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Enhancing sustainable development in West Africa despite uncertainty: The transformative potential of green financing

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ABSTRACT

Despite the increasing evidence on the adverse effects of uncertainty on sustainable development, little is known about how green financing can mitigate this effect. This paper assesses the transformative potential of green financing in promoting sustainable development amid prevailing uncertainties in West Africa, drawing on evidence from developed regions. Four different static and dynamic model estimators are employed to analyse relevant data for the 2010–2022 period drawn from 14 West African countries. The empirical findings show uncertainty as a major impediment to sustainable development, while green financing enhances sustainable development in West Africa. Further results present green financing as a significant moderator of the negative effect of uncertainty on sustainable development. The results remain robust across various estimation methods and alternative measures of green financing. Thus, the lacunas in existing green financing frameworks in West Africa must be fixed while developing/strengthening modern frameworks and policies to enhance sustainable development.

1. Introduction

Given its huge endowments (natural resources, a youthful population, and unique cultural diversity), West Africa has the necessary wherewithal to achieve sustainable development. However, the region continues to face uncertainty in its quest for sustainable development, due to environmental degradation, economic volatility, and socio-political instability (Abbass et al., 2022; Afolabi, 2023a). Its overall ecological balance and the livelihood of its population are endangered through the reliance on traditional energy sources and the dominance of extractive industries, which exacerbate environmental issues like deforestation, desertification, and climate change (Shivanna, 2022). These problems are aggravated by geopolitical conflicts and economic uncertainty, partly triggered by volatile global commodity prices. The recent coup d'états in Niger, Burkina Faso, Guinea, Chad, and Mali, as well as the current hostilities in Gaza and between Russia and Ukraine, are also causing supply chain disruptions on a global and regional scale, and increasing inflationary pressures in West Africa and other African regions. These unpleasant circumstances worsen food insecurity and poverty, cause displacement, instigate armed groups, discourage foreign investment, and set off a dangerous cycle that jeopardizes sustainable development (Hunjra et al., 2022; Huang et al., 2023).

Green finance has emerged as a ray of hope for promoting sustainable development in West Africa amidst the prevailing uncertainties (Ene et al., 2017; Zhang & Wang, 2019). It entails the distribution of funds to environmental sustainability-promoting projects, including conservation, energy efficiency, renewable energy, and sustainable agriculture (Zhang & Wang, 2019). In addition to promoting innovation, creating jobs, and strengthening resilience against environmental shocks, this type of funding helps the shift to a low-carbon economy (Doku et al., 2021). As the world moves toward sustainability, interest in green project funding is rising. Development banks, private investors, and international organizations are realizing that green finance may be used to achieve both economic and environmental goals. Even though taming uncertainty could be difficult, creating strong plans to lessen its effects is crucial. The adoption of green finance methods in West Africa has the potential to be revolutionary and help the region's countries diversify their economies, lessen their reliance on fossil fuels, and construct more durable infrastructure. However, many obstacles stand in the way of West Africa's optimal utilization of green financing. They include restricted access to finance, undeveloped financial markets, a dearth of technological know-how, and regulatory roadblocks (Afolabi,

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2022). Sadly, attempts to draw in and make good use of green investments are hampered by political unrest and weak institutional quality, among other uncertainties (Oji & Afolabi, 2022).

Despite these obstacles, there are promising signs of progress. Some West African countries have begun to develop national green finance strategies, establish green bonds, and engage in international partnerships to foster sustainable development. For example, Nigeria issued a $29.7 million sovereign green bond in 2017 and another $41 million in 2019 to fund renewable energy, afforestation, and other environmental projects.[2] In 2019, $54.5 million from the Green Climate Fund (GCF), with additional co-financing from the private sector and development partners, was earmarked to fund Ghana's renewable energy development program.[3] The 158 MW Taiba N'Diaye facility in Senegal, Africa's first utility-scale wind farm, was partly financed through green bonds (UNDP, 2024). Other notable examples are a green bond released by a commercial real estate developer in Côte d'Ivoire and two sustainability bonds; Benin's issuance of Africa's first sovereign sustainability bond, amounting to US$588 million; and Ecobank, headquartered in Togo, issued a $350 million sustainability bond in June 2021 to finance clean infrastructure projects (International Finance Corporation, 2022).

These initiatives are crucial in creating an enabling environment for green investments and ensuring that financial resources are channeled towards projects with the highest environmental and social impacts. This paper, therefore, empirically explores the transformative potential of green financing in enhancing sustainable development in West Africa, given the rising spate of uncertainty in the region. Its key objectives are to empirically unveil the impact of uncertainty on sustainable development in West Africa; account for the moderating role of green financing in the relationship; and provide evidence-based pathways toward strengthening the region's sustainable development to ensure it makes significant strides in achieving the United Nations' Sustainable Development Goals (SDGs) and the African Union's Agenda 2063. This paper contributes to the body of knowledge in three important ways. First, it adds a robust dimension to the ongoing discussion on green financing and sustainable development by analyzing the panel data of 14 West African countries from 2010 to 2022. Past studies either focused on the link between uncertainty and sustainable development (Hunjra et al., 2022; Huang et al., 2023; Qureshi et al., 2023) or on green financing and sustainable development (Banga, 2018; Nanayakkara & Colombage, 2019; Maltais & Nykvist, 2020). This paper extends knowledge on the subject by underscoring the role of green financing in moderating the impact of uncertainty on sustainable development in West Africa. This provides a basis for making informed decisions on green financing strategies needed to place the region on a sustainable development trajectory.

Second, this paper employs the novel sustainable development index developed by Hickel (2020) to holistically analyse the link between uncertainty, green financing, and sustainable development. Sustainable development is multidimensional, encompassing human development, environmental quality, and economic progress (Hickel, 2020). Past studies have used one or two of these indicators. However, each indicator has drawbacks. For example, human development (life expectancy and education) and economic progress indicators (GDP, employment, income per capita, and trade) have been criticized for not taking environmental sustainability into account, and the ecological footprint (a measure of environmental quality) jettisons human development in its computation. Integrating these three dimensions of sustainable development into a comprehensive measure offers a more holistic and accurate sustainability assessment. Each dimension gives unique insights and, when combined, addresses the limitations of using singular or dual indicators. Third, the current paper uses analytical methods, which account for cross-sectional dependence, heterogeneity, and endogeneity issues that often arise in panel studies of this nature. These methods are complementary and offer robust dimensions to the empirical analysis.

The other sections of this paper are structured as follows: the second section provides a synopsis of the extant theoretical and empirical literature, the third section describes the data and methodology, the fourth section discusses the empirical results, and the last section concludes with important policy recommendations that can unequivocally foster sustainable development in West Africa and other African regions with similar economic structures.

2. Review of Related Studies

2.1. Theoretical Literature

The theoretical literature linking uncertainty and green financing with sustainable development is diverse. The theoretical link is explained by various variants of the theories of sustainable finance: the priority theory, the positive signaling theory, the resource theory, and the peer emulation theory of sustainable finance (Ozili, 2023). The priority theory of sustainable finance posits that a country's level of commitment to sustainable finance objectives reflects the significance accorded to the sustainable finance agenda (Wilson, 2010). This prioritization can be evaluated based on three key aspects: (i) the extent of coordinated, independent, and collaborative efforts exerted by economic agents to attain sustainable finance goals, (ii) the speed at which consensus is reached, and (iii) the pace at which actions are taken to achieve sustainable finance objectives. The theory suggests that countries allocate resources to sustainability initiatives based on strategic importance. However, the positive signaling theory suggests that countries disclose positive information about their commitment to sustainable finance goals to signal their intentions to external parties who can support these goals (Park, 2018). This disclosure can be made through public announcements in the media or by providing additional financial and non-financial information in annual reports. For instance, governments may announce national sustainable finance policies to enhance their reputation and attract foreign investment for green projects.

The resource theory of sustainable finance suggests that disparities in human-made resources play a crucial role in countries' varying degrees of progress in achieving their sustainable finance goals. It contends that countries with ample resources, such as significant foreign reserves, budget surpluses, and advanced financial infrastructure, have a comparative advantage in transitioning to sustainable finance compared to those with limited resources. These countries can more easily achieve their sustainable finance objectives, swiftly transition from traditional to sustainable finance, and promote sustainable development. However, the peer emulation theory of sustainable finance suggests that economic agents tend to imitate the actions and strategies of their peers when pursuing sustainable finance goals. This occurs when there are no standardized guidelines for sustainable financing, leading agents to adopt similar policies observed in their admired or emulated peers. Emulation is stronger among agents with similar societal, political, and economic ideologies. For instance, countries with aligned views on climate change are likely to adopt comparable sustainable finance policies to achieve their goals (Ditlev-Simonsen & Midttun, 2011).

Building on these theories, green financing can mitigate the adverse effects of uncertainty through three key channels. First, it can reduce financial risks and uncertainties. For instance, green bonds and other green financial instruments can provide stable and predictable returns, which can help with risk-sharing among investors (Kim et al., 2024). This is particularly relevant in uncertain economic environments where traditional investments might be more volatile. Additionally, green finance can reduce financial constraints and improve liquidity, which is crucial for managing risks in uncertain times (Wang et al., 2024). Second, investor confidence is another critical channel through which green

[2] https://climatechange.gov.ng/brief-on-green-bonds/

[3] https://www.undp.org/africa/press-releases/green-climate-fund-approves-545m-project-reduce-deforestation-and-carbon-emissions-northern-ghana

finance can offset uncertainty. The adoption of green finance practices, such as ESG (Environmental, Social, and Governance) criteria, can enhance transparency and accountability, thereby boosting investor confidence (Habib et al., 2024). Moreover, the positive signaling effect of green finance initiatives can attract more investors, even during periods of economic uncertainty, as they perceive these investments as more sustainable and less risky (Wang et al., 2024). Third, green finance significantly promotes the adoption of green technologies, which can help mitigate the adverse effects of uncertainty. For example, green finance can alleviate financing constraints for green technology projects and make it easier for companies to invest in sustainable innovations (Hunjra, 2025). This is particularly important in regions like West Africa, where access to finance for green projects can be limited.

2.2. Empirical Literature

Apart from the theoretical evidence, the empirical evidence on the link between uncertainty, green financing, and sustainable development has been growing recently, as it attracts increasing attention. Uncertainty, particularly in the context of economic policies, can profoundly influence corporate sustainability performance, environmental outcomes, and the broader goals of sustainable development. Qureshi et al. (2023) examined how economic policy uncertainty (EPU) affects the sustainability performance of European firms. Their study indicated that during periods of high EPU, firms tend to limit their environmental and governance efforts but increase their social engagements to mitigate information asymmetry. Huang et al. (2023) investigated the effects of EPU, GDP per capita, renewable energy consumption (REC), and foreign direct investment (FDI) on environmental sustainability. Their results suggest that reducing policy uncertainty and promoting sustainable economic growth can help mitigate climate change. Hunjra et al. (2022) explored the effects of political and social risks and macroeconomic policy uncertainty on sustainable development. They found that these risks impede sustainable development in the short and long term.

Attention is increasingly turning to understanding how green financing can be leveraged to promote sustainable development, particularly in developing economies. This explains the growing volume of empirical studies on the subject. The role of financial instruments such as Eurobonds, green bonds, and climate finance mechanisms is being explored to address climate change mitigation and adaptation needs. Green financing has been highlighted as pivotal in mobilizing funds for climate adaptation and mitigation in developing countries. Banga (2018) identified green bonds' potential and barriers in developing economies, noting that despite their growth in developed countries, developing nations face significant challenges, like high transaction costs and a lack of institutional support. Similarly, Maltais and Nykvist (2020) underscored the importance of green bonds in shifting capital toward sustainable economic activities but noted the need for more empirical studies on their broader impacts. Nanayakkara and Colombage (2019) provided evidence that green bonds are traded at a premium, suggesting investor willingness to support sustainable projects despite potentially lower returns. Pham (2016) analyzed the volatility in green bond markets and found significant variability influenced by overall market conditions.

Michaelowa et al. (2020) discussed how climate finance instruments have engaged private investments in Sub-Saharan Africa (SSA) and highlighted the importance of tailored approaches to local contexts. Doku et al. (2021) investigated the factors attracting climate finance to SSA, finding that countries with higher population growth, poverty levels, and better ICT usage attract more funds, though issues like governance and corruption remain challenges. Jakob et al. (2015) analyzed financial transfers under international climate agreements, identifying potential adverse effects such as volatility and corruption. They emphasized the need for robust institutional arrangements to mitigate these risks. Halimanjaya (2015) and Weikmans and Roberts (2019) further explored the complexities of allocating and accounting for climate finance, stressing the need for transparency and equitable distribution to avoid undermining trust in international climate negotiations. Amankwa et al. (2024) demonstrated a nuanced relationship between Eurobond issuance and carbon dioxide emissions in Africa using the Eurobond Environmental Kuznets Curve (EEKC). Their findings suggest that while Eurobonds can initially increase emissions, they hold the potential for financing climate-resilient activities if linked directly to green sectors.

A cursory examination of the reviewed extant literature reveals more focus on the bilateral relationship between uncertainty and sustainable development, or green financing and sustainable development. A notable research gap, especially for the latter studies, is the assumption that the effect of green financing on sustainable development is direct, without considering various transmission channels. In addition, there is a dearth of studies that combine these three important variables in a tripartite framework. To fill this research gap, this paper provides empirical evidence on the role that green financing can play in moderating the relationship between uncertainty and sustainable development, with a particular focus on West Africa.

3. Methodology

3.1. Data

Our sample includes 14 of the 16 ECOWAS member states, excluding Cabo Verde and Guinea-Bissau due to prolonged data unavailability for key variables, particularly the Sustainable Development Index (SDI), World Uncertainty Index, and green finance flows, over the 2010–2022 period. While these countries are part of the regional bloc, consistent and comparable time-series data required for panel analysis is either incomplete or entirely missing. We acknowledge that this may introduce some sample limitations; however, the 14 included countries represent over 90 % of the region's population and GDP, and span a diverse range of income levels, governance structures, and climate vulnerabilities. The sampled countries have diverse levels of uncertainty, are at different stages of development, and attract different amounts of green finance (see Figs. 2 and 3). These features provide valuable insights into how uncertainty affects sustainable development and how green financing can moderate the impact in various contexts. The dependent variable of this paper, sustainable development, is measured using the robust Sustainable Development Index (SDI) developed by Hickel (2020). Previously, sustainable development was often measured using the Human Development Index (HDI) (Maccari, 2014; Jin et al., 2020). The HDI is defined more by social goals than GDP growth, but its limitations became evident due to rising climate change issues and the associated ecological damages. Hickel (2020) criticized the HDI for not taking ecological sustainability into account and proposed the SDI as an alternative that balances human development with ecological impact. The SDI is an efficiency metric used to evaluate how ecologically efficient nations achieve human development, computed by dividing the development and ecological indexes. The "development index" is derived from the HDI and calculated as the geometric mean of the life expectancy, education, and adjusted income indexes. The "ecological index" measures the extent to which a nation's consumption-based CO_2 emissions and material footprint surpass per-capita planetary boundary shares.

The main dependent variable of this paper is uncertainty, which is measured using the World Uncertainty Index (WUI). The WUI is calculated by aggregating the number of times the term "uncertainty" or its variants are mentioned in a country report from the Economist Intelligence Unit (EIU). These counts are normalized against the total number of words in the reports and then multiplied by 1000. Large and small values of the WUI imply high and low uncertainty, respectively. Some studies have utilized this measure of uncertainty in their analysis (Afolabi, 2023b; Jung, 2023; Afolabi & Raifu, 2024). The moderating variable of this paper is green financing, which is measured using two

proxies: climate change mitigation (CCM) and environmental funds (ENV), which track official development assistance (ODA) and other concessional flows specifically tagged for environmental sustainability and climate objectives. These data are compiled using the OECD's Creditor Reporting System (CRS), which ensures standardized project-level coding based on purpose, sector, and environmental relevance. A higher CCM and ENV generally indicate a large inflow of green funds to a country, which augments domestic resources needed to combat climate change and promote environmental sustainability. A similar measure of green financing has been used in recent studies (Nanayakkara & Colombage, 2019; Zhang & Wang, 2019).

In addition, the analysis contains control variables including GDP growth, natural resource rents, institutional quality, and exchange rate, which have been proven to influence sustainable development. GDP growth, which entails a positive increase in economic/productive activities within a country, can promote sustainable development but may undermine environmental quality (Azam et al., 2021). Hence, its overall effect on sustainable development will depend on whether the positive effect dominates the negative. Natural resource rents, measured as the share of total natural resource rent in GDP, can improve government revenue but can also raise environmental concerns (Afolabi, 2023a). Institutional quality is crucial to establishing a sound regulatory environment wherein sustainable development can be nurtured (Babatunde & Afolabi, 2023, 2024). It is measured by aggregating and normalizing six governance variables (control of corruption, government effectiveness, political stability, regulatory quality, rule of law, and voice and accountability) using a Principal Component Analysis (PCA) approach. These institutional quality variables range from -2.5 (weak institutions) to $+2.5$ (strong institutions). Exchange rate depreciation makes exports more affordable but imports dearer and vice versa. The sustainable development effect of the exchange rate is ambiguous, as it depends on whether a country is a net importer or a net exporter. Sustainable development data was obtained from the Sustainable Development Index (SDI) (https://www.sustainabledevelopmentindex.org/time-series), WUI data was sourced from Ahir et al. (2022) (https://www.worlduncertaintyindex.com/data/), green financing data was collected from the Organisation for Economic Cooperation and Development (OECD) https://stats.oecd.org/viewhtml.aspx?datasetcode=RIOMARKERS&lang=en, while other data were obtained from the World Development Indicator (WDI) https://databank.worldbank.org/source/world-development-indicators. Table 1 provides the variable description and data sources.

3.2. Theory and Model

This paper is anchored on the peer emulation theory of sustainable finance, which suggests that countries adopt green financing practices by imitating peers, especially when institutional guidelines are unclear (Ditlev-Simonsen & Midttun, 2011). In West Africa, this dynamic is amplified by shared regional challenges and structures: limited institutional capacity, underdeveloped financial markets, and high exposure to climate risks reduce the ability of countries to pioneer green finance independently (Afolabi, 2024). Instead, they look to regional leaders, such as Nigeria, Ghana, or Senegal, whose issuance of green bonds or climate finance initiatives signals feasibility and credibility. Regional integration through the Economic Community of West African States (ECOWAS) and monetary unions like WAEMU further accelerates policy diffusion by creating network effects where early adopters influence neighbours. Additionally, reliance on external funding makes countries more responsive to peer success in attracting climate finance, turning emulation into a strategic move for access to international capital. Thus, in West Africa, peer emulation is not just imitation but also a pragmatic, context-driven response to common constraints and opportunities that shape the region's path toward sustainable development.

Based on this theoretical anchor, the setup of the model is as follows:

Let N be the total number of countries; A_i be a binary variable representing whether country i adopts greening financing ($A_i = 1$ for adoption and $A_i = 0$ for non-adoption); and $\pi_i(A)$ be the profit or utility derived by country i for its green financing decision.

$$\pi_i(A) = \pi_i^0 + \alpha.A_i - \beta.(1 - A_i) + \gamma.\sum_{j \neq i} \omega_{ij} A_j - \delta.\sigma_i(A) \tag{1}$$

Where π_i^0 is the base profit of country i without considering green financing; α is the direct benefit to country i from adopting green financing; β is the cost to country i of not adopting green financing; γ is the peer influence coefficient, representing the benefit country i gains from the adoption of green financing by other countries; ω_{ij} is the weight representing the influence of country j on country i, capturing the network effect (countries in the same region might have higher weights); and $\sigma_i(A)$ represents the uncertainty or risk perceived by country i, which decreases as more countries adopt green financing.

$$\sigma_i(A) = \frac{1}{1 + \sum_{j \neq i} A_j} \tag{2}$$

Eq. (2) captures the idea that as more countries adopt green financing, the uncertainty or risk other countries perceive decreases. The adoption of green financing in developed countries has yielded positive outcomes (Nanayakkara & Colombage, 2019; Zhang & Wang, 2019). Thus, extending it to developing regions, including West Africa, might help to reduce uncertainty and promote sustainable development.

In the context of this paper, the profit from the adoption of green financing ($\pi_i(A)$), as depicted in Eq. (1), is represented as sustainable development. Thus, to capture the effect of uncertainty (WUI) and other sustainable development drivers (X) on sustainable development (SDI), the following baseline model is specified:

$$SDI_{it} = \beta_0 + \beta_1 WUI_{it} + \beta_2 X_{it} + \delta_i + \delta_t + \varepsilon_{it} \tag{3}$$

Where i and t represent cross-sections and time periods, respectively. β_0, β_i, δ_i, δ_t and ε_{it} are the intercept, the parameters of explanatory variables, unobserved time-invariant country-specific effects, time-specific shocks, and the error term, respectively. Based on previous studies, the drivers of sustainable development (such as GDP growth, natural resource rent, institutional quality, and exchange rate) enter the model as controls (Zhang & Wang, 2019; Hunjra et al., 2022).

To capture the direct and indirect effects of green financing (GF) on sustainable development, Eq. (3) is extended as follows:

$$SDI_{it} = \beta_0 + \beta_1 WUI_{it} + \beta_2 GF_{it} + \beta_3 WUI_{it} * GF_{it} + \beta_4 X_{it} + \delta_i + \delta_t + \varepsilon_{it} \tag{4}$$

Eq. (4) shows that green financing can directly affect sustainable development and could influence it indirectly through the uncertainty channel. The interaction between uncertainty and green financing ($WUI_{it} * GF_{it}$) is included to unveil the joint impacts of these variables on sustainable development and the net effect of green financing on

Table 1
Data Description and Sources.

Variables	Variable	Source
SDI	Sustainable Development Index	SDI (2024)
WUI	World Uncertainty Index	Ahir et al. (2022)
CCM	Climate Change Mitigation (US$ Million)	OECD (2023)
ENV	Environmental Funds (US$ Million)	OECD (2023)
GDPG	GDP Growth (annual %)	WDI (2023)
NRR	Total Natural Resource Rent (% of GDP)	WDI (2023)
INST	Institutional Quality (Control of Corruption, Government Effectiveness, Political Stability, Regulatory Quality, Rule of Law, and Voice and Accountability)	WDI (2023)
EXR	Official exchange rate (LCU per US$, period average)	WDI (2023)

sustainable development. The partial derivative of Eq. (4) with respect to uncertainty has to be taken to compute the net effect from the multiplicative term of uncertainty and green financing:

$$\frac{\partial SDI_{it}}{\partial WUI_{it}} = \beta_1 + \beta_3 \overline{GF}_{it} \tag{5}$$

Where $\overline{GF}_{it}$ is the average value of green financing. The combined values of β_1 and β_3 will determine whether $\frac{\partial SDI_{it}}{\partial WUI_{it}}$ will be positive, negative, or null. $\frac{\partial SDI_{it}}{\partial WUI_{it}} > 0$ implies that despite uncertainty, the combined effects of uncertainty and green financing improve sustainable development prospects. However, $\frac{\partial SDI_{it}}{\partial WUI_{it}} < 0$ indicates that both uncertainty and green financing hinder sustainable development. Lastly, $\frac{\partial SDI_{it}}{\partial WUI_{it}} = 0$ means that both uncertainty and green financing do not have an impact on sustainable development. For easy result interpretation, SDI, WUI, and exchange rate are transformed to natural logarithms, hence the prefix, *ln*.

3.3. Estimation Techniques

Both static and dynamic panel models are employed to provide holistic insights into the role of green financing in the sustainable development-uncertainty nexus. For the static models, the fixed effects (FE) and random effects (RE) models were adopted. These estimators can control for unobserved heterogeneity when time-invariant variables are potentially correlated with the explanatory variables. They also generate efficient estimates when the assumption of no correlation between individual effects and explanatory variables holds. However, they become biased in the presence of a lagged dependent variable and in short time horizons (Nickel, 1981). While these estimators have a small variance, the inherent bias can significantly distort inference, especially in dynamic panel models, where capturing the temporal dependence accurately is crucial. They also cannot address cross-sectional dependence (CD). Given the presence of CD in our sample, the Panel-Corrected Standard Error (PCSE) method, introduced by Beck and Katz (1995), was employed to estimate the empirical models. It addresses endogeneity, autocorrelation, and heteroscedasticity issues, common in panel data analysis. The PCSE method adjusts the standard errors and addresses potential error correlation within the cross-sections to overcome omitted variable bias (Babatunde & Afolabi, 2024).

Other solutions to the weaknesses of the traditional estimators (FE and RE) include the Generalized Method of Moments (GMM) estimators and quasi-maximum likelihood (QML) estimators, which also have limitations. The GMM estimator can suffer from poor finite sample properties and requires careful selection and validation of instruments, which can be technically demanding and subjective. The QML estimator requires strong assumptions about the exogeneity of regressors, which limits its application in real-life situations where endogeneity is common. The Bias-Corrected Method of Moments (BCMM) estimation approach, introduced by Breitung et al. (2022), overcomes these drawbacks as it addresses the bias inherent in FE and RE estimators by adjusting the respective moment conditions. It is also flexible and can accommodate higher-order autoregressive models, making it suitable for a wider range of dynamic panel data applications. It generates robust standard errors that account for cross-sectional dependence and outperforms the GMM and QML estimators by assuming strict exogeneity of regressors (Breitung, 2022). The BCMM, a dynamic panel model, is employed in this paper to check the robustness of estimates, and it proves quite insightful, robust, and suitable as it validates the results of earlier models. Before the main estimation, we conduct pre-estimation

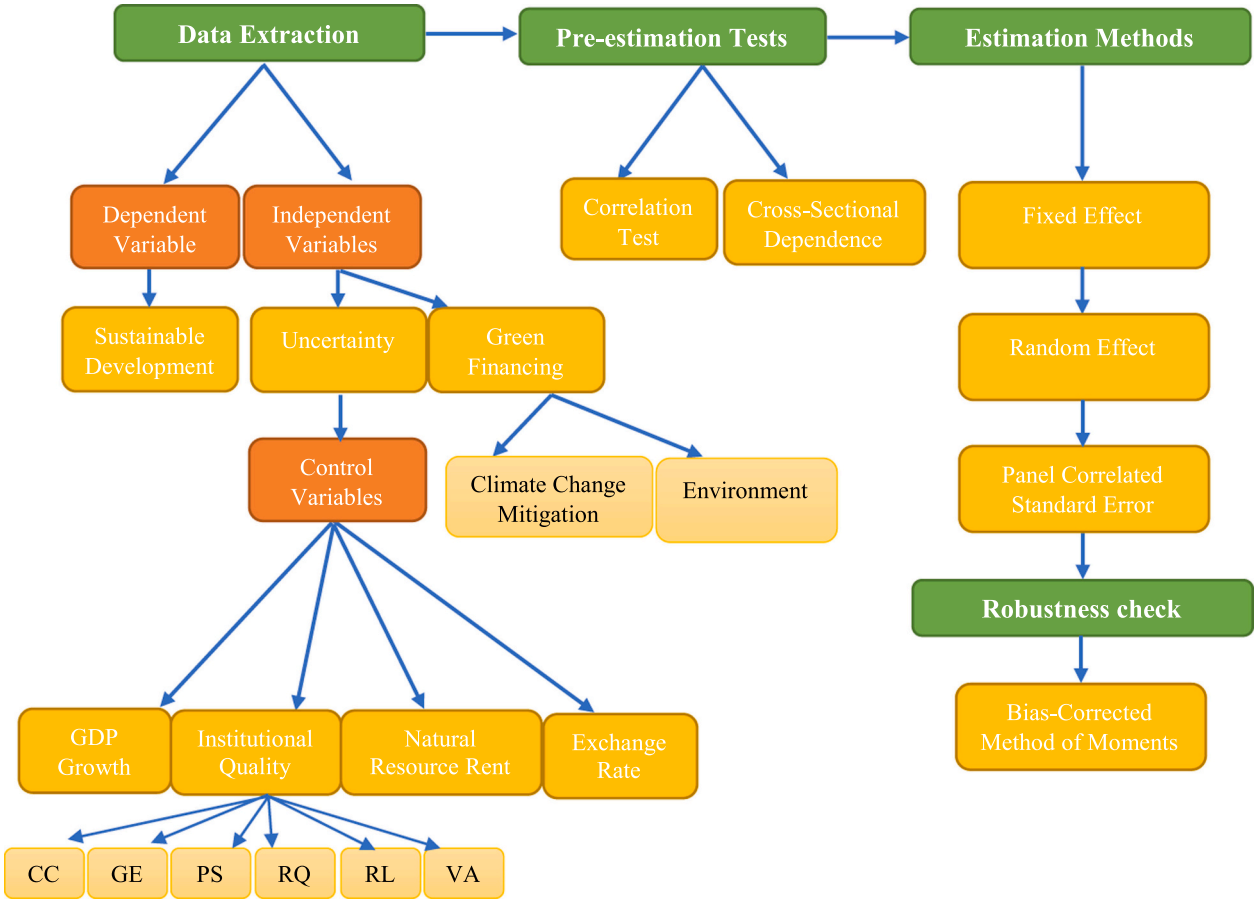

Fig. 1. Methodological Framework.

tests, including correlation and cross-sectional dependence tests, to gain preliminary insights into the relationships among our variables. Fig. 1 presents the methodological framework of this paper.

4. Results and Discussion

4.1. Pre-Estimation Analysis

This paper seeks to unveil the transformative potential of green financing in fostering sustainable development despite uncertainty. The analysis begins by describing the statistical properties of the variables and conducting pre-estimation tests – correlation and cross-sectional dependence tests. Table 2 shows the descriptive analysis with sustainable development averaging 0.51, implying that sustainable development is yet to be fully optimized in West Africa. This could be linked to uncertainty, which has a range of 0.78. The ranges of the measures of green financing (climate change mitigation and environmental funds) show that West African countries receive varying degrees of green funds, although the environmental funds are higher than the climate change mitigation funds. While GDP growth and natural resource rent averaged 4.6 % and 9.6 %, respectively, institutional quality is quite weak, and the exchange rate constitutes a major challenge for West African countries, given its high average value compared to foreign currencies. Figs. 2 and 3 show the scatter plots of the average values of key variables, revealing differences in the distribution. Fig. 2 shows a weak negative relationship between SDI and WUI, with an R-squared of only 0.02. While higher uncertainty tends to coincide with lower SDI, notable exceptions exist: Ghana and Mauritania achieve relatively high development levels despite moderate uncertainty. Nigeria, despite high uncertainty, maintains above-average SDI, likely due to its large economy and resource base, while countries like Niger and Burkina Faso face low SDI even with moderate uncertainty. In contrast, Fig. 3 shows a much stronger and positive association (R-squared=0.268) between SDI and green finance, measured through climate change mitigation, indicating that green finance plays a meaningful role in advancing sustainable development. Countries receiving higher levels of green investment, such as Ghana and Côte d'Ivoire, consistently rank at the top in SDI, reflecting the developmental returns on climate financing. Nigeria and Senegal also align with this trend, benefiting from moderate to high green funding. On the other hand, countries like Mali, Niger, and Sierra Leone remain in the lower-left quadrant, with both low green finance and low SDI, which highlights a critical gap in access to climate resources.

The correlation test describes the nature and strength of the relationship between variables, while the CD test examines whether countries are interconnected. The Pesaran (2004) CD test approach is employed to test the null hypothesis of no CD. The results of these tests are reported in Table 3. The correlation results show that uncertainty and the exchange rate have a significant negative relationship with sustainable development, while green financing variables and institutional quality have a positive link. This implies that while uncertainty and exchange rates can lower sustainable development, green financing and high institutional quality can drive sustainable development. The results conjecture the absence of multicollinearity among the variables. On the other hand, the results of the CD test suggest rejecting the null hypothesis among the sampled countries. This indicates interconnection among West African countries and reveals that when sustainable development is achieved in one country, it could engender sustainable development in others. In the same vein, the transformative role of green financing in one country can have a ripple effect on other countries within the region.

Table 2
Descriptive Statistics.

Variable	Obs	Mean	Std. Dev.	Min	Max
Sustainable Development Index	182	0.514	0.061	0.357	0.659
World Uncertainty Index	182	0.234	0.152	0	0.780
Climate Change Mitigation	165	27.539	53.917	0.007	353.245
Environmental Funds	182	40.633	50.233	0.713	255.46
GDP Growth	182	4.622	3.797	−20.491	21.079
Natural Resource Rent	168	9.566	6.172	2.304	33.270
Institutional Quality	182	0	1	−2.373	2.496
Exchange Rate	179	795.503	1857.86	1.430	9565.082

4.2. Effect of Uncertainty on Sustainable Development

The results of the baseline model (Eq. 3) estimated using the fixed effect, random effect, and PCSE methods are shown in Table 4. Each result column is generated from the respective estimators with country and time effects captured in the analysis. The coefficients of determination of each model are above 88 %, indicating a good fit and showing that uncertainty and the control variables jointly largely explain the dynamics of sustainable development. The results show overwhelming evidence of the negative effect of uncertainty on sustainable development. All three estimators unanimously reveal that uncertainty negatively and significantly affects sustainable development in West Africa. While the estimates of the fixed and random effects are the same, they differ slightly from those of the PCSE estimator. Nonetheless, they indicate that sustainable development is undermined as uncertainty increases. This affirms the postulation of the real option theory that uncertainty is a major deterrent to sustainable development, as it delays long-term investment decisions (Bagh et al., 2024). It is also consistent with previous empirical studies (such as Hunjra et al., 2022; Huang et al., 2023; Qureshi et al., 2023) and re-echoes the stance of Afolabi (2023b) that African economies are more affected by global uncertainties than in other regions. The fact that many West African countries are often heavily reliant on commodities (such as crude oil, agricultural products, and mineral resources), whose prices are highly volatile in the international market, makes them badly hit by fluctuations in global commodity prices, which lowers revenue generation and hinders long-term development planning. In general, this finding supports the argument that uncertainty is inimical to sustainable development.

We find mixed results for the estimates of our control variables. While their signs are consistent across the estimated models, the statistical significance of their impact on sustainable development is mixed. First, GDP growth exerts a positive influence on sustainable development, indicating that increased economic activity can foster sustainable development. However, this impact is only significant in the PCSE model, and it reveals that GDP growth substantially improves sustainable development in West Africa. This also suggests that one of the pathways to achieving sustainable development is to promote sustained annual GDP growth. This aligns with the theoretical prediction and affirms the findings of Hunjra et al. (2022), which demonstrated that sustained economic growth is pivotal to achieving sustainable development. Further results show that natural resource rent has a significant positive impact on sustainable development in West Africa. This is not surprising, as many West African countries are resource-dependent and earn huge sums from the exploitation of their natural resources (Afolabi, 2023b, 2024). This additional government revenue source can provide the government with the necessary financial resources to invest in public goods (such as education, infrastructure, and healthcare) that can foster sustainable development. Further findings reveal that improving institutional quality is indispensable for improving sustainable development prospects in West Africa. This is consistent with the views of Azam et al. (2021) and Babatunde and Afolabi (2024), who explained that having strong institutions helps to compel economic agents to pursue sustainable practices. Lastly, the estimates of the exchange rate are negative and significant across the models, revealing that exchange rate

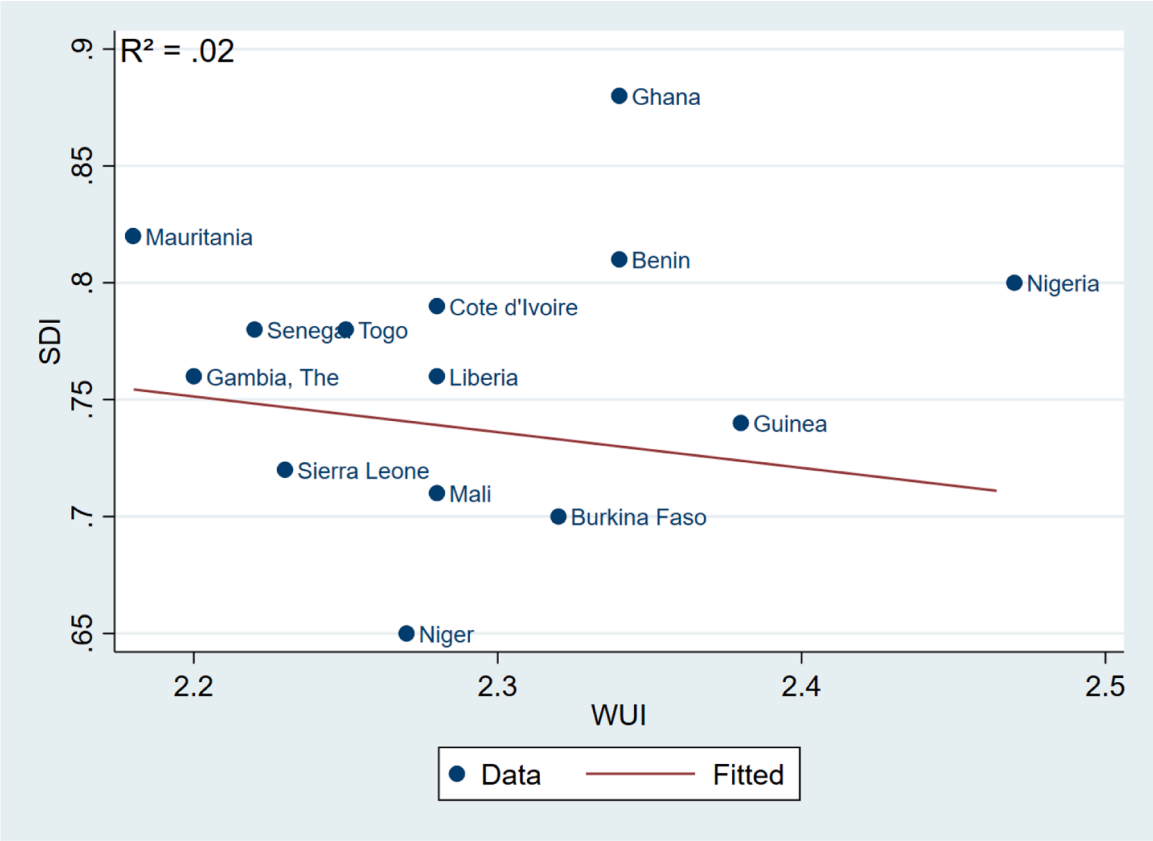

Fig. 2. Uncertainty and Sustainable Development in Africa.

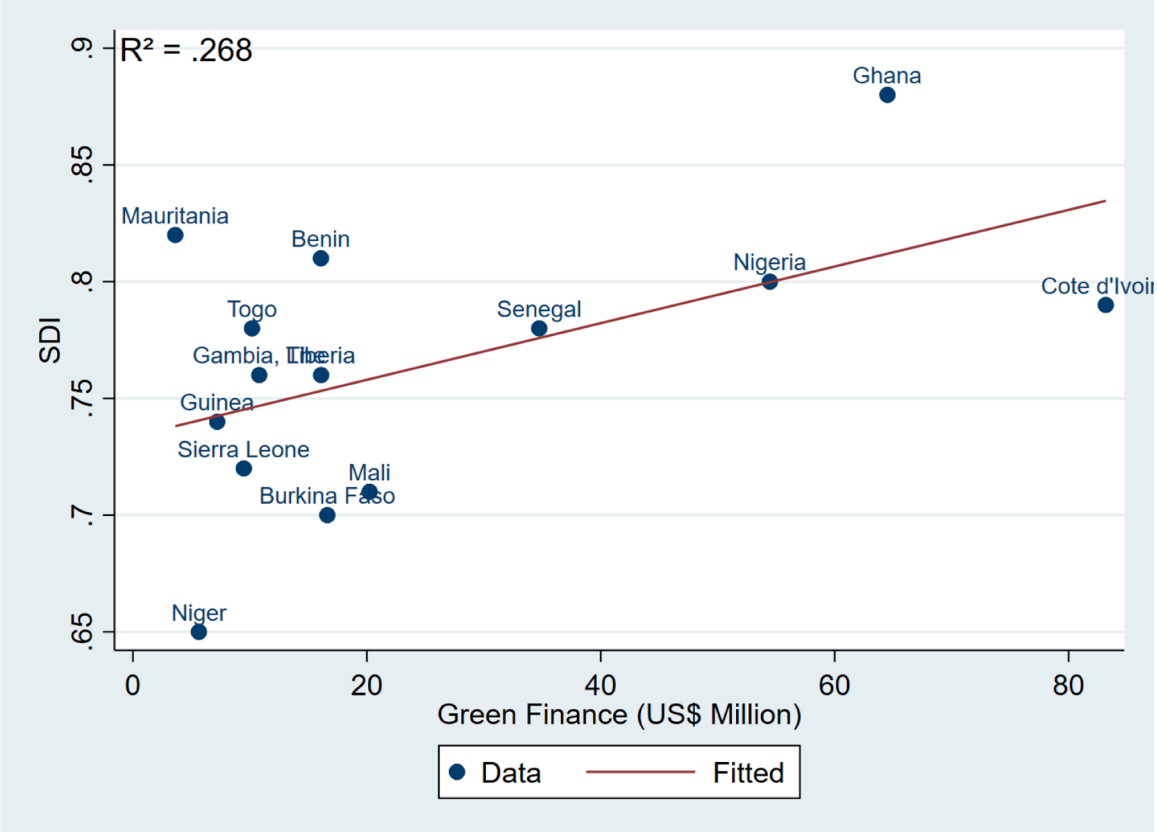

Fig. 3. Green Financing and Sustainable Development in Africa.

Table 3
Correlation and Cross-Sectional Dependence.

Variables	ln(SDI)	ln(WUI)	CCM	ENV	GDPG	NRR	INST	ln(EXR)	Pesaran CD-test
ln(SDI)	1								32.120***
ln(WUI)	−0.043**	1							7.190***
CCM	0.271***	0.093	1						3.710***
ENV	0.201***	0.122	0.469***	1					5.660***
GDPG	−0.030	−0.086	−0.002	−0.061	1				5.540***
NRR	−0.104	−0.090	−0.153*	−0.179**	0.043	1			12.270***
INST	0.258***	−0.096	0.216***	0.331***	0.105	−0.325***	1		0.390
ln(EXR)	−0.324***	0.105	−0.078	0.046	0.056	−0.117	−0.390***	1	29.840***

*** p < 0.01, ** p < 0.05, * p < 0.1

Table 4
Effect of Uncertainty on Sustainable Development.

Variables	Fixed Effect	Random Effect	PCSE
ln(WUI)	−0.005***	−0.005***	−0.003**
	(0.002)	(0.002)	(0.001)
GDP Growth	0.0005	0.0005	0.001*
	(0.0003)	(0.0003)	(0.0003)
Natural Resource Rent	0.001**	0.001**	0.0005*
	(0.0003)	(0.0003)	(0.0002)
Institutional Quality	0.006**	0.006**	0.003
	(0.003)	(0.003)	(0.002)
ln(Exchange Rate)	−0.022***	−0.022***	−0.018**
	(0.006)	(0.006)	(0.008)
Constant	−0.641***	−0.514***	−0.537***
	(0.033)	(0.040)	(0.049)
Number of obs.	162	162	162
R-squared	0.885	0.992	0.997
F-test	63.667***	163.576***	140.992***
Country Dummy	NO	YES	YES
Year Dummy	YES	YES	YES

*** p < 0.01, ** p < 0.05, * p < 0.1

depreciation is detrimental to sustainable development and vice versa. This finding is plausible as West African countries occupy the "small countries" position in international trade (Bouët et al., 2017). They have little or no influence on international prices of goods and services; rather, they are price takers. This also reflects in the value of their domestic currencies, which are often weak compared to major currencies. The depreciation of the exchange rate for price takers often leads to trade deficits, which is detrimental to sustainable development.

4.3. Moderating Role of Green Financing on Sustainable Development

Having established that uncertainty deters sustainable development, we are interested in examining how to mitigate this adverse effect through green financing (climate change mitigation). We, therefore, introduced green financing individually and as an interactive term into the model to reveal its direct and indirect (through uncertainty) effects on sustainable development. The indirect effect merits investigation to answer the question of whether green finance can moderate the negative impact of uncertainty on sustainable development. The results, reported in Table 5, show that while uncertainty continues to undermine sustainable development, green financing has a significant positive impact on it. This direct impact aligns with theoretical predictions (Ozili, 2023) and confirms the findings of Nanayakkara and Colombage (2019), Maltais and Nykvist (2020), Doku et al. (2021), and Phiri and Doku (2024), who demonstrated that green finance facilitates sustainable practices that promote sustainable development. It also reaffirms the stance of Michaelowa et al. (2020) that green finance increases private investment and drives sustainable development in SSA, of which West Africa forms a part.

The result of the indirect effect of green finance on sustainable development via the uncertainty channel is quite intriguing. It is not only positive but also statistically significant. More importantly, the

Table 5
Moderating Role of Green Financing on Sustainable Development.

Variables	Fixed Effect	Random Effect	PCSE
ln(WUI)	−0.007***	−0.007***	−0.006**
	(0.002)	(0.002)	(0.003)
Climate Change Mitigation	0.0002**	0.0002**	0.0001*
	(0.0001)	(0.0001)	(0.0001)
WUI*Climate Change Mitigation	0.0004*	0.0004*	0.0002
	(0.0002)	(0.0002)	(0.0001)
GDP Growth	0.001	0.001	0.001***
	(0.0005)	(0.0005)	(0.0003)
Natural Resource Rent	0.001**	0.001**	0.0004
	(0.0003)	(0.0003)	(0.0003)
Institutional Quality	0.008**	0.008**	0.005*
	(0.003)	(0.003)	(0.003)
ln(Exchange Rate)	−0.022***	−0.022***	−0.018***
	(0.007)	(0.007)	(0.006)
Constant	−0.648***	−0.522***	−0.541***
	(0.040)	(0.046)	(0.037)
Number of obs.	146	146	146
R-squared	0.890	0.993	0.998
F-test	51.143***	151.013***	147.338
$\frac{\partial SDI_{it}}{\partial WUI_{it}}$	0.004	0.004	0.005
Country Dummy	YES	YES	YES
Year Dummy	YES	YES	YES

*** p < 0.01, ** p < 0.05, * p < 0.1

partial derivative of uncertainty with respect to sustainable development, which captures the moderating role of green financing on the sustainable development-uncertainty nexus, shows a positive value. In fact, the finding holds regardless of the estimation technique employed. The implication is that green financing can help mitigate the negative impacts of uncertainty on sustainable development. In other words, green financing (in the form of climate change mitigation) can provide a buffer against the risks associated with uncertainty and encourage continued investment in sustainable projects despite uncertain conditions. Moreover, green financing can modify the relationship between uncertainty and sustainable development in different beneficial ways. Overall, the evidence indicates that providing funds toward climate change mitigation can simultaneously reduce uncertainty and promote sustainable development.

4.4. Robustness checks

So far, we have used climate change mitigation as the proxy for green financing. To check the robustness of our estimates, we use an alternative measure of green financing, environmental funds, and an alternative estimation technique, the BCMM, to re-estimate Eq. 4. The model was re-estimated sequentially. First, we estimate the effect of uncertainty on sustainable development without including any green financing variable. Second, we introduce the interactive effect of institutional quality. Third, we introduce climate change mitigation and its interactive term with uncertainty to the model. In the fourth model, we replace climate change mitigation with environmental funds as the

Table 6
Robustness Checks: Bias-Corrected Method of Moments.

Variables	(1)	(2)	(3)	(4)
ln(SDI(−1))	0.757***	0.760***	0.718***	0.760***
	(0.041)	(0.044)	(0.044)	(0.038)
ln(WUI)	−0.002**	−0.002**	−0.003***	−0.004***
	(0.001)	(0.001)	(0.001)	(0.001)
Climate Change Mitigation			0.0001**	
			(0.0004)	
WUI*Climate Change Mitigation		0.001***	0.0001*	
		(0.000)	(0.0001)	
Environmental Funds				0.0001***
				(0.00003)
WUI*Environmental Funds				0.0001*
				(0.00009)
Institutional Quality	−0.001	−0.003	−0.002	0.0001
	(0.002)	(0.002)	(0.002)	(0.002)
WUI* Institutional Quality		−0.001		
		(0.001)		
GDP Growth	0.001***		0.001***	0.001***
	(0.0001)		(0.0003)	(0.0001)
Natural Resource Rent	0.0002	0.0002	0.00004	0.0002
	(0.0002)	(0.0002)	(0.0002)	(0.0002)
ln(Exchange Rate)	0.006	0.005	0.005	0.004
	(0.004)	(0.004)	(0.003)	(0.004)
Constant	−0.202***	−0.199***	−0.224***	−0.193***
	(0.031)	(0.031)	(0.038)	(0.030)
Number of obs.	131	131	99	131
Number of groups	12	12	9	12
Obs. per group (average)	10.917	10.917	11	10.917
$\frac{\partial SDI_{it}}{\partial WUI_{it}}$			0.0001	0.0001
Year Dummy	YES	YES	YES	YES

*** p < 0.01, ** p < 0.05, * p < 0.1

measure of green financing. The respective results are reported in columns (1)-(4) of Table 6. The effect of uncertainty remains negative and significant, showing that uncertainty stifles sustainable development regardless of the estimation method employed. Similarly, the measures of green financing have the expected signs, suggesting that climate change mitigation and environmental funds improve sustainable development. As shown by the values of $\frac{\partial SDI_{it}}{\partial WUI_{it}}$, these green financing indicators overturn the negative effect of uncertainty on sustainable development, demonstrating them as important mechanisms for promoting sustainable development notwithstanding uncertainty. This finding amplifies the submission by Doku et al. (2021) and Phiri and Doku (2024) that green finance can foster sustainable development even in the presence of uncertainty. In addition, the coefficient of the first-period lag of sustainable development is positive and significant, suggesting an autoregressive process such that efforts and investments made toward sustainable development will have lasting positive effects over time. Thus, pro-sustainable development policies can build on past successes to create a domino effect of improvement. It also suggests that policymakers should consider the past values of sustainable development when forecasting or planning future initiatives. However, the coefficient of the interaction term of uncertainty and institutional quality in Column (2) is −0.001, but it is not statistically significant. This implies that institutional quality does not significantly buffer or mitigate the adverse impact of uncertainty on sustainable development in this specification. One possible interpretation is that, across West African countries, institutional capacities remain generally weak, as shown in Table 2, and are insufficient to effectively insulate development outcomes from uncertainty.

5. Conclusion

While significant research has been conducted on green financing, its moderating effect on the development-uncertainty nexus remains underexplored, with no specific study on West Africa. Understanding regional challenges and opportunities is crucial for effective policy-making. Thus, this paper evaluated the effect of uncertainty on sustainable development and the role of green financing in moderating the relationship. We employed two measures of green financing: climate change mitigation and environmental funds. The FE, RE, PCSE, and BCMM estimation techniques were employed to empirically analyse the samples drawn from 14 West African countries between 2010 and 2022. The empirical results reveal that while uncertainty significantly hampers sustainable development while green financing does the opposite. Further analyses reveal that green financing significantly moderates the negative impact of uncertainty on sustainable development in West Africa. GDP growth, institutional quality, and natural resource rent are found to be important determinants of sustainable development in the region.

The policy implications of these findings suggest the need to develop a comprehensive, phased plan to boost sustainable development in West Africa through green financing. While we acknowledge ongoing efforts to harness green financing in the region, significant lacunas remain in the green finance framework. Many West African countries lack clear guidelines for green bond issuance, green lending criteria, and environmental impact assessments. Where policies exist, enforcement mechanisms are often weak or inconsistent, and this undermines the effectiveness of green financing initiatives. To address these challenges, we propose a tiered approach (short-, medium-, and long-term actions) to build a resilient and scalable green finance ecosystem. In the short term, foundational coordination and monitoring mechanisms should be established. Immediate priorities should include strengthening regional coordination and building institutional capacity. ECOWAS should institutionalize an annual West Africa Green Finance Forum, where central banks, ministries of finance, regulators, and private sector actors review progress, share best practices, and align national strategies with regional goals, modeled on the West African Monetary Agency's (WAMA) surveillance framework. This low-cost, high-impact initiative can begin immediately using existing regional platforms. Additionally, national governments should designate focal agencies (such as central banks or environmental ministries) with authority to oversee green finance activities, ensure transparency, and begin compiling basic data on green expenditures.

For the medium-term, regional financing tools should be launched and standards harmonized. Building on existing initiatives like the ECOWAS Renewable Energy Policy and Regional Action Plan on Climate Change, ECOWAS should establish a Regional Green Finance Facility (RGFF). This body would: (i) harmonize definitions and standards for green bonds and loans; (ii) provide technical support for sovereign and sub-sovereign green bond issuance; and (iii) serve as a platform for pooling resources from national budgets, private investors, and international donors. Pilot projects could be co-financed using seed funding from the ECOWAS Bank for Investment and Development (EBID) and climate funds such as the Green Climate Fund (GCF), with initial focus on renewable energy mini-grids. In the long term, it is crucial to institutionalize accountability and scale domestic markets. To ensure sustainability and investor confidence, countries should adopt and mandate adherence to international standards (such as the International Capital Market Association's Green Bond Principles or the Climate Bonds Initiative certification scheme) for all public and private green issuances. ECOWAS can support this by creating a regional green finance certification mechanism, including independent third-party verification. Annual impact reports should be published, featuring measurable indicators such as tons of CO_2 reduced, MW of renewable energy deployed, and green jobs created. Over time, this will help develop deeper domestic capital markets and reduce reliance on external funding, enabling a self-sustaining green finance cycle.

The key limitation of this paper is data paucity, which limited the scope of the study to only 14 out of 16 West African countries. Additionally, the study relied on external climate and environmental funding due to limited and inconsistent data on domestic green finance instruments in West Africa. Future studies should incorporate more

comprehensive data as it becomes available. They can also extend the current study to other developing regions and explore other factors, besides green financing, that can moderate the development-uncertainty nexus. Given that this paper assumes a linear relationship between uncertainty, green financing, and sustainable development, future studies should consider whether a non-linear relationship exists among these variables. Lastly, our green finance variables capture external (international) funding and do not fully reflect domestic green finance initiatives. Future studies should consider collecting regional data to support more complete assessments.

CRediT authorship contribution statement

Joshua Adeyemi Afolabi: Writing – review & editing, Writing – original draft, Visualization, Validation, Software, Methodology, Investigation, Formal analysis, Data curation, Conceptualization.

Declaration of Competing Interest

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

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