS_{ijt} + \beta_4 FEF_{ijt} + \varepsilon_{ijt}. \quad (4)$$

Equation (1) tests Hypothesis 1 (H1), examining the relationship between ESG-related uncertainty (SUS) and capital investment (CIN). Equation (2) addresses Hypothesis 2 (H2), assessing the impact of SUS on environmental expenditures (ENX). Equation (3) tests Hypothesis 3 (H3), exploring the effect of ENX on CIN. Finally, Equation (4) tests Hypothesis 4 (H4), analyzing the mediating role of ENX in the relationship between SUS and CIN. Figure 1 is showing the research framework of the study.

Table 1 is providing the summary of these variables.

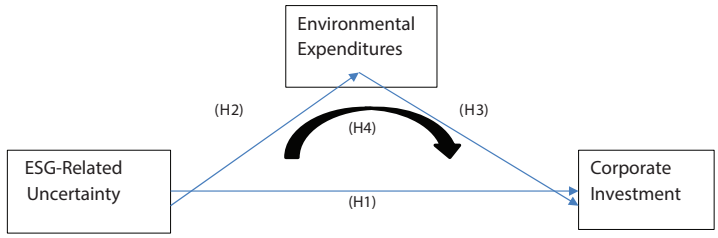

Figure 1. Research agenda of study (source: self-articulation)

Table 1. Summary of variables (source: the measurement of variables was derived from existing literature)

Acronyms	Name	Measurement	Role
CIN	Capital Investment	Capital expenditures/total assets	Dependent
SUS	ESG-related uncertainty	ESG-related Uncertainty index	Independent
ENX	Environmental expenditures	Environmental Expenditures/total revenue	Mediating
BFN	Bank financing	Total debts/total assets	Control
CHO	Cash holdings	Cash & cash equivalents/total assets	Control
FRS	Firm size	Log (total assets)	Control
FEF	Firm efficiency	EBIT/total assets	Control

4.3. Methodology discussion

In this study, several pre-estimation techniques were employed to assess the appropriateness of the model specification, detect potential issues like heteroscedasticity and endogeneity, and ensure the reliability of the regression results. These tests were conducted to guide the

selection of the most suitable regression techniques. The first step in our pre-estimation analysis was the Hausman test for model preference which helps determine whether to use a FEM or a random-effects model (REM). The Hausman test is essential because it compares the consistency and efficiency of the two models by checking if the random effects are correlated with the regressors. If such a correlation exists, the REM would produce biased estimates, making the FEM the more reliable choice. The results from Appendix Table A1 indicate a Chi-Square (χ^2) value of 227.535 with a p-value of 0.000, which strongly suggests the presence of unobserved heterogeneity across the firms. The low p-value leads us to discard the null hypothesis that the REM is appropriate and to opt for the FEM. The fixed-effects model accounts for individual firm-level differences, ensuring that we obtain consistent and unbiased estimates of the relationships among variables. Thus, the Hausman test results led us to adopt the FEM as the baseline regression model for further analysis.

The next pre-estimation test was the Likelihood Ratio (LR) test for heteroscedasticity, which was conducted to check for non-constant change of the error terms across the observations. Heteroscedasticity is a common issue in panel data where the variance of the residuals may differ across cross-sectional units or over time. The presence of heteroscedasticity can lead to inefficient estimations and biased S.E (standard error), which could distort statistical inference. The results from Table A2 display that the LR test statistic is 39.009 with a p-value of 0.000, signifying the presence of heteroscedasticity in the data. This means that the variance of the residuals is not constant, which could affect the robustness of the standard errors in the model. In response to this, we opted for robust standard errors in subsequent estimations to correct for heteroscedasticity. This ensures that our model remains valid and the statistical inferences drawn from it are reliable.

The final key pre-estimation test was the Durbin-Wu-Hausman (DWH) test for endogeneity, which assesses whether any explanatory variables exhibit correlation with the disturbance term. Endogeneity may stem from several sources, such as omitted variables, measurement errors, or simultaneity. If not addressed, it can result in biased and inconsistent estimates. Table A3 presents the results of both the DWH test, with test statistics of 9.081 (p-value = 0.001) and 10.888 (p-value = 0.031), respectively. Both tests strongly indicate the presence of endogeneity in the model, meaning that some of the explanatory variables are likely correlated with the error term. To address this issue, we decided to employ more sophisticated estimation technique like instrumental variable (IV) approach and system GMM that could account for the endogeneity problem.

5. Results presentation and discussion

5.1. Descriptive analysis

In Table 2, the mean values of key variables provide insight into the central tendencies and general characteristics of the dataset. Starting with CIN, the mean value is 0.322, suggesting that on average, firms allocate about 32.2% of their total assets to capital expenditures, indicating a moderate level of investment in physical assets and growth opportunities across the sample. This suggests that firms are actively pursuing investment strategies to develop long-term capabilities. Next, SUS has a mean value of 22.325, which reflects the average level of ESG-related uncertainty experienced by the firms in the study. This indicates a relatively high level of uncertainty related to ESG factors, as firms are grappling with fluctuating regulations and market expectations. For ENX, the mean value is 12.537, suggesting that on av-

erage, firms allocate about 12.5% of their total revenue towards environmental initiatives and sustainability efforts. This reflects the degree to which firms are investing in environmental practices, which may be influenced by the level of ESG-related uncertainty.

Table 2. Descriptive analysis (source: self-estimation)

Variable	Mean	Median	Maximum	Minimum	Std. Dev.	Skewness	Kurtosis
CIN	0.322	0.294	0.909	0.031	0.214	0.425	2.244
SUS	22.325	21.327	42.347	11.155	7.113	1.073	3.814
ENX	12.537	11.378	39.420	2.211	0.850	1.059	4.546
BFN	0.268	0.256	0.905	0.006	0.178	0.474	2.683
CHO	0.145	0.116	0.900	0.011	0.119	1.483	3.869
FRS	7.366	7.306	10.432	5.069	0.716	0.469	3.537
FEF	0.119	0.108	0.848	–0.807	0.088	0.261	2.536

Note: The abbreviation detail of variables can be seen in Table 1.

5.2. Correlation analysis

Table 3 reports the pairwise correlations between capital investment (CIN) and the explanatory variables, offering several notable observations. CIN is negatively and significantly associated with ESG-related uncertainty (SUS) with a coefficient of −0.044, indicating that higher uncertainty related to ESG issues is linked to lower levels of capital investment. The relationship between CIN and environmental expenditure (ENX) is also negative, though extremely weak (−0.023), suggesting only a marginal association between environmental spending and firms' investment activity. In contrast, bank financing (BFN) displays a positive and statistically significant correlation of 0.301 with CIN, implying that firms undertaking greater capital investment are more inclined to depend on bank-based funding. Conversely, cash holdings (CHO) are negatively and significantly correlated with CIN (−0.381), reflecting a tendency for firms with larger internal liquidity buffers to invest less in capital assets. Furthermore, an assessment of multicollinearity using the VIF indicates that all values remain well below the conventional threshold of 5, with the maximum value of 3.912 observed for firm size (FRS), thereby confirming that multicollinearity does not pose a serious issue for the empirical analysis.

Table 3. Correlation analysis (source: self-estimation)

Variable	CIN	SUS	ENX	BFN	CHO	FRS	FEF
CIN	1.000						
SUS	–0.044 [a]	1.000					
ENX	–0.023 [a]	–0.001 [b]	1.000				
BFN	0.301 [b]	0.0004 [c]	–0.049 [a]	1.000			
CHO	–0.381 [a]	0.051 [a]	0.027 [b]	–0.332 [a]	1.000		
FRS	0.192 [c]	0.050 [a]	0.001 [a]	0.237 [b]	–0.171 [a]	1.000	
FEF	0.107 [a]	–0.020 [b]	0.023 [a]	–0.282 [a]	0.066 [b]	–0.051 [a]	1.000
Multicollinearity test							
VIF	3.018	3.118	2.998	2.886	3.001	3.912	2.081

Notes: The abbreviation detail of variables can be seen in Table 1. Subscripts a, b, c are for significance levels at 1%, 5%, and 10% relatively.

5.3. Regression analysis

The experiential outcomes presented in Table 4 provide perceptions into the impact of ESG-related uncertainty (SUS) on CIN. The system GMM results reveal that SUS has a negative and significant impact on CIN at the 10% level, indicating that firms reduce their capital investments in response to ESG-related uncertainty. The uncertainty regarding future environmental policies and compliance costs may lead firms to delay capital expenditures, adopt a "wait-and-see" approach, or divert resources toward short-term liquidity management rather than long-term investment projects. The negative effect of SUS could indicate that firms allocate resources toward compliance and risk mitigation efforts rather than productive capital investment. The financial burden of adapting to uncertain ESG-related policies such as new environmental taxes, carbon regulations, or sustainability reporting mandates might divert funds away from capital-intensive projects (Zhao et al., 2025). This supports the idea that corporate sustainability risk discourages firm-level investment, leading to underinvestment in capital-intensive projects that require long-term commitment and stability (Zhang et al., 2025). In particular, the negative impact of SUS on CIN is strongly supported by the POT, which posits that firms prefer using internal financing over external sources to avoid the information asymmetry that arises with external funding. When faced with ESG uncertainty, firms tend to hoard liquidity rather than invest, fearing future financial constraints.

Table 4. Effect of SUS on Corporate Investment (CIN)

Variables	CIN as a dependent					
	Fixed effect		Two-Stage Least Squares		System GMM	
	Coefficients (Coef.)	Probability	Coef.	Probability	Coef.	Probability
C	0.319 [a]	0.000	–0.027 [a]	0.002	–0.078 [b]	0.029
CIN(–1)	–	–	0.611 [a]	0.000	0.613 [a]	0.000
SUS	–0.007 [a]	0.005	–0.001 [c]	0.078	–0.012 [c]	0.071
BFN	0.260 [a]	0.000	0.031 [a]	0.000	0.032 [a]	0.000
CHO	–0.508 [a]	0.000	–0.037 [b]	0.014	–0.030 [a]	0.014
FRS	–0.007 [a]	0.000	0.018 [a]	0.000	0.018 [a]	0.000
FEF	0.545 [a]	0.000	0.084 [a]	0.001	0.081 [a]	0.001
Adjusted R-squared		0.187	0.444		0.443	
S.E. of regression		0.200	0.051		0.052	
Second-Stage SSR		–	50.780		–	
Sargan Test		–	–		0.351	
Hansen J-Test		–	–		0.304	

Notes: Instruments specification: CIN(–2) SUS(–1) BFN(–1) CHO(–1) FRS(–1) FEF(–1).
Subscripts a, b, c are for significance levels at 1%, 5%, and 10% relatively. This table presents the direct impact of SUS on CIN using three econometric estimations. The results indicate that higher ESG-related uncertainty significantly reduces corporate investment, confirming the robustness of findings across estimation techniques.

The results in Table 5 indicate that ESG-related uncertainty (SUS) has a positive effect on environmental expenditures (ENX), suggesting that firms respond to ESG-related uncertainty by increasing their financial commitment to environmental initiatives. This implies that when firms face greater uncertainty regarding sustainability policies, regulations, and market expectations, they tend to allocate more resources toward environmental expenditures.

This response can be driven by the need to comply with evolving regulatory requirements, mitigate reputational risks, and enhance corporate sustainability performance (Hong et al., 2022). Additionally, firms may view increased environmental spending as a strategic move to maintain a competitive advantage and secure long-term financial stability. This relationship can be explained through agency theory and signaling theory. Agency theory suggests that managers may use environmental expenditures to align corporate actions with stakeholder expectations and reduce agency conflicts. By proactively investing in sustainability, firms can address concerns from investors, regulators, and consumers, ultimately improving corporate governance and risk management.

Table 5. Effect of ESG-uncertainty on environmental expenditures

Variables	Environmental expenditures as a dependent					
	Fixed effect		Two-Stage Least Squares		System GMM	
	Coefficients	Probability	Coefficients	Probability	Coefficients	Probability
C	0.219 [a]	0.000	7.955	0.835	7.952	0.831
ENX(–1)	–	–	0.472 [a]	0.000	0.471 [a]	0.000
SUS	0.344 [a]	0.007	0.751 [a]	0.002	0.756 [a]	0.000
BFN	0.201 [a]	0.005	0.465 [b]	0.016	0.463 [b]	0.015
FRS	1.149	0.941	0.362 [a]	0.000	0.361 [a]	0.000
FEF	–0.803 [b]	0.014	–0.160 [a]	0.000	–0.162 [a]	0.000
Adjusted R-squared		0.172	0.175		0.178	
S.E. of regression		351.117	366.011		366.800	
Second-Stage SSR		–	1.960		–	
Sargan Test		–	–		0.129	
Hansen J-Test		–	–		0.323	

Notes: Instruments specification: ENX(–2) SUS(–1) BFN(–1) CHO(–1) FRS(–1) FEF(–1).
Subscripts a, b, c are for significance levels at 1%, 5%, and 10% relatively. This table reports the effect of SUS on environmental expenditures (ENX). The positive and significant coefficients across models suggest that firms facing greater ESG-related uncertainty tend to increase their environmental spending, reflecting a risk-mitigation and reputation-enhancing strategy.

The results in Table 6 indicate that environmental expenditures (ENX) negatively influence CIN, suggesting that firms allocating higher financial resources toward environmental initiatives may reduce their capital investments. This negative relationship implies that firms face a trade-off between sustainability-related spending and investment in physical assets. Since environmental expenditures often require substantial financial commitments, they can limit the availability of funds for capital investments, particularly in firms operating under budget constraints. This effect may be more pronounced in firms that do not receive immediate financial returns from sustainability investments, leading them to prioritize compliance and reputation management over expanding their physical asset base. Farooq et al. (2021) and Hong et al. (2022) show that fiscal environmental expenditures impose additional costs on firms, leading to a significant "crowding-out" effect on corporate green investments. Additionally, this finding aligns with POT and RBV. The POT theory suggests that firms prefer internal financing over external financing and prioritize investments with immediate financial returns. Since environmental expenditures do not always generate short-term financial gains, firms may allocate fewer resources to capital investment to maintain liquidity and financial

stability. Similarly, RBV supports this by explaining that firms must strategically allocate their limited resources to maximize competitive advantage. If environmental expenditures consume a significant portion of available financial resources, firms may cut back on capital investment to maintain operational efficiency and long-term sustainability.

Table 6. Effect of environmental expenditures on CIN

Variables	CIN as a dependent					
	Fixed effect		Two-Stage Least Squares		System GMM	
	Coefficients	Probability	Coefficients	Probability	Coefficients	Probability
C	0.018 [b]	0.028	–0.031 [a]	0.000	–0.031 [a]	0.000
CIN(–1)	–	–	0.964 [a]	0.000	0.965 [a]	0.000
ENX	–0.081 [b]	0.021	–0.033 [b]	0.028	–0.037 [a]	0.010
BFN	0.272 [a]	0.000	0.013 [a]	0.000	0.019 [a]	0.000
CHO	–0.534 [a]	0.000	0.054 [a]	0.000	–0.052 [a]	0.000
FRS	0.034 [a]	0.000	0.003 [a]	0.000	0.008 [a]	0.000
FEF	0.471 [a]	0.000	0.009	0.339	0.005 [b]	0.033
Adjusted R-squared		0.228	0.296		0.298	
S.E. of regression		0.188	0.057		0.058	
Second-Stage SSR		–	44.486		–	
Sargan Test		–	–		0.214	
Hansen J-Test		–	–		0.322	

Notes: Instruments specification: CIN(–2) ENX(–1) BFN(–1) CHO(–1) FRS(–1) FEF(–1).
Subscripts a, b, c are for significance levels at 1%, 5%, and 10% relatively. This table examines the relationship between ENX and corporate CIN. The results demonstrate a negative association, indicating that higher environmental spending may crowd out firms' capital investment capacity, particularly under financial constraints.

The results in Table 7 confirm the mediating role of ENX in the relationship between SUS and corporate investment (CIN). The findings indicate that higher ESG-related uncertainty prompts firms to allocate more resources toward environmental expenditures, as seen in Table 5, and this increased spending on environmental initiatives subsequently leads to a decline in capital investment, as evidenced in Table 6. This two-step relationship highlights a clear mediating mechanism: firms facing heightened ESG-related uncertainty respond by increasing their environmental commitments, likely to align with regulatory expectations, enhance their reputation, or mitigate potential risks associated with ESG-related volatility. However, these additional environmental expenditures impose financial constraints, reducing the funds available for capital investment, ultimately leading to a decline in CIN. From literature, Liu et al. (2024) and Sun et al. (2025) highlight that stringent environmental regulations, such as China's NEPL and government environmental audits, significantly increase corporate environmental spending. This aligns with Farooq et al. (2024), who reveal that ESG-related regulatory uncertainty leads firms to increase cash reserves, which subsequently reduces investment.

Moreover, this mediating effect is well supported by agency theory and signaling theory. Agency theory explains that managers may allocate more resources to environmental expenditures to address stakeholder concerns and avoid regulatory penalties, even if it comes at the expense of capital investment. This behavior reflects a conflict between short-term financial priorities and long-term sustainability commitments. Meanwhile, signaling theory

suggests that firms increase environmental expenditures to signal their commitment to sustainability in response to market and regulatory pressures driven by ESG uncertainty. However, this signaling comes with financial trade-offs, as diverting funds toward environmental initiatives limits the firm's ability to pursue capital investments.

Table 7. Mediating effect

Variables	CIN as a dependent					
	Fixed effect		Two-Stage Least Squares		System GMM	
	Coefficients	Probability	Coefficients	Probability	Coefficients	Probability
C	0.039 [b]	0.034	–0.043 [a]	0.000	–0.043 [a]	0.000
CIN(–1)	–	–	0.966 [a]	0.000	0.965 [a]	0.000
SUS	–0.007 [a]	0.003	0.002 [a]	0.008	0.002 [a]	0.005
ENX	–0.004 [b]	0.026	–0.003 [a]	0.002	–0.004 [a]	0.001
BFN	0.273 [a]	0.000	0.012 [a]	0.000	0.016 [a]	0.000
CHO	–0.533 [a]	0.000	0.051 [a]	0.000	0.052 [a]	0.000
FRS	0.033 [a]	0.000	0.004 [a]	0.000	0.003 [a]	0.000
FEF	0.470 [a]	0.000	0.014	0.154	0.014 [a]	0.005
Adjusted R-squared		0.229	0.228		0.229	
S.E. of regression		0.189	0.058		0.053	
Second-Stage SSR		–	77.088		–	
Sargan Test		–	–		0.251	
Hansen J-Test		–	–		0.320	

Notes: Instruments Specification: CIN(–2) SUS(–1) ENX(–1) BFN(–1) CHO(–1) FRS(–1) FEF(–1).
Subscripts a, b, c are for significance levels at 1%, 5%, and 10% relatively. This table tests the mediating role of ENX in the relationship between SUS and CIN. The results confirm partial mediation, suggesting that ESG-related uncertainty indirectly reduces investment through increased environmental expenditures.

The validity of the system GMM model is confirmed through the Sargan and Hansen J-tests, which are used to assess the overall suitability of the instruments and the model's specification. In the context of the analysis, both tests yielded insignificant probability values in all models, as reported in Tables 4, 5, 6, and 7. This suggests that the null hypothesis of the tests, which states that the instruments are valid and uncorrelated with the error terms, cannot be rejected. In other words, the instruments used in the GMM model are appropriate, and the model specification is robust, ensuring that the results are reliable and not subject to potential bias from invalid instruments or misspecification. This validation strengthens the credibility of the system GMM estimates and their interpretation. Notably, the findings provide strong support for the alternative hypotheses (H1, H2, H3, and H4).

6. Conclusions and policies

This study investigates the impact of ESG-related uncertainty (SUS) on corporate investment (CIN), emphasizing the mediating role of environmental expenditures (ENX). Using a comprehensive panel dataset of BRICS economies from 2010 to 2022 and employing robust econometric techniques, the results consistently demonstrate that higher levels of SUS exert a negative influence on corporate investment. Firms facing heightened uncertainty in sustain-

ability-related regulations and expectations become more risk-averse, postponing or scaling back long-term capital commitments. This behavior reflects a defensive financial strategy, consistent with the pecking order theory (POT) and agency theory, where managers tend to preserve liquidity under ambiguous ESG conditions rather than engage in potentially risky investments. The findings further reveal that ESG uncertainty positively influences environmental expenditures, implying that firms often respond to rising uncertainty by strengthening their sustainability and compliance efforts. However, the analysis also reveals a negative association between ENX and CIN, highlighting a resource allocation trade-off. While increasing environmental spending enhances corporate reputation and risk management, it can simultaneously constrain firms' capacity to undertake productive investments, particularly in capital-intensive sectors.

The mediation analysis confirms the presence of an indirect channel through which ESG-related uncertainty reduces CIN via increased ENX. This finding provides empirical validation for the resource-based view (RBV) by showing that firms reallocate limited financial resources toward environmental assets that, while strategic in the long term, may limit short-term capital expansion. Collectively, the study uncovers a complex interaction between sustainability-driven behavior and investment efficiency, underscoring the dual challenge firms face in balancing environmental responsibility with financial growth. Theoretically, this research advances the literature by explicitly integrating SUS, a concept distinct from traditional economic or policy uncertainty into the corporate finance and investment behavior framework. Unlike prior studies that have primarily examined the impact of financial or policy-related uncertainties on firm performance, this study conceptualizes ESG-related uncertainty as a multidimensional construct encompassing environmental, social, and governance risks. By doing so, it extends existing theories such as agency theory, signaling theory, the resource-based view (RBV), and the pecking order theory (POT) to a sustainability-driven context, thereby providing a new theoretical perspective on how firms allocate resources under ESG-related risks.

Empirically, the study contributes by identifying and quantifying the mediating role of ENX between SUS and CIN. This mediation mechanism tested using three robust econometric techniques (FEM, 2SLS, and System GMM) on a balanced panel of BRICS economies from 2010 to 2022 offers novel evidence on how firms translate ESG uncertainty into concrete environmental actions that subsequently reshape their capital investment decisions. This specific empirical pathway had not been rigorously tested in previous research, marking a distinct contribution to the literature on sustainable corporate finance. From a practical and policy perspective, this research provides measurable insights for both firms and regulators. For firms, the findings highlight the quantifiable trade-off between sustainability spending and capital investment, suggesting that excessive ESG-related expenditures may crowd out long-term productive investments.

6.1. Policy implications

The findings of this study have important implications for policymakers, corporate managers, financial institutions, and investors. Given that ESG-related uncertainty (SUS) negatively affects capital investment (CIN) while increasing environmental expenditures (ENX), policymakers should focus on establishing clearer and more stable ESG-related regulatory frameworks. Reducing policy uncertainty can enhance corporate confidence in long-term investment decisions, ensuring that sustainability goals are met without compromising capital allocation for growth and innovation. For this, regulatory bodies should also incentivize firms to in-

tegrate environmental expenditures strategically rather than perceiving them as additional financial burdens that deter investment. For corporate managers, the study underscores the importance of balancing sustainability commitments with long-term investment strategies. Since an increased environmental expenditures reduce capital investment, firms should adopt proactive sustainability strategies that align with long-term financial goals. Managers can leverage sustainability reporting and transparency to mitigate investor concerns regarding ESG uncertainty, thereby securing stable financing options.

Financial institutions and banks play a crucial role in shaping CIN behavior. The positive effect of bank financing (BFN) on capital investment suggests that financial institutions should develop innovative green financing instruments, such as sustainability-linked loans and green bonds, to support firms in making long-term investments while fulfilling their environmental commitments. For investors, the study highlights the need to incorporate ESG-related uncertainty into their risk assessment models. The negative impact of SUS on capital investment suggests that firms facing regulatory uncertainty may be reluctant to engage in expansion and innovation, potentially affecting long-term returns. Investors should prioritize firms that demonstrate a clear ESG strategy and adaptability to evolving regulatory landscapes.

6.2. Limitations and future research

This study has certain limitations that provide avenues for future research. First, the measurement of ESG-related uncertainty (SUS) is based on an ESG-related uncertainty index, which, while comprehensive, may not fully capture firm-specific sustainability risks. Future studies can explore alternative measures or firm-level ESG disclosures to enhance precision. Second, the study focuses on a specific period and dataset, limiting its generalizability across different regions and economic conditions. Additionally, while the study establishes a mediating role of environmental expenditures (ENX) between SUS and capital investment (CIN), potential moderating factors such as corporate governance mechanisms or institutional quality remain unexplored. Future research could incorporate these elements to better understand how firms navigate ESG uncertainty.

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APPENDIX

Table A1. Hausman test for model preference (source: self-calculation)

Test Summary	Chi-Square (χ^2)	Degrees of Freedom	p-value	Decision
Cross-section random	227.535	6	0.000	FEM Preferred

Note: This table shows that LR exists.

Table A2. Likelihood Ratio (LR) Test for Heteroscedasticity (source: self-calculation)

Test Statistics	Chi-Square Value	Degrees of Freedom	p-value	Decision
Likelihood Ratio (LR) Test	39.009	10	0.000	Heteroscedasticity detected

Note: This table shows that LR exists.

Table A3. Durbin-Wu-Hausman Test for Endogeneity (source: self-calculation)

Test Statistics	Chi-Square (χ^2)	P-value	Decision
Durbin Test	9.081	0.001	Endogeneity detected
Wu-Hausman Test	10.888	0.031	Endogeneity detected

Note: This table shows that endogeneity exists.