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Non-performing loans in the MENA region: How green growth mitigates the impact of climate risk

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ABSTRACT

The objective of this study is threefold. First, it examines the impact of climate risk (CRI) on credit risk, as measured by the ratio of non-performing loans (NPLs). Second, it investigates the effect of green growth (GGI) on NPLs. Third, it assesses whether GGI moderates the relationship between climate risk and NPLs. To achieve these objectives, the study utilizes a panel dataset of 40 traditional banks from Middle East and North Africa (MENA) countries, covering the years 2010 to 2022. The estimation employs the System Generalized Method of Moments (SGMM) estimator to address endogeneity and dynamic panel bias. Empirical results indicate that climate risk significantly increases the NPL ratio, leading to deterioration in credit quality under environmental stress. Conversely, green growth has a mitigating effect, significantly reducing credit risk among MENA banks. Additionally, the interaction between green growth and climate risk is negatively related to NPLs, suggesting that green growth can effectively shield bank credit portfolios from the adverse effects of climate risk. These findings have important implications for policymakers and financial institutions in the MENA region. Strengthening green growth policies can serve as a valuable tool to enhance banking sector resilience and promote sustainable financial development.

Contribution/ Originality: This study is one of the few that contribute new evidence to sustainable finance by examining the effect of green growth on reducing climate risk associated with non-performing loans in the MENA region. The paper adds to the limited empirical studies on climate-related financial risks in emerging economies.

1. INTRODUCTION

One of the main sources of economic financing is the banking sector. The banking system plays a major role in economic growth by promoting business activity and investment. Therefore, it is essential to identify the elements that ensure bank stability and promote profitability (Hakimi, Hamdi, & Khemiri, 2023). In recent years, banks have increasingly faced the challenge of financial stability contributed by climate-related risks. These include physical and transition risks from climate change that can affect an institution's financial position through loan impairments in particular (Siregar, Ismail, Taqi, & Soleha, 2025). Non-performing loans are among the most significant challenges faced by banks and financial institutions, especially in countries highly susceptible to economic and environmental uncertainties. In recent years, climate risk has increasingly impacted the financial sector, as extreme weather events, changes in weather patterns, and long-term environmental shifts have triggered incidents that could devastate businesses, thereby accelerating loan defaults and increasing the risks of NPLs. In the MENA region, where the economy heavily depends on natural resources and the adverse effects of climate change are more

pronounced, mitigating climate-related risks is essential for maintaining financial stability (Chiaramonte, Dreassi, Goodell, Paltrinieri, & Piserà, 2024).

Green growth or economically sustainable environmental development could, in some respects, hold prospects toward finding an actual solution. These green growth initiatives emphasize that the incorporation of environmental factors in economic growth can indeed aid business firms in improving their adaptability against climate-induced hazards. In return, green growth can reduce adverse effects of climate risk through investments in renewable energy, sustainable agriculture, and other eco-friendly technologies, creating a more stable financial environment that reduces the chances of loan defaults (Maditsi & Herbert, 2024; Saif-Alyousfi & Alshammari, 2025).

Literature related to drivers of NPLs and the economic impacts of climate change already exists. However, much less is said about how the two issues can combine to aggregate, precisely with respect to green growth. What has been most lacking is empirical evidence on the extent to which green growth initiatives may mitigate the financial instability resulting from climate risks, especially for the MENA region, which has its unique environmental and economic issues. This knowledge gap constrains the formulation of relevant policies that could develop climate-resilient financial systems and attain economic growth in a sustainable manner (Nabil, 2024).

Therefore, the current research aims to assess the role of green growth in mitigating the effect of climate risk on non-performing loans (NPLs) in the MENA region. Precisely, the study seeks to: This study tries to fill this gap by investigating the nexus of climate risk, NPLs, and green growth in the MENA region. Specifically, the study seeks to: (i) examine the impact of climate risk on the prevalence of NPLs, (ii) analyze the role of green growth in alleviating this impact, and (iii) provide insights into how sustainable development practices can enhance financial stability amid environmental challenges. The findings aim to inform banks, regulators, and policymakers about green growth's role in addressing climate issues and promoting financial sustainability. The research questions are: *Does climate risk affect the NPLs of banks in the MENA region? Does green growth moderate the impact of climate risk on bank non-performing loans?*

This study investigates the intricate relationship between climate risk, Green Growth, and bank non-performing loans (NPLs) in the MENA (Middle East and North Africa) region, a land well positioned to provide an intriguing case study. MENA is extremely vulnerable to the adverse effects of climate change, including rising temperatures, water scarcity, and natural disasters, which pose considerable risks to financial systems and economic stability. At the same time, the region is increasingly focusing on Green Growth strategies to transition to sustainable economies, driven by environmental necessity as well as global pressure. The interplay between these phenomena—climate risk, Green Growth agendas, and bank financial soundness—offers a rich terrain for exploration. Additionally, the heterogeneous economic structures of the MENA region, ranging from oil-dependent economies to more diversified economies, provide a complex setting to examine how different countries regulate the financial dimensions of climate risk and sustainability agendas. These dynamics are relevant for policymakers and financial institutions to grasp in order to mitigate risks and foster resilient and sustainable economic growth in the face of climate change challenges.

The sample for this study consists of 40 banks from the MENA region across 10 countries. The banks are monitored from 2010 to 2022. The SGMM is an empirical method used in this study. Empirical findings indicate that climate risk increases non-performing loans (NPLs), but green growth has a significant negative effect on the NPLs of MENA banks. Findings also suggest that green growth and climate risk interact to significantly reduce NPLs.

This research makes several significant contributions to the literature. Firstly, to our knowledge, it is the first to investigate the effect of climate risk on non-performing loans (NPLs) in the MENA region while explicitly discussing the moderating influence of green growth. By doing so, the research fills a gap in the literature on climate risk and credit risk in banking within a region highly exposed to environmental hazards. Second, it adds to the current literature on credit risk in MENA banking by introducing green and sustainability dimensions, which

have yet to be thoroughly investigated in empirical research. Third, the study is among the limited number that examines the causality relationship between green growth and bank credit risk empirically, providing new insights into the role of sustainable development policies in risk alleviation. Finally, the conclusions have policy relevance, emphasizing the necessity for policymakers to support green growth approaches and to build regulatory institutions that can foster environmentally robust and sustainable banking systems in the face of rising climate-related financial risks.

The remainder of the paper is organized as follows: Section 2 presents the literature review; Section 3 outlines the data and empirical methodology; Section 4 presents the empirical results; and Section 5 concludes with key policy implications.

2. LITERATURE REVIEW

2.1. Climate Risk and Non-Performing Loans

In the last couple of years, climate risk, which involves physical risks such as extreme weather events and sea-level rise, and transition risks such as policy changes and technological shifts, has gained widespread recognition as one of the key financial risks. Theoretical frameworks indicate that climate risk may impact banks and other financial institutions' financial stability through an increase in the probability of loan defaults, thereby raising non-performing loans.

The empirical literature indicates the increasing role that climate risk has begun to play in decision-making within an upward trajectory across all banking systems. Nie, Regelink, and Wang (2023) explain that such natural calamities caused by climatic variations act to extend banking sector risks due to loan loss ability through falling economies. On a similar note, Zhang, Wu, Ji, Guo, and Lucey (2024) show that climate shocks significantly worsen the quality of loans in regional commercial banks in China by means of industrial and geographical exposure as critical risk channels. To further illustrate this, Brik (2024) depicts how climate risk compromises financial stability due to increased NPL ratios in Chinese banks, especially when there are weak governance structures. Specifically, in the context of the MENA region, Khemiri (2024) discusses how climate risk interrelates with economic policy uncertainty and, finally, credit risk. He finds that high climate vulnerability serves as a way to worsen NPLs, which negatively affects sustainable development. Evidence from Fan et al. (2024) indicates that climate change is leading to rising NPL ratios in China's provinces. Moreover, regional differences underline adaptive policy responses. Collectively, these studies indicate the dire need for the integration of climate risk into credit risk management frameworks to enhance resilience within banking sectors worldwide.

Although still at a nascent stage of development, both the theoretical and empirical literature have yielded a number of important insights into the nexus between climate risks and NPLs. Both dimensions of climate risk can impact bank stability by significantly increasing the probability of loan defaults. These linkages have been empirically illustrated in a number of studies across various regions, sectors, and types of financial institutions.

This paper analyzes the impact of climate risk on non-performing loans in the MENA region based on theoretical and empirical evidence from existing literature. The following hypothesis is tested in particular:

H_1: Climate risk is positively associated with non-performing loans.

2.2. Green Growth and Non-Performing Loans

Green growth can be described as promoting economic development in an environmentally sustainable manner through investments in green technology and low-carbon industries, along with efforts to reduce the negative impacts of environmental degradation. From the perspective of sustainable finance, green growth strategies are viewed as means to mitigate financial risks, including those associated with climate change. This is because green growth strategies decrease the vulnerability and exposure of the financial system by encouraging investments in

renewable resources, clean energy, and climate-resilient infrastructure, thereby ultimately reducing the likelihood of non-performing loans linked to environmental issues.

Theoretically, green growth, or economically sustainable growth, might affect NPLs through many channels. First, green growth policies, such as investments in renewable energy and energy efficiency, might reduce transition risk and enhance resilience among firms, which would diminish the probability of loan defaults. The transition to green growth, on the other hand, will, in the short run, increase NPLs in carbon-intensive sectors due to regulatory pressures, stranded assets, and low profitability.

This nexus between Green Growth and NPLs has gained more recognition in recent times, with increased enthusiasm from financial institutions toward sustainable practices. Green banking initiatives focus on reallocating capital toward environmentally friendly projects that could reduce risks related to NPLs. This connection is explored through various dimensions, including the impact of carbon intensity on loan performance and the broader implications of sustainable development goals.

Empirical literature, therefore, presents the interaction of sustainability practices and dynamics of NPLs in banking. Jadoon, Mumtaz, Sheikh, Ayub, and Tahir (2021) investigate how green growth may affect financial stability and find that facilitating environmentally sustainable policies reduces credit risks and strengthens bank resilience. Similarly, Ozili (2024) discusses the nexus between sustainable development and NPLs, noting that banks operating in economies with higher sustainability adoption have lower credit default rates. Ntarmah, Kong, Cobbinah, Gyan, and Manu (2020) present evidence from Africa on how a weak environmental sustainability framework leads to a high level of NPLs ratio and constrains financial stability. Boussaada, Hakimi, and Karmani (2023) explore European banks and show that CSR initiatives help improve credit performance through reduced NPL ratios and overall bank performance. Al-Qudah, Hamdan, Al-Okaily, and Alhaddad (2023) extend this discussion into a focus on UAE banks, demonstrating that green lending practices play a vital role in reducing credit risk and supporting sustainable financial practices.

This paper analyzes the impact of Green Growth on non-performing loans in the MENA region based on theoretical and empirical evidence from existing literature. The following hypothesis is tested in particular:

H_2: Green Growth is negatively associated with non-performing loans.

2.3. Climate Risk, Green Growth and Non-Performing Loans

The relationship between climate risk, green growth, and non-performing loans (NPLs) is increasingly considered crucial to financial stability. Studies indicate that green growth has the potential to mitigate the impact of climate risk on NPLs positively by enhancing the resilience of economies and financial systems. Theoretically, green growth economic development emphasizing environmental sustainability and the efficient use of natural resources reduces the adverse effects of climate risk on credit quality by building resilience within economic systems and promoting environmentally sensitive investments. Green growth strategies, such as the adoption of renewable energy, climate-smart infrastructure, and green finance, can decrease exposure to climate-related disruptions of economic activities, thereby reducing the likelihood of loan defaults. Additionally, green growth can facilitate a smoother transition by supporting industry changes that lead to lower carbon emissions, which in turn limits the number of stranded assets and defaults in affected industries.

The green growth initiatives, especially green credit, significantly moderate the relationship between climate risk and NPLs. This interaction underscores how proactive environmental strategies can reduce financial risks related to climate change and, consequently, improve the stability of banking systems. Empirical literature emphasizes how green financing and sustainability initiatives play an important role in moderating the relationship between climate risk, credit risk, and bank stability. Kamran, Haseeb, Nguyen, and Nguyen (2020) document that green finance and renewable energy consumption considerably mitigate the negative impact of climate change on the stability of ASEAN banks due to increased economic resilience and a resultant lower reliance on climate-

vulnerable sectors. Similarly, Hsiao and Wang (2022) establish that green credit acts to decouple the risks of businesses and financial instability faced by commercial banks operating in China through sustainable investment promotions and reduction of industries that involve more carbon. This is further supported by Boussaada et al. (2023), who prove that those banks with high CSR practices, including green financing, have lower NPLs since CSR-oriented banks are more capable of dealing with climate-related risks. Evidence from China by Song, Cao, and Shan (2024) also shows that green credit reduces banks' risk-taking behavior, thus reducing the possibility of loan defaults in the case of climate shocks. Finally, Abbas and Sabah (2024) emphasize how green finance improves the financial performance while taming credit risk in the banking sector of Pakistan, especially with strong support for capital structure. These studies, taken together, establish the fact that mechanisms of green growth, such as green financing and the adoption of renewable energy, act as critical moderators in the influence of climate risk on NPLs by fostering sustainable and resilient economic systems. Based on the development above, we can formulate the following hypothesis:

H_3: Green growth moderates the relationship between climate risk and non-performing loans.

3. METHODOLOGY

3.1. The Sample

The moderating role of Green Growth in the relationship between climate risk and non-performing loans is investigated using a sample of conventional banks from 10 MENA countries over the period 2010–2022. The dataset initially included 109 banks; however, due to limitations in data availability and continuity, the final sample was narrowed to 40 conventional banks (See Table 1).

Table 1. Distribution of the sample by country.

Middle East North Africa countries		
Countries	**Number of banks**	**%**
Jordan	4	10%
Kuwait	4	10%
Oman	2	5%
Lebanon	1	2.5%
Qatar	4	10%
Saudi Arabia	7	17.5%
United Arab Emirates	6	15%
Egypt	1	2.5%
Morocco	2	5%
Tunisia	10	25%
Number of banks	40	100%

3.2. Variable Selection and Theoretical Justification

3.2.1. Dependent Variable: Non-Performing Loans

This study extends the literature by examining the moderating role of Green Growth on the relationship between climate risk and NPLs. The dependent variable is non-performing loans, which are critical indicators of financial health and act as "financial pollution" that hinders sustainable economic growth (Makri, Tsagkanos, & Bellas, 2014). NPLs are measured by the ratio of bank non-performing loans to total loans (Hakimi & Khemiri, 2024).

3.2.2. Main Explanatory Variable: Climate Risk

As explanatory variables, according to Kreft, Eckstein, Junghans, Kerestan, and Hagen (2014), we use the Global Climate Risk Index (CRI), compiled and published by Germanwatch, to measure climate risk by country. The index aims to demonstrate the adverse effects that climate change has had on many different countries. These include climatological events like wildfires, hydrological events such as floods, and meteorological phenomena like

storms. A low climatic risk is indicated by a high index score, and a lower score on the index indicates a higher climate risk. For this reason, before estimating the empirical models, we multiplied the CRI by -1 (Ozkan, Temiz, & Yildiz, 2023). As a consequence, a higher index score indicates a high climate risk, whereas a lower index score indicates a low climate risk.

3.2.3. Other Explanatory Variable: Green Growth

The *Green Growth Index (GGI)* is a composite indicator that measures a country's progress toward sustainable development by evaluating its performance in achieving environmentally sustainable economic growth. It assesses key dimensions such as efficient and sustainable resource use, natural capital protection, green economic opportunities, and social inclusion (Acosta, Maharjan, Peyriere, & Mamiit, 2020). The index is developed by the Global Green Growth Institute (GGGI) and provides a comprehensive framework to track how well economies balance economic growth with environmental sustainability and social equity.

3.2.4. Control Variables

As outlined, our econometric model incorporates several control variables. The first category pertains to bank-specific factors, including bank size (BS). The bank size significantly reduces the level of NPLs (Jabbouri, Naili, Almustafa, & Jabbouri, 2023; Kumar, Sharma, Khan, & Kumar, 2022; Naili & Lahrichi, 2022), while Chaibi and Ftiti (2015) and Goczek and Malyarenko (2015) found a positive association between them. The relationship between capital and NPLs is ambiguous. More recently, Kryzanowski, Liu, and Zhang (2023) found that banks with strong capital quality and high equity ratios are more likely to control the level of NPLs during the COVID-19 crisis. In addition, Alnabulsi, Kozarević, and Hakimi (2022) and Phung, Van Vu, and Tran (2022) confirm these findings. In contrast, Hasan and Ashfaq (2021) showed that the NPLs ratio rises significantly with higher bank capital, while Jabbouri et al. (2023) and Radivojević et al. (2019) did not find a significant relationship.

The second category relates to industry-specific variables, such as bank concentration (CONC), which significantly reduces NPL levels (Alnabulsi et al., 2022; Karadima & Louri, 2021). More recently, Hakimi and Khemiri (2024) demonstrated that rigorous monitoring and close surveillance of the sector enable quick intervention to implement corrective measures if a potential problem arises.

The third category encompasses macroeconomic conditions, represented by the GDP growth rate (GDPG), inflation rate (INF), and the unemployment rate (UNEM). The literature considers economic growth as another essential factor of NPLs. Jabbouri et al. (2023) and Chaibi and Ftiti (2015) demonstrated that when economic conditions improve, the NPLs ratio decreases, but Radivojević et al. (2019) found an inverse effect. For inflation, Hakimi and Khemiri (2024) highlighted a positive relationship, explained by the fact that inflation leads to a decrease in consumer incomes, making loan repayment more difficult. Naili and Lahrichi (2022) and Chaibi and Ftiti (2015) observed a positive relationship between unemployment and NPLs. A high unemployment rate decreases borrowers' ability to meet financial obligations, worsening the issue of loan defaults. Moreover, low-income borrowers experience higher interest rates due to uncertainty regarding their employment, which further diminishes their ability to repay loans.

Bank-level accounting and financial data were sourced from the annual reports of individual banks and the Refinitiv Eikon database. Industry-specific and macroeconomic factors at the country level were derived from the Global Financial Indicators and World Bank Indicators databases. Data for the Climate Risk Index (CRI) were provided by Germanwatch, and Green Growth Index (GGI) data were collected from the Global Green Growth Institute (GGGI).

3.3. Empirical Approach and Model Specification

The empirical methodology used here is the System Generalized Method of Moments (SGMM) estimator. Several considerations make this method suitable for this analysis. Firstly, SGMM effectively models the dynamic pattern of credit risk by using lagged dependent variables as regressors, which reflects the persistence of non-performing loans over time. Secondly, it addresses potential endogeneity issues through the use of internal instruments, such as lagged levels of the explanatory variables, thereby eliminating simultaneity bias. Thirdly, SGMM provides consistent and efficient estimates even in the presence of heteroscedasticity and autocorrelation, which are common issues in macro-financial panel datasets. In contrast, classical estimation methods like Ordinary Least Squares (OLS), Fixed Effects (FE), and Random Effects (RE) models are often affected by omitted variable bias and measurement errors, issues that SGMM is specifically designed to address.

To this end, the study utilizes the SGMM estimation method developed by Blundell and Bond (1998) which has been widely endorsed in empirical banking and finance literature. Utilizing this method strengthens the findings since evidence in previous studies (Danisman & Tarazi, 2020; Hakimi et al., 2023; Teixeira & Queirós, 2016; Zhou, 2014).

The sample period from 2010 to 2022 was selected to cover over a decade of observations, during which financial risks related to climate and sustainability policies became increasingly relevant in the MENA region. This timeframe also ensures data availability and consistency among the selected banks and countries. Using conventional banks allows for a more comparable sample and avoids bias from the unique operating models of Islamic banks.

The empirical approach in this work is based on three phases. First, we explore the relationship between climate risk and non-performing loans. Equation 1presents the econometric to be tested in this step.

$$NPLs_{i,t} = \beta_0 + \beta_1 NPLs_{i,t-1} + \beta_2 CRI_{i,t} + \beta_3 BS_{i,t} + \beta_4 CAR_{i,t} + \beta_5 CONC_{i,t} + \beta_6 GDPG_{i,t} + \beta_7 INF_{i,t} + \beta_8 UNEM_{i,t} + \varepsilon_{i,t} \quad (1)$$

NPLs is Non-performing loans, CRI is Climate risk index, BS is Bank size, CAR is Capital adequacy ratio, CONC is Bank concentration, GDPG is growth rate of GDP, INF is inflation rate, and UNEM is unemployment rate. Moreover, i,t denote country & time indicator. β_0 is the intercept and β_1 to β_8 represents the coefficients of the explanatory variables, respectively.

We looked into how Green Growth affected bank Non-performing loans in the second stage. The following Equation 2 presents the econometric model:

$$NPLs_{i,t} = \beta_0 + \beta_1 NPLs_{i,t-1} + \beta_2 GGI_{i,t} + \beta_3 BS_{i,t} + \beta_4 CAR_{i,t} + \beta_5 CONC_{i,t} + \beta_6 GDPG_{i,t} + \beta_7 INF_{i,t} + \beta_8 UNEM_{i,t} + \varepsilon_{i,t} \quad (2)$$

The third phase involves determining whether the link between climate risk and non-performing loans is moderated by Green Growth. To capture the interaction between climate risk and Green Growth, we incorporate an interaction variable into the econometric model. Equation 3 provides the econometric model to be tested:

$$NPLs_{i,t} = \beta_0 + \beta_1 NPLs_{i,t-1} + \beta_2 CRIxGGI_{i,t} + \beta_3 BS_{i,t} + \beta_4 CAR_{i,t} + \beta_5 CONC_{i,t} + \beta_6 GDPG_{i,t} + \beta_7 INF_{i,t} + \beta_8 UNEM_{i,t} + \varepsilon_{i,t} \quad (3)$$

All variables' definitions are given in Table 2.

Table 2. Definition of variables.

Variables	Definitions	Measures
Dependent variables (NPLs)		
NPLs	Non-performing loans	Nonperforming loans/ Total loans (%)
Climate risk		
CRI	Climate risk index	Climate risk index (CRI) of German watch
Green growth		
GGI	Green growth index	Green growth index (GGI) of GGGI
Interaction variables		
CRI*GGI	Interactional variable	The interaction between CRI and GGI
Bank specifics		
BS	Bank size	Natural logarithm of total assets
CAR	Capital adequacy ratio	Bank capital to total assets (%)
Industry specifics		
CONC	Bank concentration	Bank concentration (%)
Macroeconomic conditions and financial environment		
GDPG	The growth rate of GDP	Annual growth rate of GDP (%)
INF	The inflation rate	Consumer price index (%)
UNEM	The unemployment rate	The unemployment rate (%)

4. ANALYSIS AND RESULTS

4.1. Summary Statistics and Correlation Matrix

Table 3 presents descriptive statistics for the variables used in our analysis. It outlines the key characteristics of this dataset. This Table details, for each variable, the mean, standard deviation, minimum, and maximum value. These statistics summarize the variables used in the SGMM model.

Credit risk, as expressed by non-performing loans or NPLs, stands at an average of 8.276%, while a maximum value of 42.512% and a minimum value of 0.108% were achieved. For conventional banks, the Climate Risk Index (CRI) oscillates at an average value of -100.21, with the maximum achieved being -17. The Green Growth Index (GGI), on average, is 45.412, ranging from 53.06 as the maximum value to 38.07 as the minimum. The average bank size is 23.500, ranging from 20.942 to 26.512. The Capital Adequacy Ratio (CAR) averages 15.839%, with a range from 0% to 211.47%. According to industry-specific factors, the average bank concentration (CONC) is 80.888, with a maximum of 100.000 and a minimum of 56.035.

Macroeconomic conditions, represented by the GDP growth rate (GDPG) and inflation rate (INF), are on average 2.53%, with a maximum of 19.59% and a minimum of -21.39%. The inflation rate averages 3.877%, ranging from -3.749% to 171.20%. Finally, the unemployment rate (UNEM) has an average of 8.238%, with a maximum of 19.837% and a minimum of 0.1%.

Table 3. Descriptive statistics.

Variable	Mean	Std. dev.	Min.	Max.
NPLS	8.276	7.375	0.108	42.612
CRI	-100.212	31.934	-173.67	-17
GGI	45.412	3.606	38.07	53.06
BS	23.500	1.313	20.942	26.512
CAR	15.839	10.987	0	211.47
CONC	80.888	14.140	56.035	100
GDPG	2.530	4.050	-21.399	19.592
INF	3.877	10.913	-3.749	171.205
UNEM	8.238	6.412	0.1	19.837

By computing the coefficients of linear correlation, the correlation matrix provides the degree and type of connection between the independent variables. Table 4 displays the correlation matrix for every variable used in this investigation.

Table 4. Correlation matrix.

Variable	CRI	GGI	BS	CAR	CONC	GDPG	INF	UNEM
CRI	1.0000							
GGI	0.3235* 0.0000	1.0000						
BS	0.2263* 0.0000	0.0225 0.5430	1.0000					
CAR	0.0562 0.2008	-0.0817 0.0625	0.2389* 0.0000	1.0000				
CONC	0.1459* 0.0009	-0.123* 0.0049	0.4160* 0.0000	0.2078* 0.0000	1.0000			
GDPG	0.1374* 0.0017	-0.0336 0.4454	0.0849 0.0797	0.0385 0.3809	0.1387* 0.0016	1.0000		
INF	0.0238 0.5833	-0.0731 0.0959	-0.0470 0.3322	-0.0626 0.1541	-0.1492* 0.0007	-0.1806* 0.0000	1.0000	
UNEM	-0.1521* 0.0006	0.0187 0.6750	-0.6116* 0.0000	-0.2308* 0.0000	-0.7275* 0.0000	-0.1640* 0.0002	0.0469 0.2940	1.0000

Note: *, indicate level of significance at 5%.

To further validate the results in Table 4, we performed a Variance Inflation Factor (VIF) test for multicollinearity, which measures how much the variance of estimated regression coefficients is inflated due to correlations among predictors. The VIF value of 1 indicates no correlation; values between 1 and 5 suggest moderate correlation, and values greater than 5 indicate potentially severe multicollinearity.

Results in Table 5 present the mean VIF for the first model that is, investigating the influence of climate risk on the credit risk of banks, which is approximately 1.53. This indicates no severe multicollinearity among the variables and demonstrates a moderate correlation across all values. Second, Table 5 shows the mean VIF of 1.52 for the second model, which analyzes the effect of Green Growth on bank credit risk. Again, this confirms the absence of severe multicollinearity, with moderate correlations between the variables. Finally, Table 5 presents the mean VIF value of 1.52 for the third model, which examines the interaction effect of both Green Growth and climate risk on non-performing loans. Similar to the two previously discussed models, no severe multicollinearity is expected, although a moderate correlation between the variables is observed.

Table 5. Variance inflation factor (VIF).

Model 1			*Model 2*			*Model 3*		
Variable	**VIF**	**1/VIF**	**Variable**	**VIF**	**1/VIF**	**Variable**	**VIF**	**1/VIF**
UNEM	2.62	0.381	UNEM	2.63	0.380	UNEM	2.61	0.383
CONC	2.10	0.476	CONC	2.11	0.474	CONC	2.08	0.481
BS	1.71	0.584	BS	1.66	0.602	BS	1.70	0.586
CRI	1.08	0.925	INF	1.08	0.922	CAR	1.08	0.928
INF	1.08	0.927	CAR	1.08	0.927	INF	1.08	0.928
CAR	1.08	0.929	GDPG	1.05	0.952	CRI*GGI	1.07	0.937
GDPG	1.07	0.938	GGI	1.03	0.973	GDPG	1.06	0.940
Mean VIF	1.53		Mean VIF	1.52		Mean VIF	1.52	

4.2. Discussion of the Empirical Findings

4.2.1 Findings of the Effect of Climate Risk on Non-Performing Loans

The Empirical analysis begins by assessing the influence of climate risk, measured by the Climate Risk Index (CRI), on bank credit risk in the MENA region, with credit risk being estimated by non-performing loans (NPLs). The corresponding results are reported in Table 5. Diagnostic checks, including the Sargan test for over-identifying restrictions and the Arellano-Bond test for second-order serial correlation, confirm the validity of the model. Specifically, the p-values of both tests are greater than the 5% level, indicating that the null hypotheses of valid instruments and no second-order serial correlation cannot be rejected.

Table 6. Results of the effect of CRI on NPLs.

NPLs	Coef.	St.Err.	Z	|P|>Z
NPLs (-1)	0.622	0.007	78.34	0.000***
CRI	0.008	0.001	8.25	0.000***
BS	-1.086	0.196	-5.53	0.000***
CAR	-0.006	0.004	-1.49	0.136
CONC	0.078	0.012	6.12	0.000***
GDPG	-0.156	0.007	-20.57	0.000***
INF	0.015	0.003	4.50	0.000***
UNEM	0.558	0.026	20.73	0.000***
Constant	18.728	3.980	4.71	0.000***
AR (1)	-2.8818			
Prob	0.0040			
AR (2)	-0.59895			
Prob	0.5492			
Sargan test	34.83003			
Prob	1.0000			

Note: *** p<0.01.

Table 6 presents results with the positive and significant contribution of a lagged dependent variable. These findings imply that the credit risk of the last year, computed as NPLs, exerts a positive impact on the emergence of the very same credit risk in the current year.

Results in Table 6show that the coefficient of climate risk (CRI) is positively and significantly associated with the dependent variable (NPLs), meaning that the rise in the climate risk index significantly increases the credit risk for MENA banks. The reason climate risk increases NPLs is by exposing them to a number of vulnerabilities: physical, economic, and financial. Physical risks include flooding, drought, and other extreme weather events that can damage assets, disrupt operations, and lower incomes, all factors that make it difficult for borrowers to repay loans. Transition risks are driven by a shift toward low-carbon economies and might strain industries reliant on fossil fuels, leading to financial distress and defaults. Additionally, supply chains disrupted by climate issues further devalue collateral assets and raise costs, worsening borrowers' repayment capacity. Increased insurance premiums and a wide range of macroeconomic effects, such as reduced economic activity and higher unemployment, add to financial stress. All these factors collectively heighten credit risk, especially in climate-vulnerable regions such as the MENA area, where banks face increased NPLs amidst intensifying climate risks. These findings are in line with the works of Khemiri (2024), Zhang et al. (2024), and Brik (2024). Hence, we accept Hypothesis H1.

Concerning bank specifics, findings reveal that bank size is negatively associated with the dependent variable. Bank size may also negatively impact credit risk through the utilization of diversification, sophisticated risk management systems, and economies of scale by larger banks. Indeed, larger banks have a higher likelihood of diversification in their loan portfolios both sectorally and regionally, which decreases their exposure to sector- or region-specific shocks. They invest in sophisticated risk assessment and monitoring tools, thereby enhancing the quality of lending decisions. Additionally, their access to more capital and liquidity buffers helps withstand financial stress, while stricter regulatory oversight encourages prudent lending practices. Furthermore, greater bargaining power enables them to enforce stricter terms and collateral requirements for loans granted, reducing the chances of default. All these factors collectively enable larger banks to manage credit risk more successfully compared to small ones. These findings are in line with the work of Kumar et al. (2022) and Jabbouri et al. (2023).

The coefficient of the CONC is positively and significantly associated with the dependent variable. A more concentrated banking system will increase credit risk by raising systemic risk, reducing competition, overexposing large borrowers, homogenizing lending practices, and creating moral hazard. These factors collectively make the financial system more vulnerable to various shocks and, consequently, increase the likelihood of higher NPLs. This result is in line with Ozili (2019).

Concerning macroeconomic factors, results show that the GDPG significantly decreases the NPL ratio. It reduces the NPL ratio by improving the repayment ability of borrowers, enhancing business performance, stabilizing employment, increasing asset values, boosting confidence, and promoting better credit risk management. All these factors contribute to a healthier economic environment, thereby reducing the incidence of loan defaults and generally improving the quality of banks' loan portfolios. This result is consistent with Jabbouri et al. (2023) and Chaibi and Ftiti (2015).

Conversely, the inflation rate significantly increases the non-performing loans for MENA banks. Inflation raises NPLs by reducing the purchasing power of borrowers and increasing the cost of living, thereby leaving households and businesses with less disposable income for debt servicing. Higher operating costs for businesses, along with probable rises in interest rates to control inflation, further diminish borrowers' ability to repay loans. Economic uncertainty during periods of inflation causes individuals to abstain from investment and spending, reducing revenue and increasing defaults. Furthermore, if wages and asset values do not keep pace with inflation, refinancing by borrowers or the sale of collateral may become difficult, exacerbating the repayment problem. These factors cumulatively weaken the financial position of borrowers, leading to higher defaults and an increase in NPLs. Our result confirms the finding of Khemiri (2024).

Concerning the unemployment rate, we found a positive and significant relationship with the ratio of non-performing loans at a level of 1%. In fact, the unemployment rate increases non-performing loans (NPLs) by directly reducing borrowers' income, making it difficult for individuals and businesses to meet their loan obligations. High unemployment weakens consumer spending and business revenues, leading to financial distress and higher defaults.

Additionally, job losses can cause collateral values, such as real estate, to decline, limiting borrowers' ability to refinance or sell assets to repay debts. Unemployment also creates financial and psychological stress, further impairing borrowers' capacity to manage debt. In a broader sense, high unemployment often reflects economic weakness, exacerbating financial challenges for both households and businesses, which collectively drive up the level of NPLs. In this study, the results are similar to those obtained by Hakimi and Khemiri (2024) for the case of MENA region.

4.2.2. Findings of the Effect of Green Growth on Non-Performing Loans

The results in Table 7 are relative to the effect of Green Growth on the ratio of NPLs. Findings indicating that the index of green growth significantly reduces the ratio of NPLs in the MENA region. Green growth decreases NPLs by promoting economic growth that is sustainable with limited environmental risks, thereby reinforcing financial stability and the resilience of borrowers. It encourages investment in renewable energy, energy efficiency, and environmentally friendly technologies; as a result, it supports industries that are less vulnerable to climate-related or regulatory shocks, making revenues stable and default rates low. This also creates employment opportunities and stabilizes incomes, thereby improving borrowers' repayment ability. Green growth enhances risk management practices, including environmental, social, and governance factors in business operations, which encourages prudent lending decisions. Additionally, it benefits from regulatory incentives, green financing, and positive market sentiments, all of which improve the financial health of enterprises and individuals, reducing the probability of loan defaults and consequently lowering the NPL ratio.

Concerning the effect of bank specifics, industry characteristics, and macroeconomic conditions, results in Table 7 indicate that there is no significant change compared to the results displayed in Table 6. For example, we found that bank size and economic growth significantly decrease credit risk. However, bank concentration, inflation, and unemployment significantly increase the level of the NPL ratio.

Table 7. Results of the effect of green growth on NPLs.

NPLs	Coef.	St.Err.	Z	|P|>Z
NPLs (-1)	0.593	0.021	28.11	0.000***
GGI	-0.767	0.063	-12.04	0.000***
BS	-1.132	0.213	-5.31	0.000***
CAR	-0.006	0.005	-1.02	0.308
CONC	0.042	0.009	4.31	0.000***
GDPG	-0.120	0.009	-12.95	0.000***
INF	0.000	0.004	0.04	0.966
UNEM	0.442	0.042	10.36	0.000***
Constant	-11.223	7.018	-1.60	0.110
AR (1)	-2.9515			
Prob	0.0032			
AR (2)	-0.53337			
Prob	0.5938			
Sargan test	29.5817			
Prob	1.0000			

Note: *** p<0.01.

4.2.3. Findings of the Interactional Effect of Climate Risk and Green Growth on Non-Performing Loans

Results displayed in Table 8 are relative to the moderating effect of Green Growth in the climate risk-NPLs relationship. We found that Green Growth moderates the climate risk-NPLs relationship because the coefficient is negative and statistically significant, meaning that the interaction between Green Growth and Climate risk (CRI*ESG) significantly decreases the NPLs ratio for MENA Banks.

Table 8. The interactional effect of CSR and climate risk on NPLs.

NPLs	Coef.	St.Err.	Z	|P|>Z
NPLs (-1)	0.617	0.010	60.06	0.000***
CRI*GGI	-0.000	0.000	-3.84	0.000***
BS	-1.154	0.202	-5.70	0.000***
CAR	-0.005	0.004	-1.22	0.223
CONC	0.074	0.012	5.87	0.000***
GDPG	-0.150	0.009	-15.26	0.000***
INF	0.017	0.003	5.26	0.000***
UNEM	0.552	0.027	19.77	0.000***
Constant	20.630	4.188	4.93	0.000***
AR (1)	-2.8629			
Prob	0.0042			
AR (2)	-0.53251			
Prob	0.5944			
Sargan test	34.20443			
Prob	1.0000			

Note: *** p<0.01,* p<0.1.

The interaction of climate risk with green growth will reduce credit risk by aligning economic activities with sustainable ones, thereby reducing climate-related vulnerability and promoting financial stability in the long term. Green growth mitigates risks arising from physical hazards of climate change, such as extreme weather events, by facilitating renewable energy and resilient infrastructure in response to climatic changes. Additionally, it assists in transitioning companies to low-carbon practices, which reduces regulatory risks and operational costs. Green growth incorporates climate risk into decision-making processes for improved risk management and innovation, making companies more resilient to various economic and environmental fluctuations. Furthermore, the availability of green financing, employment creation in greener industries, and improved market sentiment enhance borrowers' financial positions, thereby decreasing the likelihood of loan defaults and overall credit risk.

For the effect of bank specifics, industry specifics and macroeconomic conditions, no significant changes with comparison to the results discussed in Table 6.

5. CONCLUSION

The objective of this paper was to explore the relationship between climate risk and non-performing loans (NPLs) in the MENA region, with particular focus on the moderating role of green growth. Using a panel of MENA banks covering the period 2010–2022, the empirical examination offers three main results: (i) climate risk increases the level of NPL ratio, (ii) green growth contributes to reducing credit risk, and (iii) green growth moderates the impact of climate risk on NPLs, suggesting that policies of sustainable development can enhance the resilience of banks to climate shocks.

The results of this paper would, no doubt, help policymakers and bankers in many ways. First, integrating green growth strategies into national economic plans to reduce the vulnerability of banks to climate-related shocks that increase their NPLs would have to be a concern at the forefront of policymakers' minds. They may achieve this by incentivizing investment in renewable energy, sustainable agriculture, and climate-durable infrastructure a strategy that develops new economic opportunities while reducing dependency on climate-sensitive sectors. Second, the regulatory frameworks need to be improved so that banks are obligated to appraise and disclose climate-related risks in loan portfolios, and better risk management practices are assured. Third, the central banks and financial regulators of the MENA region could also develop stress-testing models, including climate risk scenarios, to enable banks to prepare for potential financial disruptions. Finally, this might also be promoted through regional cooperation, such as by the Union of Arab Banks, allowing for the dissemination of best practices and harmonization of standards on green finance. As policymakers work to interlink economic growth and environmental sustainability, they will help reduce adverse consequences on bank asset quality due to climate risk and foster long-term stability in the financial system.

This, of course, has a number of limitations that should be acknowledged. First, data availability and quality regarding NPLs and climate risk exposure can be poor in the MENA region, which may undermine the robustness of the analysis. Second, although the study focuses on the MENA region, which is contextually valuable, this may limit the generalizability of the findings to other regions with different economic structures and climate risk profiles. Third, since the impacts of green growth on NPLs occur via indirect effects and over longer time horizons due to technological factors, policy response lags, and global market dynamics, direct associations may not fully capture the impact of green growth on NPLs.

Future research could overcome these limitations by expanding the geographical scope to include comparative studies across multiple regions, providing insights into how different regulatory and environmental contexts influence the relationship between climate risk, green growth, and NPLs. Longitudinal studies could also be conducted to better understand the temporal dynamics of these relationships and the effectiveness of green growth policies over time. Additionally, it may further explore the potential role that innovative financial instruments could play in supporting mitigation strategies against climate risks and the reduction of NPLs, for example, green bonds and climate insurance. By addressing these gaps, future research can provide a more comprehensive understanding of how green growth can serve as a tool for financial resilience in the face of climate risk.

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