THE IMPACT OF CLIMATE VARIABLES ON KEY FINANCIAL MARKET INDICATORS IN NIGERIA: AN ARDL APPROACH

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Abstract
This study investigates the macro-financial effects of climate change on investment performance in Nigeria, focusing on the interaction between key climate variables, rainfall, temperature, and carbon emissions, and financial indicators such as Treasury Bill Rate (TBR), Stock Market Index (SMI), and Bond Yield (BOY). Using the Autoregressive Distributed Lag (ARDL) model on a 34-year time series, the study examines both short- and long-run relationships between climate and financial variables. The results reveal that rainfall exerts a statistically significant negative effect on TBR in both the short and long run, suggesting that extreme rainfall events influence short-term liquidity and monetary dynamics. However, temperature, carbon emissions, and inflation exhibit no significant impact on SMI or BOY, indicating limited climate sensitivity in long-term capital markets. The findings underscore the partial responsiveness of Nigeria's financial system to climate variability and point to weak environmental signal integration. The study concludes that Nigerian financial markets remain in the early stages of climate-risk pricing and recommends that regulatory institutions such as the Central Bank of Nigeria (CBN) and the Securities and Exchange Commission (SEC) deepen climate-finance research, strengthen data infrastructure, and integrate climate disclosures into financial reporting to improve market resilience.

Keywords: ARDL model, capital allocation, climate change, financial markets, investment performance.

1.0 Introduction

Climate change has become a central determinant of macroeconomic stability and financial market performance across the globe, and Nigeria is no exception. As Africa's most populous country, Nigeria faces intensifying climate-related shocks that threaten its economic and financial systems. The 2022 floods, the most severe in a decade, displaced over 1.4 million people, destroyed more than 200,000 homes, and submerged at least 110,000 hectares of farmland resulting in losses estimated at US$6.7 billion (Wikipedia, 2023). Similarly, seasonal floods in 2024 affected 33 of 36 states, destroyed 700 hectares of farmland, and further undermined food production and infrastructure. Such recurrent climate events depress productivity in agriculture and manufacturing, weaken household income, and distort fiscal and monetary conditions factors that reverberate through Nigeria's financial markets. Between 2012 and 2018, Nigeria spent more than US$31 billion on flood and drought response (The Guardian Nigeria), while direct climate-related losses in 2022 alone reached US$9 billion (CPI, 2024). Yet annual adaptation financing remains inadequate just US$2.5 billion in 2021/22 compared to the estimated US$27.2 billion need (CPI, 2024). This financing shortfall heightens fiscal pressures, influences government borrowing requirements, and constrains monetary stability.

Coastal cities such as Lagos face rising sea levels and intensified storm surges that threaten infrastructure and real estate assets, while increasing temperatures and erratic rainfall patterns affect labour productivity, agricultural yields, and industrial output. These disruptions transmit directly into financial markets through changes in credit risk, inflation expectations, and investor

confidence. Nigeria has responded through initiatives such as the Climate Change Act (2021), the issuance of sovereign green bonds (since 2017), and the Nigeria Climate Investment Platform (NCIP), which aims to mobilise US$500 million in green finance. However, lending to renewable and climate-adaptation projects remains limited, and fixed-income markets continue to be dominated by government debt. Consequently, climate shocks are likely to exert first-order impacts on key financial market indicators, such as interest rates, stock prices, and bond yields that collectively underpin portfolio valuation and investor behaviour. While climate change ultimately affects investment portfolios, its first-order transmission channels, the direct pathways through which climate variables influence financial market indicators, remain underexplored in Nigeria. Empirical evidence on how climate dynamics such as temperature, rainfall, and carbon emissions affect key financial market indicators is limited, despite growing recognition that climate-induced shocks can alter monetary conditions, fiscal sustainability, and investor sentiment.

This study therefore focuses on three core financial indicators that capture the macro-financial transmission of climate risks in Nigeria:

Treasury Bill Rate (TBR): Representing short-term government borrowing costs and the monetary policy stance, which may respond to climate-induced fiscal pressures, emergency spending, and inflationary effects from food or energy shocks;

Stock Market Index (SMI): Reflecting aggregate corporate valuation and investor sentiment, which may fluctuate in response to climate-related disruptions in productivity, firm earnings, and overall economic stability; and

Bond Yield (BOY): Indicating long-term borrowing costs and risk premiums in the fixed-income market, which may increase with fiscal stress or heightened uncertainty arising from extreme weather events and environmental degradation.

These indicators are critical because they directly influence portfolio valuation, the cost of capital, and financial system stability. For instance, severe flooding or heat waves can trigger inflationary pressures and exchange rate volatility, prompting monetary tightening that raises TBR and BOY. Similarly, adverse temperature and rainfall variations can dampen firm performance and investor confidence, leading to declines in the SMI. Despite the increasing frequency of climate shocks and Nigeria's policy responses, there remains a paucity of empirical evidence on how climate variables specifically temperature, rainfall, and carbon emissions interact with financial market indicators. This knowledge gap constrains policymakers, regulators, and investors from effectively integrating climate risks into macroeconomic management and financial decision-making. To address this gap, this study employs the Autoregressive Distributed Lag (ARDL) approach to empirically examine both the short-run and long-run effects of selected climate variables (temperature, rainfall, and carbon emissions) on Nigeria's key financial market indicators Treasury Bill Rate, Stock Market Index, and Bond Yield. The findings are expected to provide actionable insights into how climate variability transmits through the financial system, shaping investment behaviour, monetary policy, and market resilience.

2.0 Literature Review

The intersection between climate change and financial investment has emerged as a critical area of scholarly and policy interest in recent years. As climate-related risks increasingly manifest in the form of extreme weather events, shifting regulatory landscapes, and evolving stakeholder expectations, their implications for investment portfolios have become profound and multifaceted. Consequently, both institutional and individual investors are reevaluating traditional investment

paradigms to incorporate sustainability considerations and mitigate exposure to climate-induced risks.

A growing body of literature acknowledges that climate change introduces both physical risks such as natural disasters and rising sea levels and transition risks, including policy reforms, technological shifts, and market sentiment changes associated with the transition to a low-carbon economy (TCFD, 2017; IPCC, 2022). These risks have far-reaching implications for asset valuation, capital allocation, and long-term portfolio performance. As such, investment strategies are increasingly being reshaped by environmental, social, and governance (ESG) considerations, with climate risk becoming a central determinant of financial viability and resilience.

Traditional financial theories such as the Modern Portfolio Theory (Markowitz, 1952) and the Efficient Market Hypothesis (Fama, 1970) have provided foundational insights into portfolio diversification and information efficiency. However, these models are now being challenged for their limited capacity to account for long-term, systemic risks posed by climate change. In response, recent theoretical advancements including stakeholder theory (Freeman, 1984), institutional theory (Meyer & Rowan, 1977), and behavioural finance (Thaler, 1980s) offer more holistic perspectives that incorporate the socio-environmental dimensions of financial decision-making.

Furthermore, empirical studies have begun to explore the impact of climate risk on asset prices, investor behaviour, and financial market stability. Research in this domain has highlighted that companies with robust sustainability practices tend to outperform their peers in terms of risk-adjusted returns and investor attractiveness (Krueger, Sautner, & Starks, 2020; Whelan et al., 2021). Additionally, the development of climate finance instruments such as green bonds and ESG indices underscores the financial sector's evolving role in climate mitigation and adaptation.

This review, therefore, seeks to synthesise the theoretical and empirical literature that underpins the evolving relationship between climate change and investment portfolio management. It begins by examining the core financial theories and how they have been reinterpreted in light of climate realities. The review also considers institutional and behavioural dimensions, followed by a critical discussion of recent empirical findings on climate risk integration in portfolio strategies. The aim is to establish a conceptual and evidential foundation for analysing how climate considerations are transforming modern investment practices, particularly within emerging markets such as Nigeria.

Theoretical Perspectives

The intensifying global climate crisis has necessitated a reevaluation of conventional finance and investment theories. Traditional financial models are increasingly being scrutinised and extended to account for climate-related risks and sustainability imperatives. This section critically discusses relevant theories that provide the conceptual foundation for understanding how climate change affects investment portfolio decisions, while also identifying their originators and year of introduction.

Modern Portfolio Theory (MPT)

Modern Portfolio Theory (MPT), developed by Harry Markowitz in 1952, advocates for portfolio diversification to optimise the trade-off between risk and return. However, in the era of climate change, new and evolving risks, especially physical (e.g., hurricanes, floods) and transition risks (e.g., carbon pricing, regulatory changes) pose significant threats to the stability of returns. These climate-related risks introduce systemic uncertainty, which traditional portfolio models may not adequately capture. As a result, investors are incorporating environmental, social, and governance

(ESG) metrics into their portfolio construction to mitigate climate volatility and enhance long-term resilience (Battiston et al., 2017).

Efficient Market Hypothesis (EMH)

Eugene Fama's Efficient Market Hypothesis (1970) asserts that asset prices fully reflect all available information. Nonetheless, the hypothesis faces criticism in the context of climate change due to the inadequate and inconsistent disclosure of climate-related financial risks. This informational asymmetry leads to the mispricing of climate-exposed assets such as fossil fuel companies potentially inflating a "carbon bubble." Recent frameworks, such as the Task Force on Climate-related Financial Disclosures (TCFD), are attempting to address this gap, promoting transparency and enabling markets to more accurately reflect climate risks (Hong, Li & Xu, 2019).

Institutional Theory

Institutional theory, as advanced by Meyer and Rowan in 1977, explains how institutional norms, rules, and pressures influence organisational behaviour. Within the financial ecosystem, institutional investors are increasingly influenced by regulatory, normative, and cognitive pressures to adopt sustainable investment practices. Regulatory bodies (e.g., EU Sustainable Finance Disclosure Regulation) and global accords (e.g., the Paris Agreement) now encourage or mandate climate-conscious portfolio construction. Thus, institutional pressures have become a significant force steering investment managers toward sustainability-aligned strategies (Clark, Feiner & Viehs, 2015).

Stakeholder Theory

Edward Freeman’s Stakeholder Theory (1984) expands the focus of business decisions beyond shareholders to include all stakeholders affected by corporate actions. Climate change represents a critical stakeholder issue, impacting employees, communities, regulators, and future generations. Investment portfolios that prioritise firms with strong environmental performance and stakeholder engagement are better positioned to ensure long-term value creation. As environmental accountability grows in importance, stakeholder-informed investing becomes increasingly relevant, especially for fiduciaries concerned with intergenerational equity and sustainable outcomes

Behavioural Finance Theory

Behavioural finance, notably advanced by Richard Thaler beginning in the 1980s, challenges the notion of fully rational investors by revealing systematic psychological biases. Investors often display short-termism, loss aversion, and herding behaviour, which can impair the integration of long-term climate risks into portfolio decisions. These biases may lead to underinvestment in green innovations or delayed divestment from high-emission sectors. Recognising these limitations, behavioural finance supports the use of interventions such as climate labelling, ESG ratings, and investor education to realign perceptions with long-term environmental realities (Krueger, Sautner & Starks, 2020).

Climate Finance Theory

Climate Finance Theory is an emerging interdisciplinary framework developed through efforts by institutions like the United Nations Environment Programme (UNEP) and the Intergovernmental Panel on Climate Change (IPCC) in the early 2000s. It focuses on mobilizing financial resources to support mitigation and adaptation efforts in response to climate change. This theory emphasizes that investments must align with climate objectives through instruments such as green bonds, sustainability-linked loans, and carbon markets. Investors guided by this framework seek to direct capital toward low-carbon assets, facilitating the global transition to net-zero economies (UNEP FI, 2020).

Risk Management Theory

Risk Management Theory, rooted in the work of Frank H. Knight (1921), distinguishes between measurable risks and immeasurable uncertainties. Climate change introduces both types, including tail risks (e.g., wildfires, droughts) and chronic risks (e.g., sea-level rise, regulatory changes). Traditional risk models like Value-at-Risk (VaR) are now being enhanced with climate stress tests, scenario analysis, and stochastic modelling to better assess the financial exposure of portfolios to climate events. As climate-related risks increasingly resemble systemic risks, investors are compelled to adopt dynamic, forward-looking risk management approaches.

Environmental Economics and Externality Theory

Arthur Pigou, in his 1920 work *The Economics of Welfare*, introduced the concept of negative externalities costs imposed on third parties not accounted for in market transactions. Climate change is the most prominent global externality, as greenhouse gas emissions create widespread environmental damage not reflected in market prices. Investment strategies informed by Pigou's externality theory aim to internalise these environmental costs through mechanisms like carbon pricing and ESG integration. Portfolios constructed with this perspective tend to favour companies that proactively manage their environmental impact and align with regulatory developments in sustainability.

Synthesis and Implications

Collectively, these theories underscore a fundamental shift in investment logic from focusing on short-term returns to prioritising long-term sustainability and risk resilience. Traditional frameworks such as MPT, EMH, and risk management are now being augmented with broader considerations drawn from institutional theory, behavioural economics, stakeholder perspectives, and environmental economics. As financial markets grapple with the systemic nature of climate change, integrating these theories provides a robust foundation for constructing portfolios that are not only financially viable but also environmentally responsible.

In emerging markets such as Nigeria, where climate vulnerability is high and financial markets are still maturing, these theoretical insights are particularly valuable. They guide the formulation of sustainable investment frameworks that address both local development goals and global climate commitments. Future research should explore the contextual adaptation of these theories to fit the peculiarities of frontier and developing economies.

Empirical Review

Recent empirical research has increasingly examined how climate change and sustainability considerations influence investment strategies, asset pricing, and portfolio performance. These studies primarily focus on the firm or investor level, assessing how environmental, social, and governance (ESG) factors are integrated into financial decision-making.

Whelan, Atz, Van Holt, and Clark (2021) conducted a meta-analysis of over 1,000 studies (2015–2020) and found a strong positive relationship between ESG performance and financial returns. Firms with better climate and sustainability practices demonstrated superior long-term risk-adjusted performance, underscoring the financial value of incorporating climate considerations into investment portfolios. Similarly, Krueger, Sautner, and Starks (2020) surveyed over 400 institutional investors worldwide and found that climate risks especially transition risks are now central to investment analysis and capital allocation decisions.

In Europe, Miniaoui, Chahine, and Baijou (2022) discovered that institutional investors increasingly favour low-carbon assets and green bonds, a finding consistent with Previtali and Cerchiello (2023), who observed that portfolios exposed to high-emission industries experience

greater volatility. Pagkalou, Lazaris, and Papapetrou (2024) further emphasized that standardized climate disclosures improve market efficiency by reducing information asymmetry.

In emerging markets, Amalia and Syamsul (2024) found that Indonesian firms with higher ESG scores have lower capital costs and attract more investors. Similarly, Wahyuningrum, Budiono, and Santosa (2023) reported that ESG disclosure quality significantly enhances stock performance, particularly in climate-sensitive industries. African studies, such as Oyerogba, Adelowotan, and Adekunle (2024), found rising but limited awareness of climate risk among Nigerian institutional investors, with increasing interest in green bonds following the issuance of Nigeria's Sovereign Green Bond.

Other studies in developing regions echo this pattern. For example, Kouaib and Ines (2022) found that firms with strong environmental practices in Saudi Arabia had better equity financing access, while Khodamipour, Karampour, and Naderi (2024) revealed that environmentally responsible firms in Iran were more resilient to regulatory changes. Likewise, Sharma, Ghosh, and Ghoshal (2023) documented that Canadian pension funds are reallocating capital toward climate technology and renewable energy, achieving lower volatility and improved risk-adjusted returns.

Across developing economies, including Nigeria (Muhammad & Oladele, 2021; Ibrahim, Okpanachi, & Yusuf, 2023), the literature shows that while ESG awareness is growing, the integration of direct physical climate risk into financial models remains limited, largely due to inadequate disclosure, data availability, and weak regulatory frameworks.

Beyond firm-level ESG considerations, a smaller but growing body of research has examined how physical climate variables such as rainfall, temperature, and carbon emissions affect macroeconomic and financial market performance. These studies provide the most direct theoretical and empirical foundation for the present research.

Dell, Jones, and Olken (2012) established that temperature shocks negatively affect aggregate output and investment flows, especially in developing countries. Similarly, Burke, Hsiang, and Miguel (2015) found that rising temperatures are associated with reduced economic growth, which can indirectly influence capital markets and interest rates through lower productivity and fiscal strain.

At the market level, Addoum, Ng, and Ortiz-Bobea (2020) investigated the impact of temperature anomalies on U.S. stock market returns and found that industries exposed to weather variability, such as energy and agriculture, experience statistically significant valuation declines during extreme temperature periods. In a similar vein, Bansal, Kiku, and Ochoa (2016) provided evidence that climate risks are priced into global equity markets, suggesting that rising temperatures increase long-run risk premia and affect expected returns.

In the Asian context, Alagidede and Panagiotidis (2022) used time-series data to show that rainfall and temperature variations significantly influence stock market volatility in India and Indonesia. Their findings indicate that climate variables can act as *macroeconomic shocks*, affecting investor confidence and liquidity. In Africa, Nhamo, Chikodzi, and Mjimba (2021) found that prolonged droughts and flood events in Southern Africa reduce agricultural output, increase inflation, and lead to higher interest rates as central banks respond to climate-induced price pressures.

In Nigeria, empirical research directly linking climate variables to financial market indicators remains scarce. However, studies such as Oludare and Olayinka (2022) have shown that rainfall variability and rising temperatures adversely affect agricultural GDP and inflation, suggesting that

such climate shocks could influence monetary policy responses, Treasury Bill rates, and bond yields. Similarly, Akinbobola and Olateju (2023) reported that extreme weather events contribute to exchange rate volatility and capital market instability through their effects on output and investor sentiment. These studies highlight that climate change can influence the cost of borrowing (interest rates), aggregate market valuation (stock indices), and bond yields—key financial market indicators that form the first-order channels through which environmental shocks transmit into the financial system.

Overall, the empirical literature provides robust evidence that climate change has financial implications. However, two key patterns emerge: Firstly, most existing studies focus on firm-level ESG performance and portfolio returns, leaving the macroeconomic transmission of physical climate risks underexplored. Secondly, while theoretical models recognize that temperature, rainfall, and carbon emissions can influence financial stability, empirical studies using time-series econometric models to quantify these effects in Nigeria are virtually nonexistent.

Hence, a critical knowledge gap persists regarding the direct impact of physical climate variables (rainfall, temperature, carbon emissions) on key Nigerian financial market indicators (Treasury Bill Rate, Stock Market Index, and Bond Yield). This study addresses this gap by employing the Autoregressive Distributed Lag (ARDL) approach to capture both short-run and long-run dynamics between climate variables and financial market performance in Nigeria. By doing so, it contributes to the emerging macro-financial literature on climate risk transmission in developing economies.

3.0 Methodology

The study adopted the Autoregressive Distributed Lag (ARDL) developed by Pesaran and Shin (1999) and extended by Pesaran, Shin, and Smith (2001)**.** It is used to estimate both short-run dynamics and long-run relationships among time series variables, especially when the variables are a mixture of stationary at level (I (0)) and first difference (I (1))**.** Unlike traditional co-integration techniques such as the Johansen or Engle-Granger approaches, ARDL can be applied regardless of whether the underlying regressors are purely I(0), purely I(1), or a mixture of both. This makes it especially appropriate in developing country data contexts, where time series may often be of mixed order.ARDL provides estimates of both short-run dynamics and long-run relationships in a single equation. The short-run effects are captured through the differenced variables, while the long-run relationship is derived from the levels of the variables.The ARDL model employs a bounds testing procedure to determine the presence of a long-run relationship between variables. The test involves conducting an F-statistic to check the joint significance of lagged level variables. If the computed F-statistic exceeds the upper bound of the critical values, co-integration is confirmed.Another major advantage of the ARDL approach is its effectiveness in small and finite sample sizes, which is often the case in developing country studies or when data availability is limited.

Model Specification

$$SMI = f(RF, TP, CE, DPR, INFL) \quad (1)$$

$$BOY = f\ (RF, TP, CE, DPR, INFL) \quad (2)$$

$$TBR = f\ (RF, TP, CE, DPR, INFL) \quad (3)$$

The econometric representation of eq. 1, 2 and 3

$$SMI_t = \beta_0 + \beta_1 RF_t + \beta_2 TP_t + \beta_3 CE_t + \beta_4 DPR_t + \beta_5 INFL_t + \varepsilon_t \quad (4)$$

$$BOY_t = \alpha_0 + \alpha_1 RF_t + \alpha_2 TP_t + \alpha_3 CE_t + \alpha_4 DPR_t + \alpha_5 INFL_t + \varepsilon_t \quad (5)$$

$$TRB_t = \sigma_0 + \sigma_1 RF_t + \sigma_2 TP_t + \sigma_3 CE_t + \sigma_4 DPR_t + \sigma_5 INFL_t + \varepsilon_t \quad (6)$$

Whereas:
SMI = Stock Market Index
BOY= Bond Yield
TRB = Treasury Bill Yield
RF = Rainfall
TP = Temperature
CE= Carbon Emissions
DPR= Deposit Rate
INFL = Inflation

$$\Delta SMI_t = \beta_1 SMI_{t-1} + \beta_2 RF_{t-1} + \beta_3 TP_{t-1} + \beta_4 CE_{t-1} + \beta_5 DPR_{t-1} + \beta_6 INFL_{t-1} + \sum_{i=1}^{a} \varphi_{1i}\, \Delta SMI_{t-i} + \sum_{i=0}^{b} \varphi_{2i}\, \Delta RF_{t-i} + \sum_{i=0}^{c} \varphi_{3i}\, \Delta TP_{t-i} + \sum_{i=0}^{d} \varphi_{4i}\, \Delta CE_{t-i} + \sum_{i=0}^{e} \varphi_{5i}\, \Delta DPR_{t-i} + \sum_{i=0}^{f} \varphi_{6i}\, \Delta INFL_{t-1} + \varepsilon_t \quad (7)$$

$$\Delta BOY_t = \beta_1 SMI_{t-1} + \beta_2 RF_{t-1} + \beta_3 TP_{t-1} + \beta_4 CE_{t-1} + \beta_5 DPR_{t-1} + \beta_6 INFL_{t-1} + \sum_{i=1}^{a} \varphi_{1i}\, \Delta BOY_{t-i} + \sum_{i=0}^{b} \varphi_{2i}\, \Delta RF_{t-i} + \sum_{i=0}^{c} \varphi_{3i}\, \Delta TP_{t-i} + \sum_{i=0}^{d} \varphi_{4i}\, \Delta CE_{t-i} + \sum_{i=0}^{e} \varphi_{5i}\, \Delta DPR_{t-i} + \sum_{i=0}^{f} \varphi_{6i}\, \Delta INFL_{t-1} + \varepsilon_t \quad (8)$$

$$\Delta TBR_t = \beta_1 TBR_{t-1} + \beta_2 RF_{t-1} + \beta_3 TP_{t-1} + \beta_4 CE_{t-1} + \beta_5 DPR_{t-1} + \beta_6 INFL_{t-1} + \sum_{i=1}^{a} \varphi_{1i}\, \Delta TBR_{t-i} + \sum_{i=0}^{b} \varphi_{2i}\, \Delta RF_{t-i} + \sum_{i=0}^{c} \varphi_{3i}\, \Delta TP_{t-i} + \sum_{i=0}^{d} \varphi_{4i}\, \Delta CE_{t-i} + \sum_{i=0}^{e} \varphi_{5i}\, \Delta DPR_{t-i} + \sum_{i=0}^{f} \varphi_{6i}\, \Delta INFL_{t-1} + \varepsilon_t \quad (9)$$

The Error Correction Models (ECM)
The error correction (EC) representation of the ARDL models can be written as:

$$\Delta SMI_t = \varphi_0 + \sum_{i=1}^{a} \varphi_{1i}\, \Delta SMI_{t-i} + \sum_{i=0}^{b} \varphi_{2i}\, \Delta RF_{t-i} + \sum_{i=0}^{c} \varphi_{3i}\, \Delta TP_{t-i} + \sum_{i=0}^{d} \varphi_{4i}\, \Delta CE_{t-i} + \sum_{i=0}^{e} \varphi_{5i}\, \Delta DPR_{t-i} + \sum_{i=0}^{f} \varphi_{6i}\, \Delta INFL_{t-1} + \underline{\omega} ECM_{t-1} \quad (10)$$

$$\Delta BOY_t = \varphi_0 + \sum_{i=1}^{a} \varphi_{1i}\, \Delta BOY_{t-i} + \sum_{i=0}^{b} \varphi_{2i}\, \Delta RF_{t-i} + \sum_{i=0}^{c} \varphi_{3i}\, \Delta TP_{t-i} + \sum_{i=0}^{d} \varphi_{4i}\, \Delta CE_{t-i} + \sum_{i=0}^{e} \varphi_{5i}\, \Delta DPR_{t-i} + \sum_{i=0}^{f} \varphi_{6i}\, \Delta INFL_{t-1} + \underline{\omega} ECM_{t-1} \quad (11)$$

$$\Delta TBR_t = \varphi_0 + \sum_{i=1}^{a} \varphi_{1i}\, \Delta TBR_{t-i} + \sum_{i=0}^{b} \varphi_{2i}\, \Delta RF_{t-i} + \sum_{i=0}^{c} \varphi_{3i}\, \Delta TP_{t-i} + \sum_{i=0}^{d} \varphi_{4i}\, \Delta CE_{t-i} + \sum_{i=0}^{e} \varphi_{5i}\, \Delta DPR_{t-i} + \sum_{i=0}^{f} \varphi_{6i}\, \Delta INFL_{t-1} + \underline{\omega} ECM_{t-1} \quad (12)$$

4.0 Results and Discussions

Table 1:

Descriptive Statistics of the Variables

	BOY	SMI	TBR	RF	TP	CE	DPR	INFL
Mean	14.77647	23204.60	13.64824	1192.463	27.31912	98027.48	11.11941	18.55176
Median	14.85000	23965.15	13.85500	1185.200	27.38000	97931.00	10.20000	12.94500
Maximum	18.00000	74773.77	26.90000	1488.620	27.86000	127942.0	23.24000	72.84000
Minimum	11.80000	513.8000	4.500000	1051.710	26.59000	72768.80	4.210000	5.390000
Std. Dev.	2.217330	18066.67	4.799762	83.98726	0.296529	13707.37	4.310443	16.09341
Skewness	0.250480	0.736043	0.169014	1.003516	0.329609	0.218420	0.737239	2.078563
Kurtosis	1.639124	3.310355	3.362399	5.745121	2.774668	2.285479	3.434880	6.418317
Jarque-Bera	2.979172	3.206426	0.347928	16.38215	0.687570	0.993606	3.347874	41.03600
Probability	0.225466	0.201249	0.840327	0.000277	0.709081	0.608473	0.187507	0.000000
Sum	502.4000	788956.5	464.0400	40543.73	928.8500	3332934.	378.0600	630.7600
Sum Sq. Dev.	162.2462	1.08E+10	760.2445	232777.4	2.901674	6.20E+09	613.1374	8546.930
Observations	34	34	34	34	34	34	34	34

Source: Author's Computation, 2025.

Descriptive Statistics

Table 1 presents the descriptive statistics of the variables employed in this study over 34 observations. The variables include Bond Yield (BOY), Stock Market Index (SMI), Treasury Bill Rate (TBR), Rainfall (RF), Temperature (TP), Carbon Emissions (CE), Deposit Rate (DPR), and Inflation Rate (INFL). The aim is to understand the central tendency, dispersion, and distributional properties of the data before conducting inferential analysis.

The average value for Bond Yield (BOY) is 14.78, with a minimum of 11.80 and a maximum of 18.00, indicating a moderate spread over the observed period. The standard deviation of 2.22 implies a moderate variation in the data. The skewness (0.25) and kurtosis (1.64) suggest that the distribution is slightly right-skewed and platykurtic (less peaked than normal), respectively, with a Jarque-Bera (JB) probability of 0.23, indicating normality.

Stock Market Index (SMI) has a mean of 23,204.60 and ranges from 513.80 to 74,773.77, with a high standard deviation of 18,066.67, reflecting significant fluctuations in the Nigerian stock market over time. The distribution is moderately skewed to the right (skewness = 0.74) and leptokurtic (kurtosis = 3.31), but the JB probability (0.20) suggests no significant departure from normality.

For the Treasury Bill Rate (TBR), the mean is 13.65, with values ranging from 4.50 to 26.90. The standard deviation is 4.80, indicating noticeable variability. The distribution appears nearly symmetric (skewness = 0.17) and mesokurtic (kurtosis = 3.36), and the JB test (p = 0.84) confirms normality.

The Rainfall (RF) has an average value of 1,192.46, with relatively low dispersion (standard deviation = 83.99). The distribution is right-skewed (skewness = 1.00) and leptokurtic (kurtosis = 5.75), with a JB p-value of 0.0003, suggesting significant deviation from normality.

Temperature (TP) shows a mean of 27.32 with a tight dispersion (standard deviation = 0.30), suggesting stability over the observed period. The distribution is mildly right-skewed (0.33) and slightly platykurtic (2.77), and the JB probability (0.71) supports the normal distribution assumption.

Carbon Emissions (CE)have a mean value of 98,027.48 and shows moderate variation with a standard deviation of 13,707.37. Its distribution is approximately symmetric (skewness = 0.22), slightly platykurtic (kurtosis = 2.29), and passes the JB test for normality (p = 0.61).

Deposit rate (DPR) records a mean of 11.12 with a range between 4.21 and 23.24. The distribution is moderately right-skewed (0.74) and leptokurtic (3.43), but the JB probability (0.19) suggests no significant deviation from normality.Lastly, Inflation Rate (INFL) exhibits the highest mean value of 18.55 with a considerable standard deviation of 16.09, reflecting significant volatility. The skewness (2.08) and kurtosis (6.42) values indicate a highly skewed and peaked distribution, and the JB p-value (0.0000) confirms non-normality.

Overall, most variables, except RF and INFL, exhibit approximately normal distributions based on the Jarque-Bera test results. The variables also show varying levels of dispersion, suggesting the necessity for appropriate econometric techniques that account for potential non-normality and heteroskedasticity in further analysis.

Table 2:
Correlation Matrix of the variables for Multicollinearity test

	RF	TP	CE	INFL	DPR
RF	1.000000				
TP	0.119048	1.000000			
CE	0.306606	0.358298	1.000000		
INFL	0.082985	-0.458191	-0.151709	1.000000	0.400801
DPR	-0.229478	-0.587760	-0.579678	0.400801	1.000000

Source: Author's Computation, 2025.

The correlation matrix presented provides insight into the potential multicollinearity among the independent variables used in the regression analysis. Multicollinearity occurs when two or more explanatory variables in a model are highly linearly related, which can distort coefficient estimates and weaken the statistical power of the model.The correlation coefficients across all pairs are below the critical threshold of 0.70, indicating the absence of significant multicollinearity among the independent variables. This suggests that the regression estimates are unlikely to be biased or inefficient due to multicollinearity. Nonetheless, caution should be exercised in interpreting relationships involving TP and DPR, where correlations are relatively stronger. Further robustness checks using the Variance Inflation Factor (VIF) could reinforce these findings.

Table 3:
Unit root test (stationarity test) of the variables
(a)Augmented Dickey-Fuller Test

Variables	Levels		First Differences		Order of Integration
	Intercept	Intercept and trend	Intercept	Intercept and Trends	
BON	-1.960	-2.341	-5.148***	-5.084***	I (1)
SMI	-0.353	-2.430	-5.243	-5.272***	I (1)
TBR	-3.075	-3.063	-5.148	-6.201***	I (1)
RF	-5.038***	-5.089***			I (0)
TP	-2.935**	-4.741***			I (0)
CE	-1.457	-2.572	-5.830***	-5.756***	I (1)
INFL	-2.119	-2.275	-4.528***	-4.440***	I (1)
DPR	-2.767**	-3.587**			I (0)

Source: Author's Compilation, 2025.

(b) Phillips-Perron Test

Variables	Levels		First Differences		Order of Integration
	Intercept	Intercept and trend	Intercept	Intercept and trend	
BON	-1.960	-2.278	-5.122***	-4.991***	I (1)
SMI	-0.353	-2.593	-5.236***	-5.265***	I (1)
TBR	-3.129	-3.128	-7.008***	-7.186***	I (1)
RF	-5.068***	-5.117***			I (0)
TP	-2.787*	-4.749***			I (0)
CE	-1.281	-2.572	-6.738***	-7.218***	I (1)
INFL	2.418	-2.608	-4.513***	-4.418***	I (1)
DPR	-2.672**	-3.972**			I (0)

Source: Author's Compilation, 2025.

Unit Root Test

It is commonly believed that the simple time series around a deterministic pattern is stationary or at least stable; this is not always accurate. Nevertheless, the co-integration technique of ARDL does not require unit root testing. However, to prevent ARDL from crashing in the presence of an embedded stochastic pattern of I (2), the study performs unit root tests to determine the presence of a unit root in the series. To confirm the outcome properties of the time series, this study used Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) tests. The null hypothesis for the test (both ADF and PP) affirms that the data series in question has a unit root, while the alternative hypothesis affirms that the series is stationary. Table 3 above shows the results of the unit root testing. The results show that RF and TP are stationary at levels, while other variables in the model become stationary after first differencing. This depicts that the series has a combination of I (0) and I (1), which makes ARDL appropriate for estimation.

Table 4:
ARDL bound test (test of co-integration) (Model 1)

Significance (α %)	Critical values		Computed F-statistics
	Lower Critical Bound I (0)	Upper Critical Bound I (1)	4.424671
10	2.26	3.35	
5	**2.62**	**3.79**	
2.5	2.96	4.18	
1	3.41	4.68	

Source: Author's Compilation, 2025.

Table 5:
ARDL bound test (test of co-integration) (Model 2)

Significance (α %)	Critical values		Computed F-statistics
	Lower Critical Bound I (0)	Upper Critical Bound I (1)	0.797497
10	2.26	3.35	
5	**2.62**	**3.79**	
2.5	2.96	4.18	
1	3.41	4.68	

Source: Author's Compilation, 2025.

Table 6:
ARDL bound test (test of co-integration) (Model 3)

Significance (α %)	Critical values		Computed F-statistics
	Lower Critical Bound I (0)	Upper Critical Bound I (1)	1.693362
10	2.26	3.35	
5	**2.62**	**3.79**	
2.5	2.96	4.18	
1	3.41	4.68	

Source: Author's Compilation, 2025.

Estimation of Long-run relationship (Co-integration Test)

In time series analyses, it is common to have a mixed stationarity property of variables which necessitate the test of co-integration. Thus, the estimation technique that captures this is considered in line with Paseran *et al* (2001), this study uses bound testing for the long-run relationship among the variables. Pesaran and Shin (1995, 1998) suggested two critical values to evaluate the relationship (lower and upper bound) due to the limitations of the traditional Wald-test *F*-statistic. The computed *F*-test is then compared with the critical values for the hypothesis test at 5 per cent level. Therefore, if the calculated *F*-statistic is less than the lower bound value, the null is not rejected. On the contrary, the existence of a long-term relationship between the variables is suggested if the calculated *F*-statistics exceed the upper limit value. The results of ARDL bound testing which explains the long run relationship among the variables is reported in Table 4 and 5 above. It shows that the F-statistic (4.424671) for model 1is greater than both the lower and the upper critical values at the benchmark of 5 per cent significance level. This invalidates null hypothesis of no co-integration and supports the existence of long-run dynamics. However, model

2 and 3 F-statistics is lower than both the lower and the upper critical values at the benchmark of 5 per cent. These validates the null hypotheses of no co-integration and supports the existence of no long-run dynamics.

Table 7:
Long and short run Dynamics Estimated Results for the selected ARDL (Selected Model: ARDL (2, 0, 0, 0, 1, and 0)

Panel A: Long Run Dynamics: TBR				
Variables	**Coefficients**	**Standard Error**	**T-Statistics**	**P-Value**
RF	-0.030103	0.014189	-2.121600	0.0449**
TP	4.621304	4.680177	0.987421	0.3337
CE	0.000122	0.000096	1.273909	0.2154
DPR	0.309011	0.394723	0.782856	0.4417
INFL	0.132234	0.075768	1.745234	0.0943*
C	-94.718955	124.675806	-0.759722	0.4551
Panel B: Short-Run Dynamics				
D(TBR(-1))	0.262201	0.174887	1.499255	0.1474
D(RF)	-0.020286	0.008356	-2.427646	0.0234**
D(TP)	3.114203	2.842718	1.095502	0.2846
D(CE)	0.000082	0.000075	1.096747	0.2841
D(DPR)	0.642509	0.244604	2.626733	0.0151**
D(INFL)	0.089110	0.052695	1.691037	0.1043
CointEq(-1)	-0.673880	0.211098	-3.192266	0.0041
Cointeq = TBR - (-0.0301*RF + 4.6213*TP + 0.0001*CE + 0.3090*DPR + 0.1322*INFL -94.7190)				
Panel C: Goodness-of-fit measures				
R –Squared	0.618957			
Adj. R-Squared	0.486421			
F- statistics	4.670086			
P-value (F-stat.)	0.001705			
Durbin-Watson Statistics	2.187760			
Panel D : Diagnostic Tests				
			Test	**Probability**
Breusch-Godfrey Serial Correlation LM Test:			1.429361	0.4893
Heteroskedasticity Test:Breusch-Pagan-Godfrey			6.899153	0.5476
Heteroskedasticity Test: ARCH			1.760710	0.1845

Ramsey RESET Specification Test	0.701932	0.4111
Jarque-Bera Statistics	0.753564	0.686066

Note: ***, **, and * are 1%, 5% and 10% level of significance respectively
Source: Author's Compilation, 2025.

The results from the long-run estimation (Panel A) in Table 7 indicate that rainfall (RF) has a statistically significant negative effect on Treasury Bill Rate (TBR) at the 5% level. Specifically, the coefficient of RF is -0.0301 (p = 0.0449), suggesting that an increase in rainfall, possibly associated with climate variability, reduces the Treasury Bill Rate in the long run. This could imply that climatic shocks such as excessive rainfall may contribute to reduced short-term returns in government securities, possibly due to macroeconomic adjustments or market uncertainty.

Conversely, temperature (TP), carbon emissions (CE), deposit rate (DPR), and inflation (INFL**)** do not exhibit statistically significant long-run effects on TBR. Although INFL shows a marginal significance at the 10% level (p = 0.0943), its coefficient (0.1322) suggests a weak positive relationship with TBR in the long term. However, this association lacks strong statistical backing, warranting caution in its interpretation. The model's intercept (C) is also not statistically significant.

Panel B presents the short-run coefficients, revealing several noteworthy dynamics. The first lag of TBR (D(TBR (-1))) is positive (0.2622) but statistically insignificant (p = 0.1474), suggesting a weak persistence effect in Treasury Bill Rate.Importantly, the first difference of rainfall (D(RF)) is negative and significant at the 5% level (coefficient = -0.0203; p = 0.0234), reinforcing the long-run result and indicating that increases in rainfall have immediate, short-run depressive effects on TBR. Similarly, deposit rate (DPR) exerts a positive and statistically significant effect in the short run (coefficient = 0.6425; p = 0.0151), suggesting that rising dividend payments may signal investor confidence or liquidity flows that positively influence short-term investment yields like TBR.

Other variables such as temperature (TP), carbon emissions (CE), and inflation (INFL**)** are not statistically significant in the short run.The error correction term (CointEq **(-1))** is negative and statistically significant (coefficient = -0.6739; p = 0.0041), confirming the existence of a stable long-run equilibrium. The speed of adjustment indicates that approximately 67% of the previous period's deviation from equilibrium is corrected in the current period, validating the suitability of the ARDL model and the presence of co-integration among the variables.

Panel C shows a reasonably good model fit with an R-squared of 0.6190 and an adjusted R-squared of 0.4864, indicating that approximately 49% of the variation in TBR is explained by the model after adjusting for degrees of freedom. The F-statistic (4.6701; p = 0.0017) confirms the overall significance of the model at the 1% level.

Diagnostic checks in Panel D affirm the reliability of the model estimates. The Breusch-Godfrey test for serial correlation and the Breusch-Pagan-Godfrey test for heteroskedasticity both return high p-values (0.4893 and 0.5476, respectively), suggesting no evidence of serial correlation or heteroskedasticity. The ARCH test further confirms the absence of conditional heteroskedasticity (p = 0.1845). The Ramsey RESET test (p = 0.4111) implies the model is correctly specified, while the Jarque-Bera test confirms that the residuals are normally distributed (p = 0.6861).

Overall, the ARDL results provide compelling evidence that climatic factors, particularly rainfall, have both short- and long-term implications on Treasury Bill Rate, a key investment portfolio

variable. Additionally, dividend payout exhibits a significant short-run influence. The presence of a stable long-run relationship and robust diagnostic outcomes support the validity of the estimated model.

Table 8:
Long and short run Dynamics Estimated Results for the selected ARDL (Selected Model: ARDL (1, 0, 0, 0, 0, and 0)

Panel A: Long Run Dynamics: SMI				
Variables	**Coefficients**	**Standard Error**	**T-Statistics**	**P-Value**
RF	91.734056	92.507177	0.991643	0.3305
TP	32706.412512	28198.3360	1.159870	0.2566
CE	0.672524	0.588992	1.141821	0.2639
DPR	-1537.242055	2233.50072	-0.688266	0.4974
INFL	298.815946	503.334100	0.593673	0.5579
C	-1028394.21874	806232.341	-1.275556	0.2134
Panel B: Short-Run Dynamics				
D(RF)	23.925382	20.284369	1.179498	0.2489
D(TP)	8530.238963	7435.74027	1.147194	0.2617
D(CE)	0.175403	0.157491	1.113731	0.2756
D(DPR)	-400.931838	579.008544	-0.692445	0.4948
D(INFL)	77.934913	119.998392	0.649466	0.5217
CointEq(-1)	-0.260812	0.144378	-1.806452	0.0824
Cointeq = SMI - (91.7341*RF + 32706.4125*TP + 0.6725*CE -1537.2421 *DPR + 298.8159*INFL -1028394.2187)				
Panel C: Goodness-of-fit measures				
R -Squared	0.788164			
Adj. R-Squared	0.739279			
F- statistics	16.12276			
P-value (F-stat.)	0.00000			
Durbin-Watson Statistics	1.917648			
Panel D : Diagnostic Tests				
			Test	**Probability**
Breusch-Godfrey Serial Correlation LM Test:			2.094879	0.3508
Heteroskedasticity Test:Breusch-Pagan-Godfrey			9.692448	0.1382
Heteroskedasticity Test: ARCH			1.841526	0.1748
Ramsey RESET Specification Test			0.321206	0.5759
Jarque-Bera Statistics			1.04402	0.6009

Note: ***, **, and * are 1%, 5% and 10% level of significance respectively
Source: Author's Compilation, 2025.

The long-run estimation results in Table 8 reveal that none of the explanatory variables, rainfall (RF), temperature (TP), carbon emissions (CE), deposit rate (DPR), or inflation rate (INFL), exert a statistically significant influence on the Sustainable Market Index (SMI) at the 5% level. Rainfall has a positive but insignificant effect (β = 91.73, p = 0.331), suggesting that variations in rainfall might not substantially affect sustainable market performance in the long run. Temperature similarly shows a positive and statistically insignificant effect (β = 32,706.41, p = 0.257), while carbon emissions exhibit a weak positive influence (β = 0.673, p = 0.264), which does not attain statistical significance.

Interestingly, dividend payout ratio exerts a negative but insignificant effect (β = -1,537.24, p = 0.497), implying that higher dividend payouts may reduce sustainable investment performance, albeit not significantly. Inflation shows a positive coefficient (β = 298.82, p = 0.558), but this effect remains statistically weak. The intercept term is negative and insignificant, further suggesting that other omitted variables may also influence the SMI. Overall, the long-run relationship between climate and financial variables with SMI lacks strong statistical backing in this model.

In the short run, changes in the explanatory variables do not significantly affect the SMI. First-differenced rainfall (D(RF)) and temperature (D(TP)) display positive but statistically insignificant effects with p-values of 0.249 and 0.262, respectively. The impact of changes in carbon emissions (D(CE)) is similarly weak and insignificant (β = 0.175, p = 0.276). The negative short-run coefficient of the dividend payout ratio (β = -400.93, p = 0.495) suggests a potential adverse effect on sustainable investment, although the result lacks statistical precision. The inflation rate also exerts a weak positive effect in the short term (β = 77.93, p = 0.522).

However, the error correction term (CointEq(-1)) is negative and marginally significant at the 10% level (β = -0.2608, p = 0.082), indicating that approximately 26% of disequilibrium from the previous period is corrected in the current period. This supports the presence of a stable long-run relationship among the variables, albeit weakly.The ARDL model demonstrates strong explanatory power, with an R-squared of 0.7882 and an adjusted R-squared of 0.7393, indicating that approximately 74% of the variation in SMI is explained by the included variables. The F-statistic (16.12, p< 0.001) confirms the overall significance of the model.

Diagnostic tests support the robustness of the model. The Breusch-Godfrey Serial Correlation LM test (p = 0.351), Breusch-Pagan-Godfrey test for heteroskedasticity (p = 0.138), and ARCH test (p = 0.175) all indicate no evidence of autocorrelation or heteroskedasticity. The Ramsey RESET test (p = 0.576) does not suggest model misspecification, while the Jarque-Bera test (p = 0.601) confirms that the residuals are normally distributed. The Durbin-Watson statistic (1.918) is close to 2, implying no first-order autocorrelation. The stability test (see appendix) confirms stability in the model.

Although the estimated ARDL model passes key diagnostic checks and indicates a stable long-run equilibrium via the error correction mechanism, the individual explanatory variables, climate-related (rainfall, temperature, carbon emissions) and macro-financial (dividend payout, inflation), do not significantly influence sustainable market investment in either the long or short run. This suggests that while sustainable investment might be broadly influenced by climate and financial factors, the specific proxies used in this model may not capture the dynamics sufficiently, warranting further investigation with alternative variables or nonlinear modelling.

Table 9:
Long and short run Dynamics Estimated Results for the selected ARDL (Selected Model: ARDL (1, 0,0,0,1 and 0))

Panel A: Long Run Dynamics: BOY				
Variables	**Coefficients**	**Standard Error**	**T-Statistics**	**P-Value**
RF	0.022524	0.040019	0.562828	0.5786
TP	-0.903078	10.992831	-0.082152	0.9352
CE	-0.000086	0.000270	-0.319783	0.7518
DPR	-0.634768	1.649635	-0.384793	0.7036
INFL	0.440314	0.751547	0.585877	0.5632
C	20.913265	305.170400	0.068530	0.9459
Panel B: Short-Run Dynamics				
D(RF)	0.002041	0.002985	0.683739	0.5004
D(TP)	-0.081820	0.990247	-0.082625	0.9348
D(CE)	-0.000008	0.000023	-0.346904	0.7316
D(DPR)	0.110843	0.090935	1.218928	0.2342
D(INFL)	0.039893	0.019975	1.997117	0.0568
CointEq(-1)	-0.090601	0.124984	-0.724898	0.4752
Cointeq = BOY - (0.0225*RF -0.9031*TP -0.0001*CE -0.6348*DPR + 0.4403*INFL + 20.9133)				
Panel C: Goodness-of-fit measures				
R -Squared	0.746042			
Adj. R-Squared	0.674934			
F- statistics	10.49163			
P-value (F-stat.)	0.000004			
Durbin-Watson Statistics	1.986541			
Panel D: Diagnostic Tests				
			Test	**Probability**
Breusch-Godfrey Serial Correlation LM Test:			0.018704	0.9907
Heteroskedasticity Test: Breusch-Pagan-Godfrey			8.101909	0.3237
Heteroskedasticity Test: ARCH			1.676262	0.1954
Ramsey RESET Specification Test			1.224242	0.2795
Jarque-Bera Statistics			2.074016	0.354514

Note: ***, **, and * are 1%, 5% and 10% level of significance respectively
Source: Author's Compilation, 2025.

The long-run coefficients from the ARDL (1, 0, 0, 0, 1, 0) model (Panel A) in Table 9 reveal that none of the explanatory variables, rainfall (RF), temperature (TP), carbon emissions (CE),

dividend payout ratio (DPR), and inflation (INFL), exert statistically significant effects on bond yield (BOY) at conventional levels. Specifically, rainfall has a positive but insignificant coefficient (β = 0.0225, *p* = 0.5786), implying that changes in rainfall may not exert a meaningful long-term impact on BOY. Similarly, temperature demonstrates a large negative coefficient (β = -0.9031) but is highly insignificant (*p* = 0.9352), suggesting no discernible long-term relationship with BOY. Carbon emissions (β = -0.000086, *p* = 0.7518) and dividend payout ratio (β = -0.6348, *p* = 0.7036) are also insignificant, reflecting weak linkages with BOY over the long horizon. Inflation (β = 0.4403, *p* = 0.5632), although positive, is not statistically significant. Overall, the long-run equilibrium relationship does not present any strong evidence of climate variables or financial policy indicators having substantial long-term effects on bank output yield.

In the short-run estimates (Panel B), only inflation (D(INFL)) approaches significance at the 10% level with a positive coefficient (β = 0.0399, *p* = 0.0568), suggesting that a rise in inflation may have a contemporaneous positive impact on BOY in the short term. Other variables, including rainfall, temperature, carbon emissions, and dividend payout ratio, remain statistically insignificant in the short-run model. The error correction term (CointEq (-1) = -0.0906, *p* = 0.4752) is negative but not significant, indicating weak speed of adjustment from short-run deviations back to the long-run equilibrium. This result suggests that deviations in BOY from its long-run path due to climate or financial shocks are not quickly corrected within the model framework.

Panel C and D provide insight into the model's overall performance. The model demonstrates a high explanatory power, with an R-squared value of 0.746 and an adjusted R-squared of 0.675, indicating that approximately 67.5% of the variation in BOY is accounted for by the explanatory variables. The F-statistic of 10.49 (with *p* = 0.000004) confirms that the model is statistically significant as a whole. The Durbin-Watson statistic of 1.99 suggests no first-order autocorrelation.

Regarding diagnostic tests, the Breusch-Godfrey Serial Correlation LM test (p = 0.9907) and Breusch-Pagan-Godfrey test (p = 0.3237) confirm absence of serial correlation and heteroskedasticity, respectively. Additionally, the ARCH test (p = 0.1954) supports the absence of autoregressive conditional heteroskedasticity. The Ramsey RESET test (p = 0.2795) indicates no misspecification of the functional form, and the Jarque-Bera test (p = 0.3545) confirms normality of the residuals. The stability test (see appendix) shows that the two test CUSUM and CUSUM square shows stability. Collectively, these results validate the robustness, reliability, and statistical integrity of the estimated ARDL model.

Discussion of Findings

This study examined how climate-related variables (rainfall, temperature, and carbon emissions) and selected macroeconomic indicators (dividend payout ratio and inflation) affect key financial market indicators, Treasury Bill Rate (TBR), Stock Market Index (SMI), and Bond Yield (BOY), in Nigeria using the ARDL framework. It is important to acknowledge at the outset that the analysis focuses on aggregate market indicators rather than constructed investment portfolios. This distinction limits the interpretation of results to market-level responses rather than portfolio performance or investor-level outcomes. Nevertheless, the results provide important insights into how climate variability interacts with Nigeria's financial environment.

The most robust finding across models is the significant negative effect of rainfall on TBR in both the short and long run. This suggests that higher rainfall, often associated with flooding and agricultural disruptions in Nigeria, may influence short-term monetary and financial conditions. One plausible economic channel is that severe rainfall events depress economic activity, especially in the agricultural and logistics sectors, leading to lower output and liquidity stress. In response, the Central Bank may adjust its monetary stance toward easing liquidity, reducing Treasury bill rates to stimulate credit expansion and consumption.

Another possible mechanism is through market uncertainty: heavy rainfall and flood risk can heighten investor uncertainty, prompting a flight to safety and greater demand for government securities. This increased demand pushes T-bill yields downward. This aligns with climate risk theory (Krueger, Sautner & Starks, 2020), which posits that extreme weather events affect asset pricing through risk perception and liquidity channels.

The short-run positive effect of dividend payout ratio (DPR) on TBR further reinforces signaling theory (Bhattacharya, 1979). Higher dividends may be interpreted by investors as a sign of corporate strength, attracting short-term capital inflows and pushing up short-term yields. The combination of these findings suggests that Nigeria's short-term money market reacts more swiftly to liquidity and sentiment-driven variables rainfall and dividend signals than to structural climate factors such as emissions or temperature.

The absence of statistically significant relationships between climate variables (rainfall, temperature, carbon emissions) and the SMI in both the long and short run suggests that the Nigerian equity market has not yet internalized climate-related financial risks. This may be due to several factors. First, the information inefficiency of the market (as explained by the Efficient Market Hypothesis, Fama, 1970) implies that climate signals are not fully priced into stock valuations, either because they are perceived as distant risks or because investors lack sufficient ESG and climate-related information to make informed pricing decisions.

Second, the institutional theory (Meyer & Rowan, 1977) helps explain why these results differ from those in developed markets. Weak institutional frameworks, limited disclosure standards, and inadequate regulatory enforcement mean that climate-related financial reporting is still nascent in Nigeria. Consequently, the connection between environmental shocks and stock market performance remains muted. This finding resonates with Wasiuzzaman and Wan Mohammad (2020), who observed similar weak linkages in Malaysia, and contrasts with Whelan et al. (2021), who found strong ESG-financial performance relationships in mature markets.

From an economic perspective, Nigerian firms and investors may prioritize immediate macroeconomic conditions, such as exchange rate movements or interest rate policy over environmental factors. Hence, the lack of sensitivity of SMI to climate indicators could reflect short investment horizons and limited ESG integration in capital allocation.

The ARDL results for BOY reveal no significant long-run effects of climate or macroeconomic variables, though inflation exerts a marginally significant positive effect in the short run. This suggests that bond yields in Nigeria respond more to macro-financial shocks than to climate variations. In the short term, rising inflation may increase investors' inflation expectations, prompting them to demand higher yields on government bonds as compensation for purchasing power erosion. However, the absence of a significant error-correction mechanism indicates that such responses are transitory and not anchored in long-run equilibrium adjustments.

The insignificance of rainfall, temperature, and carbon emissions on BOY aligns with the resource-based view (RBV), which argues that financial institutions' long-term behavior is shaped more by internal capabilities and strategic responses than by external climatic shocks. Furthermore, the weak climate-finance linkage reflects low penetration of green finance instruments and limited market depth in Nigeria's bond market, as also observed by Ben-Fatma and Chouaibi (2021) in developing economies.

The absence of significant effects of temperature and carbon emissions across all models is itself revealing. Several plausible explanations emerge: First, might be traced to data and measurement

limitations; as Nigeria's climate data are spatially heterogeneous, and national-level averages may not capture local climate shocks that affect sectoral or regional markets. Secondly, it might due to Time horizon mismatch. Temperature and carbon emissions represent slow-moving risks whose financial impacts unfold over decades, whereas TBR, SMI, and BOY reflect short-term market dynamics. In addition, it may be due to model specification: The ARDL framework captures linear effects, yet, climate–finance linkages may be nonlinear or threshold-based (e.g., only extreme temperatures significantly alter financial outcomes). Lastly, it may be due to market adaption and indifference. Investors in emerging markets may not yet view carbon emissions as financially material, suggesting that climate-related risks are not priced into financial instruments, a deviation from EMH assumptions. These explanations underscore that the absence of statistical significance is not evidence of irrelevance, but rather an indication that Nigerian financial markets may still be in the early stages of climate risk pricing.

From a theoretical standpoint, the findings partially support climate risk theory and signaling theory, but challenge the assumptions of market efficiency. The negative rainfall, TBR relationship reflects short-term liquidity and uncertainty channels consistent with climate risk pricing. Meanwhile, the insignificance of other variables suggests that Nigerian financial markets are information inefficient with respect to environmental risks, in line with behavioral finance views emphasizing limited attention and cognitive bias in emerging markets.

Economically, the results imply that climate variability influences monetary and liquidity conditions, but its transmission to broader financial markets remains weak. Policymakers, especially the Central Bank of Nigeria, may need to incorporate climate risk assessments into monetary policy design, particularly in forecasting liquidity shocks due to weather-induced disruptions. Strengthening ESG disclosure frameworks and improving climate data integration in financial reporting could enhance the market's ability to price climate risks more effectively.

5.0 Conclusion

This study examined the relationship between climate change and investment performance in Nigeria by analyzing how rainfall, temperature, and carbon emissions alongside key macroeconomic indicators such as inflation and dividend payout ratio (DPR) influence Treasury Bill Rate (TBR), Stock Market Index (SMI), and Bond Yield (BOY). Using the Autoregressive Distributed Lag (ARDL) model over a 34-year period, both short- and long-run dynamics were investigated.

The findings reveal that rainfall has a statistically significant negative effect on TBR in both the short and long run, indicating that short-term financial instruments in Nigeria are sensitive to climate variability, particularly rainfall-induced disruptions. The dividend payout ratio (DPR) also exerts a positive short-run effect on TBR, reflecting short-term investor confidence responses to corporate payout decisions. However, temperature, carbon emissions, and inflation show no significant impact on stock market or bond yield performance, suggesting that the broader financial market remains largely unresponsive to environmental shocks. This limited sensitivity implies that while climatic factors affect short-term liquidity and interest rate dynamics, they have not yet translated into significant structural impacts on the Nigerian capital market.

From a theoretical standpoint, the results lend partial support to climate risk theory and signaling theory, as they highlight that only specific climate variables like rainfall transmit risk through short-term money market channels. The absence of strong long-run or broad market effects suggests weak institutional adaptation, consistent with institutional theory, which emphasizes regulatory and disclosure deficiencies in developing markets. Overall, the findings underscore that

Nigerian financial markets are still in the early stages of integrating climate-related risks into financial pricing and decision-making.

Recommendations

Based on the findings of the study, the following recommendations were postulated:

i. The Central Bank of Nigeria (CBN) and the Securities and Exchange Commission (SEC) should investigate the transmission channels between extreme weather events, especially rainfall, and short-term interest rates, as part of broader financial stability monitoring. Understanding this link will help in designing climate-sensitive monetary and prudential policies.
ii. Market participants, including money market dealers and institutional investors, should recognize the potential impact of heavy rainfall and flooding on short-term liquidity conditions and interest rate movements. This awareness can support improved risk pricing and investment timing in the money market.
iii. Government agencies, in collaboration with research institutions, should develop comprehensive, real-time climate data systems capturing rainfall intensity, temperature variability, and carbon emissions. Reliable data will enhance climate-finance modeling accuracy and support evidence-based policy formulation.
iv. Financial regulators should build institutional capacity for climate-related risk assessment and integrate such risks into macroprudential frameworks, in line with global best practices like the Task Force on Climate-related Financial Disclosures (TCFD).

Limitations and Directions for Future Research

This study's conclusions are constrained by the use of aggregate macro-level financial indicators (TBR, SMI, and BOY) as proxies for investment performance, rather than actual portfolio or fund-level data. Consequently, the findings capture market-wide reactions rather than specific investor or institutional portfolio adjustments. Future research could extend this analysis by employing micro-level portfolio data, examining sectoral sensitivities to climate shocks, or exploring nonlinear and threshold effects of climate variables on financial performance. Incorporating firm-level ESG disclosure data could also provide deeper insights into how environmental awareness translates into financial outcomes.

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