

ASSESSING THE IMPACT OF GREEN FINANCE AND CLIMATE RISK ON FINANCIAL MARKET DEVELOPMENT IN SUB-SAHARAN AFRICA

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Abstract

Financial market development remains low and uneven in the face of desired green finance encumbered by climate risk in sub-sahara Africa. This study explores the interplay between green finance, climate risk, and financial market development by investigating the effect of green finance in mitigating climate-related risks, examining whether financial market development enhances the impact of green finance on climate risk mitigation, and analyzing the influence of financial market development on green finance inflows. Employing a panel data analysis of 40 Sub-Saharan out of 54 African countries from 2015 to 2022, the findings reveal that green finance inflows significantly reduce CO2 intensity (coef: -0.001, p=0.045) and climate vulnerability (coef: -0.0000411, p=0.048), at 5% significance level, supporting their role in mitigating transition and physical climate risks, though no significant effect was found on climate readiness. Financial market development amplifies the effect of green finance on CO2 intensity (coef: -0.005, p=0.073) and climate vulnerability (coef: -0.0003827, p=0.058), indicating that robust financial systems enhance the efficacy of green finance, no significant impact on climate readiness. Financial market development, through low non-performing loan ratios (coef: -46.398, p=0.099) and high private sector credit (coef: 0.714, p=0.07), significantly drives green finance inflows. The findings are consistent with the Environmental Kuznets Curve Hypothesis. The study concludes that green finance helps in mitigating climaterelated risks in Sub-Saharan Africa and recommends that governments scales up green financial instruments as green bonds and green loans, by offering tax incentives and subsidies to attract private sector investment. Also, implement green banking guidelines and risk-sharing mechanisms and capacity building for financial institutions.

Keywords: *Green Finance, climate risk, financial development, Non-Performing Loan, Subsahara Africa*

1.0. Introduction

The global financial landscape has undergone significant transformation in recent decades, driven by the increasing recognition of climate change as a critical risk to economic stability and growth. Financial investments towards sustainable projects and initiatives focusing on solving environmental issues that have been termed as green finance have turned out to be a critical instrument in curbing climate risks as well as sustainable advancement (Wang & Zhi,

2016). Green finance(Eco-finance) and the role played by the financial market have been seeing more and more attention in Africa where the effects of climate change are more drastic than in other regions due to the vulnerability of the continent and its low level of adapting to the changing conditions. Such effects, including anomalous rainfall cycles and extended periods of drought, rising sea levels, and more concerning weather activities, imply the economic security of the continent as well as food security and social development (IPCC,

2022). Green finance has become a significant tool to direct available financial resources to activities undertaken by the banks and address the risk of climate related impacts.

The finance sector has a vital role in enabling us to respond to environmental changes, most obviously it provides the capital needed to support the transition to a low-carbon and environmentally sustainable economy and to adapt and respond to the unavoidable impact of climate change. The amount of investment required for climate and low-carbon resilient infrastructure is estimated by the OECD to be around USD 6.9 trillion a year up to 2030(OECD,2017). Low-emission infrastructure investment is less than 1% of the portfolio of institutional investors globally. To date, the SDGs have been significantly underfinanced, to achieve the SDGs by 2030, the gap between current investment and the required investment is \$2.5 trillion per annum (UNCTAD, 2014).

The African green bond market is at an initial stage and has less than 1 percent of world-wide green bond market, estimated around USD 2.2 trillion by the year 2023. Although this share is insignificant, Africa has high prospects of increasing the issuances of green bonds due to the high demand of climate finance in the continent, given the availability of various natural resources.

Green finance can be used to stimulate the development of the financial market in Africa since such finance will be invested in green infrastructure, renewable energy infrastructure, and climate-resistant agriculture. Green finance has the potential to do much more than reduce climate risks because it can be used to drive economic growth and innovation by harmonizing financial flows according to the environmental goals (Banga, 2019). Nevertheless, development of green finance in Africa is associated with a number of challenges, which include low levels of awareness, poor regulatory frameworks and absence of standardized indicators in determining the environmental impact. These hurdles impede the scalability of green finance projects as well as crossing the threshold in financial market development. Nevertheless, this is not all gloomy since a few countries in Africa have started to issue green bonds, found green banks, and incorporate environmental, social, and governance (ESG) factors in investment decisions (Dikau & Volz, 2021). Green finance has the potential of promoting the development of financial markets through diversification of investments, better risk management practices, and innovation in the financial products and services.

Conversely, the formation of powerful finance is vital to the viable mobilization and allocation of green finance because they supply the infrastructure, housed supply of liquidity, and investor confidence (Zadek & Flynn, 2013). Climate risks have the capacity to discourage investments and slow the progress of financial markets since it enhances uncertainty and capital cost (World Bank, 2019), whereas green finance can become an important factor in reducing chances of climate risks since investments in climate resilient infrastructure, renewable energy and sustainable practices of agriculture can be funded (Campiglio et al., 2018). In addition, the deployment of healthy financial market may enable mobilisation of green finance through the availability of a variety of sources of funds, better management of risks, and higher transparency (UNEP FI, 2018). This is because this relationship puts more emphasis on learning about the processes that occur between green finance, climate risk and developing financial markets especially within the context of uniqueness of African economies and environment conditions.

1.2 Problem Statement

The African continent has yet to unleash the possibilities of green finance facilitated by the development of the financial market. It has been estimated that Africa needs about 52.7 billion dollars annually in climate actions but the amount invested is way below one percent of the USD 2.2 trillion green bond market approximately in 2023.

Investment needs on climate and low-carbon resilient infrastructure are estimated by the OECD to be ca. USD 6.9 trillion yearly to 2030. According to African Development Bank, Africa requires total climate financing of US\$1.3 trillion or more to US\$1.6 trillion annually by the year 2030. The SDGs so far are greatly under financed and to attain the SDGs by 2030, its cost would be 2.5 trillion USD annually according to estimates. This means Africa will need USD 2.8 trillion to finance its Nationally Determined Contributions (NDCs), under the Paris Agreement by 2030.

The African financial markets are still struggling to embrace the green finance in their systems. The list of these issues can be comprised of poor regulatory initiatives, insufficient stakeholder awareness, or the absence of the accepted measurement of the environmental impact (BCG Report, 2024; IFC Report, 2023; UNDP Report, 2024). Although the provision of green finance may advance further development of financial markets through drastically diversifying investment opportunities and closing risk management gaps, robust financial market development is also essential to facilitate mobilization and allocation of green finance to specific projects (Chen et al., 2024; Ben Ameer et al., 2024; Habib et al., 2023; Faruq & Chowdhury, 2025). Nevertheless, there is lack of empirical evidence on the role effect of the development of the financial market on green finance.

So far, Zhang and Ke (2022) studied green finance and carbon intensity across different regions; Zhao and Li (2024), green finance and climate change risks mitigation; Wu, Liu and Cai (2023) on green finance on carbon emission efficiency ; Zu and Li (2023) on green bonds and carbon emissions reduction in China; as He, Duan , Cao and Wen (2024) looks at green finance on corporate climate risk exposure. Most of studies are from developed markets in Europe and Asia (Mavlutova et al. ,2023) but only a 2023 AfDB report on Climate Change and Green Growth in Africa is available

This literature gap restricts the capacity of policy makers, investors, and financial organizations to develop and implement policies that utilize the green finance and manage climate risks and create a sustainable economy. The study results will support imperative guidelines that could guide stakeholders in harmonizing the financial systems with environmental sustainability policies and develop African economies resilience to climate change.

2.0 LITERATURE REVIEW

2.1 Conceptual Review

2.1.2 Green Finance

Green finance is about financial investments in green bonds, green loans; green investment funds; and carbon trading schemes to finance projects, initiatives, and activities that will bring positive environmental consequences (Wang & Zhi, 2016;Banga, 2019;Dikau & Volz, 2021; NGFS, 2020).

2.1.2 Financial Market Development

Financial market development Financial market development describes the extent of growth and maturity of financial systems, such as depth, liquidity, and access of financial markets. IMF Financial Development Index (FD Index), Private Credit % of GDP(Levin, Loayza, Beck , 2000),Bank Deposit to GDP (King & Levine (1993) and Interest Rate Spread (Demirguc and Maksimovic (1998) and Non-Performing Loan (NPL) Ratio(Berger & De Young ,1997) (Zadek & Flynn, 2013).

2.1.3 Climate Risk

the financial risks that arise in connection to the climate and include losses that may be incurred due to the climate change or due to the measures used to mitigate the same, which can have a bearing on the safety and soundness of specific financial institutions and induce system-wide effects(BCBS, 2021;NGFS, 2020).it measures the amount of carbon emitted against the economic revenue or the GDP(Choi, Gao, and Jiang (2020,Andersson, Bolton, & Samama, 2016,Wied

2.2 Theoretical Review

The theoretical underlying basis of this study is the theory of sustainable finance, Environmental Kuznets Curve (EKC) and the theory of financial development.

2.2.1 Theory of Sustainable Finance

Sustainable Finance Theory, discussed first by Hart and Zingales (2005) and formalized in due time by UNEP Finance Initiative and OECD (2020), suggests that financial decisions should be aligned with long-term environmental, social and governance (ESG) objectives to strengthen performance of assets and control climate-related risks. It promotes the creation of instruments like green bonds, ESG indices and sustainability-linked loans and stresses that sustainable finance contributes to more financial market stability and resilience. The theory is however criticised by Amel-Zadeh and Serafeim (2018)

2.2.2 Environmental Kuznets Curve hypothesis

The eco-environmental Kuznets Curve (EKC) by Grossman and Krueger (1991) supposes an inverse U shape relationship between economic development and environmental degradation. It implies that environmental deterioration is more with economic growth in the low-income levels because nations are more focused on the need to industrialize and extract natural resources. But after a certain level of income, the quality of the environment increases as the richer the society, the harder they push to have a cleaner environment, invest in environmental technologies and environmental standards.

2.2.3 Financial Development Theory

The theory of Financial Development led by Levine (2005) and Beck and Levine (2004) focuses on the substantial existence of financial systems in enhancing a stable form of economic growth. Based on this theory, the presence of developed financial markets makes the economy perform better through mobilizing savings, providing funds to useful investments, and managing risks.

2.3 Empirical Review

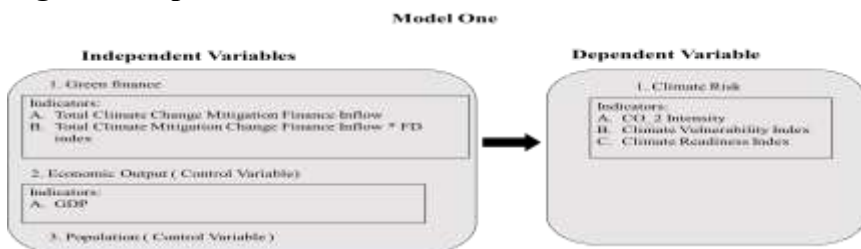
There are empirical studies relating to the importance of green finance in terms of climate risk mitigation and promoting the financial market growth within the developing regions. As an example, Jahanger et al. (2024) Agrawal et al. (2024) and Li et al. (2024) research that was conducted in China focused on green finance and the role of green finance in mitigating climate change risks. Zhao and Li (2024), Zhang and Ke (2022) and Yi and Zhang (2024) focus on the interplay between green information and communication technology (ICT) development and carbon emission reductions. Mavlutova, et al (2023) examined the functions of green finance in establishing the economic sustainability and renewable energy provision in Europe. Based on a two-step system GMM, Zatoon, Qurat-ul-Ann, and Mushtaq (2023) analyze the interdependence between climate finance and CO 2 emissions in 52 developing countries between the years 2002 and 2021.

The Relationship Between Financial Market Development and Green Finance inflows Aden (2024), Hu and Gan (2024) Lv, et al (2022), Monasterolo, et al (2022) and Levine (2005) made a study on the relationship between financial market development and green finance inflows in Djibouti and china. Regarding green finance, empirical evidence considerations indicate that the lack of financial market development is a critical factor to consider in scaling the green finance agenda (Banga,2019;Zadek and Flynn,2013). In Africa, Allen et al. (2011) explored and found that green finance is determined by specific challenges and opportunities.

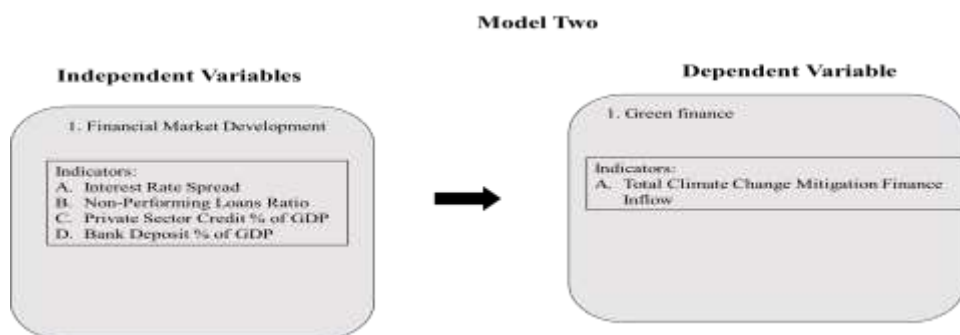
Gaps in the Literature.

Despite the growing body of empirical literature on green finance, climate risk, and financial market development, several gaps remain, particularly in the African context. As studies by Zhao and Li (2024) Zhang and Ke (2022), Yi and Zhang (2024), Bai et al. (2022), Zhange et al (2023), Wu, Liu, and Cai (2024), He, *et al* (2024), Lv et al. (2022) & Xiu and Min (2025) were all done in China. Studies from Europe holds that Mavlutova et al. (2023) analyzed the role of green finance, in EU OECD countries. While studies from Africa are Aden (2024), Allen et al. (2011), Banga (2019), AfDB (2023) but non on green finance, climate risk and financial development. This study fills the gap noted in literature.

Fig 1: Conceptual Model



Source: Researcher compilation, 2025



Source: Researcher compilation, 2025

3.0 Methodology 3.1 Research Design

This particular study employed an exploratory, ex-post facto, quantitative longitudinal and causal design to analyze the relationships between green finance, climate risk, and financial market development in 40 out of 54 Africa countries . It utilized panel data, as information was collected from multiple units over a span of time. This was a good decision, as the study concerned the hypotheses formulated based on the existing theories and previous empirical research, it was not based on controlling the variables, quite the contrary, the variables and their natural state were observed. There were two models for the complex and bidirectional variables. North Africa, the islands, South Sudan and Zimbabwe were dropped from the population lack of sufficient data. This represents 81.6% of the countries in sub-Saharan Africa. The collected data was organized, tabulated, and simplified using python and Excel to facilitate easier analysis, interpretation, and comprehension in STATA at 0.05 & 0.1% level of significance.

3.3 Data Collection

Green Finance (GF): Data on green finance inflows is sourced from the OECD database, which provides information on mitigation-related development finance received by African countries. **Climate Risk (CR)** obtained from World bank (CO2 intensity) and the University of Notre

Dame Global Adaptation Initiative (Vulnerability and Readiness Index) **Financial Market Development (FMD)** collected from the World Bank's Global Financial Development Database, which also includes indicators such as private credit to GDP, bank deposits to GDP, and nonperforming loans (NPL) ratio and interest rate spread; **Control Variables:** Data on economic growth (GDP), and population growth (POP) are sourced from the World Bank Base.

3.4 Model Specification

The study employs three separate panel data models, with each variable (GF, CR, FMD) taking a turn as the dependent variable. The models are specified as follows:

Model One - Climate Risk as Dependent Variable

$$CO2_{i,t} = B_0 + B_1GF_{i,t} + B_2GF_{i,t} * FDI_{i,t} + B_2GDP + B_5POP + e_{i,t}$$

$$CVindex_{i,t} = B_0 + B_1GF_{i,t} + B_2GF_{i,t} * FDI_{i,t} + B_2GDP + B_5POP + e_{i,t}$$

$$CRindex_{i,t} = B_0 + B_1GF_{i,t} + B_2GF_{i,t} * FDI_{i,t} + B_2GDP + B_5POP + e_{i,t}$$

Model 2: Green Finance (GF) as Dependent Variable:

$$GF_{i,t} = B_0 + B_1 IRS_{preadi,t} + B_2 NPL + B_3 PSC_{i,t} + B_4 BDi_{i,t} + e_{i,t}$$

3.5 Analysis Technique

The study used The Fisher's type Test Panel Data Unit Root because it has been proven empirically to perform better (Maddala and Wu, 1999). The Fisher's Type proposed panel unit root test is based on combining the p-values of the N-cross sectional unit roots test. The test uses the Hc1 alternative hypothesis which allows for some but not all of the cross sections to be stationary.

$$H_{c1}: i < 0, i = 1, 2, 3, \dots, N$$

$$i = N + 1, N + 2, \dots, N$$

$$H_0: i = 0, i = 1, 2, 3, \dots, N$$

The null hypothesis is that all series contain a unit root

Estimation Method

The study employs panel data regression models to analyze the relationships between green finance, climate risk, and financial market development. The choice between Fixed Effects (FE) and Random Effects (RE) models is determined by the Hausman test, which evaluates whether the unobserved individual-specific effects are correlated with the independent variables.

Fixed Effects (FE) Model The FE model is specified as:

$$Y_{i,t} = \beta_0 + \sum_{ni=1} \beta_i X_{i,t} + \alpha_i + e_{i,t}$$

Y_{i,t} is the dependent variable for country i at time t

X_{i,t} represents the independent variables *α_i represents the country-specific fixed effects.*

e_{i,t} is the error term

Random Effects (RE) Model:

The RE model is specified as:

$$Y_{i,t} = \beta_0 + \sum_{ni=1} \beta_i X_{i,t} + U_i + e_{i,t}$$

Y_{i,t} is the dependent variable for country i at time t

X_{i,t} represents the independent variables

U_i represents the random country-specific effects..

e_{i,t} is the error term

Hausman Test

The Hausman test is conducted to determine whether the FE or RE model is more appropriate. The test compares the coefficients from the FE and RE models. If the test statistic is significant, the FE model is preferred; otherwise, the RE model is used.

Null Hypothesis (H₀): The RE model is appropriate (no correlation between the unobserved effects and the independent variables).

Alternative Hypothesis (H₁): The FE model is appropriate (correlation exists between the unobserved effects and the independent variables). If the test statistic is significant, the FE model is preferred; otherwise, the RE model is used.

4.0. Results

This chapter includes the descriptive statistics which provides the summary statistics, normality, correlation, the panel unit root test, the empirical models

4.1 Descriptive Statistics

Table 4.1.1 Summary Statistics

Variable	Obs	mean	std	min	25%	50%	75%	max	Authors
Green Finance Inflow	336	87.55	148.15	0	3.44	24.94	98.87	1034.84	
Financial Development Index	287	0.14	0.10	0.04	0.09	0.11	0.15	0.59	
Private Credit % of GDP	299	20.67	19.43	0.00	11.71	15.23	22.93	127.20	
Non-Performing Loan Ratio	202	11.36	9.12	1.54	5.11	9.22	14.63	55.41	
Interest Rate Spread	160	7.04	5.64	-1.84	3.25	6.68	10.31	21.26	
Bank Deposit % of GDP	248	26.52	14.10	8.13	16.65	21.92	33.87	72.50	
Climate Vulnerability Index	328	0.53	0.06	0.38	0.49	0.52	0.57	0.66	
Climate Readiness Index	328	0.29	0.06	0.12	0.26	0.30	0.32	0.46	
GDP (million usd)	320	4704.60	4442.56	738.56	1821.41	2961.14	5503.13	21118.87	
Population (million)	328	25.69	36.70	1.01	4.13	14.47	29.22	218.54	
CO2 Intensity	320	3213.92	5855.87	111.68	514.47	1541.12	3198.77	34036.92	

computation 2025

Table 4.1.1 of the summary statistics indicates that Green Finance Inflow, has not only a very large range of values, but also, the mean is large, viz. 87.55m, the standard deviation is also large, viz. 148.15m which implies a great deal of variability across the observations. The maximum value of 1.03484 trillion USD indicates that large volumes of green finance flowed into some countries whereas the minimum value of zero indicates that in some years there were no flows of green finance into such countries. The median (24.94 million USD) is very much different compared to overall mean; a right skewed distribution shown with some high levels of inflow boosting the average. The mean of the Financial Development Index is 0.14 with a relatively small standard deviation of 0.10 meaning that there is consistency in the observations, but the highest value of 0.59 points to some outliers, which are more developed financial systems. The average amount of Private Sector Credit taken up in the market, as a percentage of the GDP, is 20.67 averagely spread but has an extreme -high value of 127.20 and low value in terms of 0, and indicates differences in the ease of credit accessibility among various economies. Bank Deposit as per cent of GDP also shows a variation with an average of 26.52 percent and a spread of between 8.13 percent and 72.50 percent.

Non-Performing Loan Ratio and Interest Rate Spread, portray the difficulty in financial stability. The Non-Performing Loan Ratio has 11.36% average and 9.12% standard deviation, which shows a big variance in the quality of loans observation-wise. Interest Rate Spread averages are at 7.04% with a variation between -1.84 and 21.26%, which may indicate that there is inefficiency in banking and risk premiums. Climate-related variables, such as the Climate Vulnerability Index and Climate Readiness Index have moderate vulnerability (mean of 0.53) and rather low readiness (mean of 0.29), with little variation. Economic and demographic controls are GDP and Population, which show the diversification of the sample with the average value of GDP equal to 4704.60 million USD and Population is 25.69 million, but the range is large. Mean CO2 Intensity of 3213.92 and large standard deviation of 5855.87 highlights the great differences in the environmental impact of the sample. Overall, the table reveals substantial heterogeneity in the data, which will be crucial for understanding the relationships between green finance and climate risk and the examined factors.

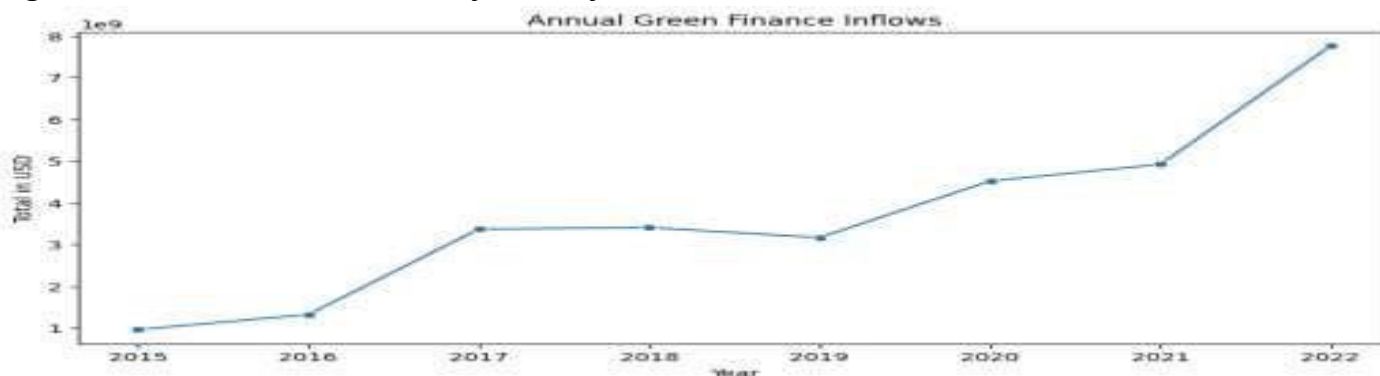
Table 4.1.2 Correlation Matrix

	GF	FDIndex	PSC	NPL	IRSpread	BD	CVIndex	CRIndex	GDP	Pop
FDIndex	0.04									
PSC	0.13	0.89								
NPL	-0.17	-0.37	-0.3							
IRSpread	-0.03	-0.31	-0.37	0.17						
BD	0.01	0.66	0.68	-0.36	-0.18					
CVIndex	-0.13	-0.57	-0.5	0.09	0.06	-0.52				
CRIndex	0.03	0.54	0.43	-0.48	-0.3	0.48	-0.3			
GDP	-0.05	0.53	0.45	0.17	-0.19	0.33	-0.73	0.28		
Pop	0.45	0.12	0.02	-0.21	0.17	-0.13	-0.15	-0.18	-0.09	
CO2	0.33	0.57	0.6	-0.22	-0.08	0.23	-0.37	0.01	0.2	0.67

Author's computation 2025

The correlation matrix in Table 4.1.2 reveals that all variables except FDI index and Private Sector credit correlates moderately and minimally while FDI and PSC had high correlation indicating that economies with developed financial systems also tend to have higher private credit availability.

Figure 4.1.3 Total Green Finance inflow to Africa



The line graph in fig4.1.3 illustrates the trend of annual green finance inflows over the period from 2015 to 2022. The inflows, measured in USD, show an overall increasing trajectory across these years. Starting at approximately \$1 billion in 2015 to \$7.8b in 2022, suggesting a growing momentum in green finance investments

.Fig 4.1.4 Climate Vulnerability Index



Fig 4.1.4 shows the heatmap of climate vulnerability index. The sample of the study looks at 40 countries in sub-Saharan African and the map built on the sample of the study. The figure shows that countries along the west coast of Africa are more vulnerable to climate risk as indicated by the stronger hue.

Fig 4.1.5 Climate Readiness Index



4.2 Unit Root Test for Stationarity

The study therefore prefers the use of Fisher type unit root test since it has been empirically confirmed to outperform the other tests and also has high powers in terms of the ability to distinguish between the null and the alternative hypothesis Maddala and Wu (1999). The Fisher is a type of unit root test that decomposes the p-value

of the available cross sectional type unit root test. The hypothesis employed in the test is Hc1 alternative that permits some or not all, but not all of the cross sections to be stationary. The null is all series include a unit root.

Table 4.2 Panel Unit Root Test

Critical Values

	Form	df = 2N	t-stat	1%	5%	10%	P-value
GF	Level	84	130.37	117.06	106.39	100.98	0.0009
FDindex	Level	82	141.72	114.69	104.14	98.78	0.0000
PSC	Level	78	137.06	109.96	99.62	94.37	0.0000
NPL	Level	54	197.26	81.07	72.15	67.67	0.0000
IRSpread	Level	52	228.12	78.62	69.83	65.42	0.0000
BD	Level	76	92.84	107.58	97.35	92.17	0.0918
ΔBD	First difference	76	196.02	107.58	97.35	92.17	0.0000
ΔCVIndex	Level	82	123.99	114.69	104.14	98.78	0.0019
ΔCRIIndex	Level	82	293.49	114.69	104.14	98.78	0.0000
GDP	Level	80	81.55	112.33	101.88	96.58	0.4308
ΔGDP	First difference	80	146.42	112.33	101.88	96.58	0.0000
Pop	Level	82	60.32	114.69	104.14	98.78	0.9654
ΔPop	First difference	82	115.89	114.69	104.14	98.78	0.0082
C02	Level	80	247.87	112.33	101.88	96.58	0.0000

Results from the Fisher's type test in fig4.2 shows that all the variables were stationary in their level form except for population, GDP and Banking sector deposit; all of which had to be differenced once to be stationary. This means that in the model estimation, GDP growth will be used instead of GDP , population growth instead of population and change in banking sector deposit instead of its level form.

4.3 Panel Model Selection

Table 4.3 Model Selection Dependent Variable: **CO2** Independent Variable: **GF, GF_FDI, Δpop, Δgdp** Test Method: **Breusch Pagan LM Hausman**

Variable	Fixed effect. test	an Test Method	For Pagan	LM	Hausman
CO2	P=0.0000	P=0.0000	P=0.0000	P=0.0000	P=0.0000
CVI	P=0.0000	P=0.0000	P=0.0000	P=0.0000	P=0.0000
CRI	P=0.0000	P=0.0000	P=0.0000	P=0.0000	P=0.0000
GF	P=0.0005	P=0.0004	P=0.0005	P=0.0004	P=0.0005

The Breusch-Pagan Lagrange Multiplier (LM) test estimates the probability to use random effects rather than using pooled OLS. The p-value is very tiny in each of the scenarios (0.0000 or 0.0004 in the case of GF), an indication that alongside cross-sectional variation, a pooled OLS is also worse than random effects. The last option of the fixed effects or the random effects lies in the Hausman test, which serves as the test of endogeneity: the non-observable individual effect is correlated with the regressors. In the case of CO₂, Hausman test p-value is 0.0000, and the null hypothesis that the random effects are consistent is rejected. This means fixed effects have to be employed to prevent biased estimations. Contrastingly, CVI, CRI, and GF all fail to reject the null hypothesis at the customary level of 0.05 because the p-values obtained under the Hausman test equal 0.2848, 0.1015, and 0.1192 separately. An implication of this is that, the random effects of these modelling specifications are efficient and consistent and therefore they are the choice models to work with.

4.5 Specific Objective I : Effect of green finance in mitigating climate-related risks.

The tables below shows the results from the regression of each measure of climate risk (Co₂ , CVindex and CRIndex)

Table 4.5.1 Co₂ Model

Co ₂	Coef.	St.Err.	t-value	pvalue	[95% Conf	Interval]	Sig
ΔGF	-.001	.0003069	-2.02	.045	-.001	-.0000127	**
GF_FDI	-.005	.003	-1.81	.073	-.011	.001	*
Δpop	7.46e-08	1.31e-07	0.57	.571	-1.85e-07	3.34e-07	
Δgdp	.0000533	.0000117	-4.54	0.00	.0000765	.0000302	***
Constant	7.311	.101	72.74	0.00	7.113	7.51	***
Mean dependent var	7.357		SD dependent var	1.309			
F-test	6.746		Number of obs	208			
Akaike crit. (AIC)	-435.173		Prob > F	0.000			

*** $p < .01$, ** $p < .05$, * $p < .1$

Bayesian crit. (BIC) -418.485

In the CO₂ model (Table 4.5.1), estimated using a fixed effects approach, the coefficient for green finance inflow (ΔGF) was -0.001 with a p-value of 0.045. This result is statistically significant at the 5% level, indicating that green finance inflows have a measurable effect in reducing CO₂ intensity, a key indicator of climate-related transition risks. The negative coefficient suggests that for every dollar increase in green finance inflow, CO₂ intensity decreases by 0.001 KgCo₂.

Table 4.5.2 CVIndex Model

CVI	Coef.	St.Err.	t-value	pvalue	[95% Conf	Interval]	Sig
ΔGF	-.0000411	.0000206	-1.99	.048	-.0000818	-3.50e-07	**
GF_FDI	-.0003827	.0002002	-1.91	.058	-.0007781	.0000126	*
Δpop	2.05e-08	8.84e-09	2.32	.022	3.02e-09	3.79e-08	**
Δgdp	8.92e-07	07.89e-07	1.13	.260	-6.66e-07	2.45e-06	
Constant	-.542	.007	-80.15	0.00	-.555	-.528	***
Mean dependent var		-0.526	SD dependent var		0.059		
F-test		2.667	Number of obs		208		
Akaike crit. (AIC)		-1558.252	Prob > F		0.000		
*** $p < .01$, ** $p < .05$, * $p < .1$			Bayesian crit. (BIC)		-1541.564		

The Climate Vulnerability Index (CVI) model (Table 4.5.2) based on random effects estimation method had coefficient of green finance inflow (GF) of -0.0000411 and a p-value of 0.048. The outcome has a probability of less than 5 percent that it is not due to chance therefore green finance inflows curtail climate vulnerability. A negative coefficient indicates that when the inflow of green finance goes up by one unit, the CVI decreases by 0.0000411 units, which is associated with a smaller exposure to physical climate risks, including extreme weather conditions or changes in sea levels

Table 4.5.3 CRIndex Model

CRIndex	Coef.	St.Err.	t-value	pvalue	[95% Conf	Interval]	Sig
ΔGF	1.34e-11	8.85e-12	1.51	.131	-3.99e-12	3.07e-11	
GF_FDI	-3.33e-11	4.42e-11	-0.75	.451	-1.20e-10	5.33e-11	
Δpop	-5.93e-09	7.10e-09	-0.83	.404	-1.98e-08	7.99e-09	
Δgdp	2.85e-07	8.83e-07	0.32	.747	-1.45e-06	2.02e-06	
Constant	.3001266	.0096218	31.19	0.00	.281	.319	***
Mean dependent var		0.297	SD dependent var		0.056		
			Number of obs		234		

*** $p < .01$, ** $p < .05$, * $p < .1$

With a random effects estimation method in the Climate Readiness Index (CRI) model (Table 4.5.3), the coefficient of green finance inflow (6GT) was 1.34e-11 and p-value was 0.131. The conclusion is not statistically significant at either 50 or 10 percent level meaning that green finance inflows do have a significant effect of enhancing the climate readiness of the SubSaharan Africa. The insignificant but positive coefficient indicates

that there is a possible minor positive relationship between green finance and readiness, and it cannot be concluded that the relationship remains highly effectual since it is not statistically meaningful.

These results are consistent with the works by Zhao and Li (2024);Zhang and Ke (2022); Jahanger et al. (2024) who found out that green finance leads to the effect of environmental sustainability and decrease of CO 2 intensity. Nonetheless, the trivial impact of climate preparation echoes Agrawal et al. (2024), who mentioned that green finance is insufficient and should be supplemented with technological breakthroughs and policy solutions, to cover more comprehensive climate resilience, especially in developing markets. Other barriers policymakers can overcome as discussed by Banga (2019) include low consciousness and poor regulatory provisions that limit the scope at which green finance initiatives reach.

4.6. Discussions

Specific Objective II: Mitigating Effect of Financial Market Development on the impact of Green Finance on Climate Risk

Table 4.5.1 Co2 Model

In the CO 2 model (Table 4.5.1), calculated in line of fixed effects strategy, the estimate of the interaction term (GF FDI) was -0.005 and its p -value was 0.073. This finding is significant at the level of 10 percent, which means that the mitigation of green finance on CO 2 intensity is increased in the situation of financial market development. The negative coefficient indicates that the effect of green finance in decreasing the CO 2 intensity is more powerful in the countries that are characterized with a greater level of financial market development, e.g. the Financial Development Index is higher. This result means that well-developed financial markets, which are more deep, liquid and efficient, contribute to efficient allocation of green finance to projects that emit less carbon, i.e. to renewable energy or energy-saving infrastructure, to increase the decline of carbon emission.

In the Climate Vulnerability Index (CVI) model (Table 4.5.1), which fits the estimated model using random effects model, the value of the coefficient of interaction term (GF FDI) was 0.0003827 with p-value 0.058. The result shows statistical significance at 10 percent level of significance, and it implies that the development of financial markets augments the impact of green finance in mitigating climate vulnerability. The negative coefficient indicates that the influence of green finance is more powerful on the decreasing of the CVI in the countries with more advanced financial markets, which indicates the decreased exposure to physical climate risks. This observation indicates the importance of strong financial systems in directing green finance at climate-resilient infrastructure and adaptation, which is vital to reduce the effects of severe weather conditions and other physical risk in Sub-Saharan Africa

Table 4.5.3 CRIndex Random Effect Model

CRIndex	Coef.	St.Err.	t-value	pvalue	[95% Conf	Interval]	Sig
ΔGF	1.34e-11	8.85e-12	1.51	.131	-3.99e-12	3.07e-11	
GF_FDI	-3.33e-11	4.42e-11	-0.75	.451	-1.20e-10	5.33e-11	
Δpop	-5.93e-09	7.10e-09	-0.83	.404	-1.98e-08	7.99e-09	
Δgdp	2.85e-07	8.83e-07	0.32	.747	-1.45e-06	2.02e-06	

Constant	.3001266	.0096218	31.19	0.00	.281	.319	***
Mean dependent var	0.297		SD dependent var		0.056		
Overall r-squared	0.078		Number of obs		234		
Chi-square	.		Prob > chi2		.		
R-squared within	0.008		R-squared between		0.080		

*** $p < .01$, ** $p < .05$, * $p < .1$

In the Climate Readiness Index (CRI) model (Table 4.5.3), estimated using a random effects approach, the coefficient for the interaction term (GF_FDI) was $-3.33e-11$ with a p-value of 0.451. It indicates that the level of financial market establishment is not statistically significant at both 5 percent and 10 percent levels in strengthening the effect of green finance on raising climate readiness. The significant but small magnitude of coefficient would indicate that there is the slight possibility that the development of financial markets would assist green finance in improving preparedness, but the insignificance of the value would indicate that this relationship is not presently strong. It may be because climate readiness, defined as institutional and policy structures to support climate adaptation, are likely to depend on the quality of governance (or technical capacity), rather than on the development of financial markets alone.

These results should be analyzed to state that financial market development is extremely important in making green finance effective in addressing particular climate risks, especially those connected with CO₂ intensity and climate vulnerability. All interaction terms in the CO₂ and CVI models are significant, which means that strong financial markets are critical to maximizing green finance influence on transition and physical risks, probably by facilitating much-discussed infrastructure, liquidity, and efficiency to allocate funds to low-carbon and resilient projects. Nevertheless, the unmarked impact on the CRI model indicates that the development of the financial market is not a defining factor in determining the availability of green finance to improve the adaptive capacity, perhaps, because of the larger range of systemic facts that control accessibility, corresponding to policy structure or institutional robustness. The overall impact at the 10 percent level of CO₂ and CVI depicts the prevalence of the development of monetary markets in certain climatic hazard scenarios, whereas the insignificance of CRI explains the necessity to implement complementary activities. These results can be compared to those of Zadek and Flynn (2013),Banga (2019),Zhang and Ke (2022), though the low-significance outcome of this factor on climate readiness coincides with Dikau and Volz (2021). The implication of this include policymakers focusing on the development of financial markets using strategies like developing market liquidity, enhancing regulatory conditions, and expanding financial innovation in order to maximize the advantages of green finance to achieving climate-mitigation and resilience-building goals. Nonetheless, the inability to influence the climate preparedness implies that the reforms of financial markets should be supplemented by major policy actions, e.g., consolidate governance and establish institutional preparedness to cover the risks associated with adaptation.

4.7 Specific Objective III: Impact of financial market development on the inflows of green finance

Table 4.7 Green Finance random effect model

GF ¹	Coef.	St.Err.	t-value	pvalue	[95% Conf Interval]	Sig
ΔNPL	-46.398	27.055	1.71	.086	-99.425 6.629	*
PSC	.714	.394	1.81	.070	-.057 1.485	*
ΔBD	11.698	82.635	0.14	.887	-150.263 173.66	
Δpop	.0000633	8.59e-06	7.37	0.00	.0000465 .0000801	***
Constant	20.275	15.586	1.30	.1930	-10.273 50.823	
Mean dependent var	81.342		SD dependent var	125.022		
Overall r-squared	0.320		Number of obs	128		
Chi-square	57.996		Prob > chi2	0.000		
R-squared between	0.074		R-squared between	0.637		

*** $p < .01$, ** $p < .05$, * $p < .1$

Second, the coefficient related to change in Non-Performing Loan (NPL) ratio was negative with value of -46.398 ($p = 0.099$) and this was marginally significant. This negative value is an indicator that the financial instability that is symbolized by a higher NPL ratio result in less inflow of green finance. Health of the financial sector is essential in relation to the attraction of the green investments as investors can see more risks in those countries where the banking systems are underdeveloped. This finding complies with that of Berger & DeYoung (1997). Non-Performing Loans (NPL) analysis results correspond to Private Sector Credit ones. In particular, the coefficient of the private sector credit as a ratio of the GDP was +0.714 ($p = 0.07$), implying statistical significance with 10% level of confidence. In other words, more access to private credit has positive links with more inflow of green finance. This point means that the more elaborate and open credit market will indicate a healthier financial system and an imperative function of assisting investments in sustainable or environmentally inclined projects. This low importance of the relationship can show that in African nations, green finance is more motivated by governmentwide and global financing in comparison with the domestic individual credit market. The given finding favors the reasoning expressed by Levine et al. (2000) who reported that the financial depth in itself cannot lead to generation of investment flows in the specified sector in the country unless it is combined with definite policies aimed at this direction.

The growth of bank deposit ($p = .887$) coefficient of 11.698 was insignificant. It means that the increase in the volume of bank claims has no strong impact on the inflows of green finance. This is possibly given that the African financial systems are not yet developed in terms of harnessing savings to raise sustainable projects. King & Levine (1993) emphasize that deposit mobilization is not enough because it should be supported by the institutional structure that reinforces green lending, which the current research results are agreeable to.

In spite of the fact that the model specifically had no interaction terms, to evaluate the moderation effect of financial market development on the effects of green finance, the Financial Development Index (FD Index) was

¹ The green finance variable GF has been standardized in millions by dividing the total inflows by 1000,000

incorporated in Model One (CO Green finance effectiveness in the reduction of emissions depends on the financial market development, which was indicated by the presence of a significant coefficient of the interaction term (GF_FDI) in the CO 2 model ($p = 0.000$). This implies that more stable financial systems are more effective in attracting and directing green capital and this supports both Zadek & Flynn (2013) and Banga (2019) and their argument that developed financial markets are better in improving the efficiency of green capital allocation.

This objective was satisfied because it was proved that a stable financial situation, expressed in low NPL ratio, robust increase in the private sector credit is essential in attracting inflows of green finance, as the investors will not want to be subjected to high-risk conditions. Nevertheless, it turned out that deposit growth was not sufficient drivers of green finance, which means that structural changes, including green banking principles and ESG platforms, should be established to facilitate green investments. In addition, even stronger is the effect of green finance to the development of financial markets, as indicated by the interaction term in Model One. These findings are supported by supporting literature (Berger & DeYoung (1997; Zadek & Flynn (2013; & Levine et al. ,2000). The fact that green bonds and financial innovation are based on stable liquid markets is pointed out by Berger & DeYoung (1997) Banga (2019) AND Monasterolo et al. (2022).

5.0 Summary and Conclusion

This section summarizes the findings and made possible conclusions thereof.

5.1 Summary

Objective 1: The paper concludes that the green finance inflows bear a significant negative impact to CO2 intensity (coefficient: -0.001, $p=0.045$) and climate vulnerability (coefficient: 0.0000411, $p=0.048$), which means that green finance has been effective in terms of mitigating the transition and physical climate risks but has no significant effect on climate readiness (coefficient: $1.34e-11$, $p=0.131$). it is in line with Sustainable Finance Theory (Sch The empirical evidence is provided by Zhao and Li (2024) and Jahanger et al. (2024).

Objective II: Developed financial market can strengthen the impact of green finance on the CO2 intensity (coefficient: -0.005, $p=0.073$) and climate vulnerability (coefficient: -0.0003827, $p=0.058$), but the green finance fails to affect climate readiness (coef: $-3.33e-11$, $p=0.451$), which indicates that financial markets that perform well can complement the impact of green finance to certain climate-related risks. This confirms the Financial Development theory and Environmental Kuznets Curve Hypothesis, (Zadek and Flynn (2013) & Banga (2019)

Objective III: Recording low non-performing loan ratios (coefficient: -46.398, $p=0.099$), high backing of the private sector credit (coefficient: 0.714, $p=0.07$), and green finance inflows are significantly financed by favorable ratios because development bank deposit growth is nonsignificant (coefficient: 11.698, $p=0.887$). This is in line with the Financial Development Theory which lays criterion on the importance of financial stability through attracting investments (Beck & Levine, 2004). As noted by Berger and DeYoung (1997), investing is deterred in conditions of high NPLs because of the lack of strength in bank balance sheets, whereas Levine et al. (2000) indicate that financial depth cannot be sustained without specific policies, and this is further evidence in support of green-specific financial reforms.

5.2 Conclusion

The research concludes that green finance helps in mitigating climate-related risks in SubSaharan Africa in a tremendous way. In particular, the inflows of green finance were found to have a statistically significant negative impact on the intensity of the CO₂ emissions (coefficient = -0.001; $p = 0.045$) as well as on the Climate Vulnerability Index (coefficient = 0.0000411; $p = 0.048$), proving that green finance helps to resolve transition and physical climate risk. Nonetheless, green finance did not have a significant impact on climate readiness (coefficient = $1.34e-11$, $p = 0.131$), which reveals that inflow of money into climate-related sluices is not able to enhance adaptive capacity in the absence of the corresponding institutional and policy support.

The results also conclude that green finance to climate-reduction effect is made stronger with financial market development (the results are moderated by financial market development on CO₂ intensity (the interaction term coefficient = -0.005, $p = 0.073$) and climate vulnerability (interaction coefficient = -0.0003827, $p = 0.058$). However, similar to green finance, the financial market development did not show a real influence on climate preparedness (coefficient = $-3.33e-11$, $p = 0.451$), which indicates the weakness of market-dependent mechanisms in promoting universal adaptation planning.

Regarding the sources of green finance inflows, financial stability indicators low nonperforming loan (NPL) ratios (coefficient = -46.398, $p = 0.099$) and high private sector credit (coefficient = 0.714, $p = 0.070$) strongly affect the inflow of green finance, indicating that the accessibility of credit and financial risk-reduction are so crucial in acquiring green investments. Conversely, the growth of deposits in banks was not significant (coefficient = 11.698, $p = 0.887$), and classic metrics of financial depth do not have significant effect on green finance.

5.3 Recommendations

Based on findings, governments should prioritize scaling up green financial instruments, such as green bonds and loans, by offering tax incentives and subsidies to attract private sector investment.

Strengthening regulatory frameworks to integrate environmental, social, and governance criteria into financial decision-making will enhance the allocation of green capital toward lowcarbon and resilient infrastructure projects.

Financial market development, shown to amplify green finance's impact, should be supported through measures that enhance market liquidity, improve credit access, and reduce nonperforming loan ratios, as these factors significantly drive green finance inflows.

Central banks and financial regulators should implement green banking guidelines and risksharing mechanisms to incentivize sustainable lending practices, addressing the finding that financial stability is critical for attracting green investments. Capacity-building programs for financial institutions can further promote awareness and expertise in green finance, overcoming barriers such as limited stakeholder knowledge and inadequate metrics for environmental impact assessment.

5.4. Further Research Suggestion

Limitations In the future, the study excluded the island countries and North African countries, indicating the possibility of increasing the area to encompass regional differences in climate vulnerabilities and financial appreciation systems and finding regional peculiarities of challenges and opportunities in these regions. As

another point of advice, examining green financing through the lens of the private sector may help drill in a bit further with regard to how Corporate investment and innovations can be applied to help achieve sustainable results which this study focuses on the public and international sources of funds.

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