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Evaluating the Effect of Climate Risk on Financial Fragility in Arab Countries

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Abstract

This study explores the impact of climate risk on the financial fragility in Arab countries, which is partitioned into four categories pursuant to the level of income from 2007 to 2019. This has been performed using an aggregate banking stability index, as a measure of financial fragility in 18 countries, including (i.e. Algeria, Bahrain, Djibouti, Egypt, Iraq, Jordan, Kuwait, Lebanon, Libya, Mauritania, Morocco, Oman, Qatar, Saudi Arabia, Sudan, Tunisia, UAE, Yemen). The outcomes reveal that climate risk has significant positive effects on financial fragility. The findings show that importance of climate-related risk and some factors in explaining financial fragility, where broad money, domestic credit to private sector by banks, GDP growth, and income seem to have significant effects on financial fragility. Robustness test using alternative measures of financial fragility and changing estimation method to assure the reliance of study results. Both approaches confirm the previous findings. The study contributes to the literature by providing empirical evidence on the effect of climate-related risk on banking stability in Arab countries over 13 years and emphasizing that climate risk is source of risk for the financial system. The research insights of this contribution can inform policymakers and central banks to assess climate-related financial risks, highlighting the need for a better understanding of the impact of climate shocks on world financial system across countries.

Keywords: aggregate banking stability index, Arab countries, climate risk index, financial fragility, unexpected climate shocks

1. Introduction

Recently, the academic community has started paying growing attention to climate change impacts, where climate change is a major source of risk for the financial system (Ozili, 2020). Climate risk is systemic and non-linear, and it can generate prolonged socio-ecological and economic crises, with profound implications for financial sector participants (van Benthem et al., 2022) and financial system stability (Battiston et al., 2021; Hua, 2023; Liu et al., 2024). Most studies have primarily focused on the theoretical aspect of the relationship between climate-related risk and financial system, but a limited number of studies have focused on examining the empirical implications of this issue. Theoretical frameworks provide valuable insights into the importance of incorporating climate change considerations into policies of central banks, financial supervisors and institutional investors, where the climate shocks can unsettle the financial system (Ozili, 2020; Battiston et al., 2021).

On the other hand, empirical studies provide practical insights by investigating the relation between climate shocks and financial stability (Hua, 2023; Liu et al., 2024) or systemic risk (Mao et al., 2023; Conlon et al., 2024), but these studies have largely neglected the connection between climate risk and financial fragility. Also, previous studies have largely overlooked the exploration of this issue in Arab countries. The impact of financial fragility or instability may lead to systemic risks and financial crises that have severe consequences for the economy. Recent regional developments, particularly the conflicts in some Arab countries and the rise in uncertainty, have had indirect effects on the economy, especially on the financial sector of these countries. The climate change challenges of this issue faced by Arab countries remain largely unexamined, this emphasizes the need for more applied research that bridges this gap. This study aims at filling this gap by focusing on the impact of climate-related risks on financial fragility and suggesting financial instruments that aim at mitigating these risks.

This study makes several important contributions as follows. Firstly, this study aims to enhance the

understanding of the complex relationship between climate risk and financial fragility by providing theoretical insights supported by empirical data. Secondly, it identifies factors that influence financial fragility over 13 years for 18 Arab countries, filling a critical gap in the existing literature. Thirdly, this study considers the income levels of the countries specified in the sample and utilizes an aggregate banking stability index to assess financial fragility. This index considers four key elements: capital adequacy, asset quality, liquidity, and profitability. Finally, this study conducts robustness tests using alternative measures of financial fragility and changes the estimation method. As the Z-score index measures the likelihood of a bank defaulting and is based on the bank's profit levels and their volatility (Kassem, Awdeh, & EL-Moussawi, 2014). By employing both Z-score as the alternative measure and the panel generalized method of moments (GMM) model are consistent with this study's outcomes. Also, the results provide recommendations for policymakers, emphasizing the importance of integrating climate risk considerations into policy frameworks to promote financial stability.

Results disclose the importance of climate risk in explaining financial fragility, where climate risk has significant positive effects on financial fragility. The outcomes also indicate that domestic credit to private sector by banks and income have a significant positive effect on financial fragility, while broad money has a significant negative effect, most notably on the alternative measure side. Besides, there is a positive effect of GDP growth on financial fragility but weak significant. The research insights into this contribution can inform policymakers and central banks to assess climate-related financial risks, highlighting the need for a better understanding of the effect of climate shocks on world financial markets. The rest of this study is structured as follows. Section 2 describes the problem of research, but Section 3 reviews the literature. Section 4 is devoted to describing data and methodology. Section 5 presents empirical results while Section 6 concludes the study.

2. The Problem Statement

Climate change is a new source of financial risk, and it has an adverse impact on financial stability (e.g. Battiston et al., 2021 Hua, 2023; Liu et al., 2024). Some countries have relatively weak industrial systems and simultaneously lack awareness and capacity to preclude disasters, resist risk, address these challenges. This issue exasperates the impact of climate risk on the real economy in these countries, and then hurts the financial system. However, climate risk affects across countries worldwide, the extent of harm varies greatly from region to region. Most of the relevant papers are theoretical and few studies are empirical.

Some studies have addressed the relation between climate shocks and financial stability (Hua, 2023; Liu et al., 2024) or systemic risk (Mao et al., 2023; Conlon et al., 2024), but these studies have largely neglected the connection between climate risk and financial fragility. Moreover, the existing literature ignores the effect of climate risk in Arab countries, despite the challenges face. The findings from the banking sector remain limited. The financial sector is one of the most crucial sectors of managing climate-related risks and assisting the economy transfer to a low-carbon one. So, it is important to understand the effects of climate change events on financial institutions and the financial system. Where climate risks pose significant challenges for financial stability and the economy. By highlighting the gaps in existing literature, it becomes clear that the need for more applied research to bridges this gap, allowing for a more holistic view of this issue effects in Arab countries. Hence, this study contributes to literature by bringing evidence to examine the relationship between climate risk and financial fragility, rather than theoretical aspect like most of the literature. Figures 1 and 2 display the climate risk index and aggregate banking stability index for 16 Arab countries during the period of 2015-2019, as follows:

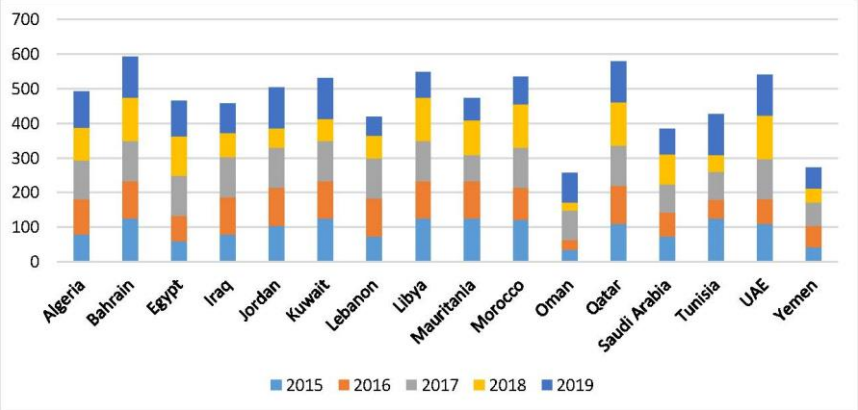

Figure 1. Climate risk index in Arab countries

Source: Prepared by Researcher.

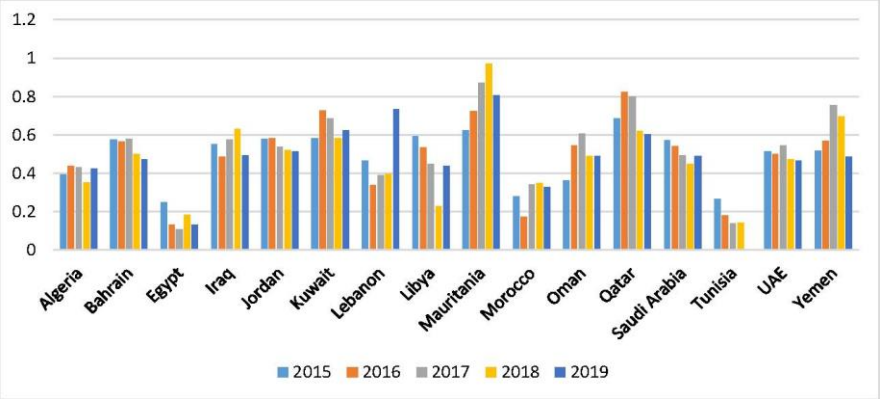

Figure 2. Aggregate banking stability index in Arab countries

Source: Prepared by Researcher.

It can be observed that some countries exhibit high climate risk due to extreme weather conditions, droughts, rising temperatures and natural disasters, while others enjoy low climate risk, indicating the disparity in climate-related risks levels among countries. Concurrently, some countries display fluctuations that negatively impact their stability.

This study contributes to fill a gap in the exiting literature by exploring into the effect of climate risk on financial fragility in Arab countries over 13 years, providing insights for central banks and regulatory authorities on the necessity of taking action to address climate challenges to achieve financial stability. This study considers the income levels for the countries under examination and uses an aggregate banking stability index to assess financial fragility. The current also investigates the determinants of financial fragility in Arab countries. In summary, this study seeks to answer the following questions: -Does climate risk affect financial fragility in Arab countries?

-Do macroeconomics factors affect financial fragility in Arab countries?

3. Related Literature and Research Hypotheses

Section 3 presents a review of previous literature concerning the economic and financial impact of climate change and the factors influencing banks' fragility. Regarding the relation between climate risk and the financial system, some studies have addressed this issue from a theoretical perspective (Ozili, 2020; Battiston et al., 2021; van Benthem et al., 2022), while others have approached it empirically (Hua, 2023; Mao et al., 2023; Liu et al., 2024; Conlon et al., 2024).

Ozili (2020) assures that climate shocks can unsettle the overall financial system by the adverse impact on financial institutions and financial markets. Battiston et al. (2021) sheds light on the relationship between climate risks and financial stability and suggests that the importance of assessing the financial risk, using climate and weather derivatives to hedge climate risk and pricing correctly financial assets. van Benthem et al. (2022) examines the impact of climate risks on the interactions between financial markets and energy firms. Theoretical frameworks assure that the importance of incorporating climate change considerations into policies of central banks and financial supervisors, where the climate shocks can destabilize the financial system.

Hua (2023) investigates the link between climate risks and financial stability, suggesting the existence of a complex relation where each significantly influences the other in China during 2015 to 2021. Besides Hua (2023) reveals that increasing climate risk has adverse effect on green economic recovery. Mao et al. (2023) finds that climate risk leads to aggravates systemic risks during 1990 to 2017 for five countries, namely France, Japan, China, US and UK. Regarding conveyors of climate shocks, the bond and stock markets are the basic Carriers. Authors have indicated that the forex and commodity markets seem to be more sensitive to climate-related information.

Liu et al. (2024) indicates that climate risk adversely influences financial stability in 53 countries during 20072019, considering levels of both economic and financial development, and competition across countries. Further, the results disclose that the country has a good national governance system and the existence of macroprudential policies can mitigate the adverse impact of climate risk on financial stability. Conlon, et al. (2024) reveals that banks' climate risk exposure acquired by cross-state lending increases their individual and systemic risks using yearly data comprised of 42 lender banks and 1,314 borrower firms during 1999–2019.

Besides, they disclose that banks reduce lending and increase loan loss reserves after facing an unanticipated climate risk. The banks' profitability minimizes the adverse effects of climate risk.

The previous studies have largely neglected the connection between climate risk and financial fragility. Also, previous studies have largely overlooked the exploration of this issue in Arab countries. The climate change challenges of this issue faced by Arab countries remain largely unexamined, this emphasizes the need for more applied research that bridges this gap. This study aims to analyze the influence of climate risk on financial fragility over 13 years for 18 Arab countries. Considering this debate, this study poses the following hypothesis:

Hypothesis 1. Climate risk has a significant effect on financial fragility in Arab countries. It can be clarified as follows:

HO1: There is no significant effect of climate risk on financial fragility.

HA1: There is a significant effect of climate risk on financial fragility.

Regarding financial fragility measures and the factors influencing them, as well as financial stability, this section can be divided into studies that focused on measures of financial fragility, such as the use of the following indicators: return on total assets, capital adequacy ratio, liquidity ratio, and non-performing loan ratio in the study by (Shang et al., 2024), or the use of the Z-score index in the study by (Kassem et al., 2014), and studies that addressed financial stability measures, such as Z-score in (Diaconu & Oanea, 2014; Alshubiri, 2017; Ozili, 2019; Pham et al., 2021; Mkadmi et al., 2021; Yensu et al., 2021; Güngör, 2023; Yitayaw et al., 2023; Tsegaye et al., 2024; Alfadli & Sahraoui, 2024), or banking stability index in (Kočišová, 2015 and Al-Rjoub, 2019).

Besides studies that focused on factors influencing financial fragility in a particular country, such as (Ahn et al., 2015; Wafula et al., 2022; Shang et al., 2024), or in certain countries, like (Kassem et al., 2014), as well as studies that addressed factors affecting financial stability in a specific country (Diaconu & Oanea, 2014; Ozili, 2019; Pham et al., 2021; Mkadmi et al., 2021; Salamat & Al-Kharouf, 2021; Yitayaw et al., 2023) or certain region (Pham et al., 2021). Most studies indicated mixed results, with some finding a positive effect between macroeconomic factors and financial fragility, such as (Rezaee et al., 2022), or financial stability, as noted in (Pham et al., 2021; Yitayaw et al., 2023). Others demonstrated a negative impact of these factors on financial fragility (Kassem et al., 2014) or on financial stability (Ozili, 2019), while some studies showed no significant effect (Alshubiri, 2017; Mkadmi et al., 2021). The following studies attempt to identify sources of fragility or probable factors affecting financial stability, as follows:

Kassem et al. (2014) finds that the likelihood of default decreases with an increase in bank capital and rising inflation rates, while the probability of default increases with higher bank liquidity, credit risk, and profitability in 12 MENA countries from 2005 to 2011. Wafula et al. (2022) uses the fragility index as a measure of financial stability and indicates that it is a strong early warning signal for the financial stability of 38 commercial banks in Kenya during 2011-2018. Fragile banks should find ways to merge to ensure their financial stability. Shang et al. (2024) suggests that banks with lower fragility achieve better results in both liquidity and non-performing loan ratios and calculates the total score of financial system fragility during 2007-2022 among 15 banks in China.

Diaconu and Oanea (2014) discovers that both GDP growth and the 3-month interbank offering rate have a positive impact on financial stability of the Romanian co-operative bank, but no significant factors were found in the case of commercial banks during 2008 -2012. Chauhan and Ramesha (2016) discovers that the growth rates of both credit and the stock market index, as well as short-term interest rates, are key factors in determining both banking and financial stability, measured by the non-performing loan ratio and credit extension, respectively, using quarterly data for 8 sectors in India during 2000-2009. Alshubiri (2017) determines that income diversity and the price-to-earnings ratio have a significant effect on financial stability, while macroeconomic and external governance factors are not significant across all variables using OLS regression method for six listed banks in Muscat Security Market of Oman during 2008-2014.

Ozili (2019) finds that business cycle volatility and inflation rate have a significant negative impact on bank stability, while bank profitability, efficiency, financial system depth, and concentration positively influence on their stability during 2003-2016 in Nigeria. Albuquerque and Rajhi (2019) indicates that natural disasters and state fragility can lead to significant economic and financial disruptions in 66 developing countries during 1995 to 2011. Yensu et al. (2021) concludes that the inflation, GDP growth, bank size, net profit margin, having a male CEO, a large board size and the frequency of board meeting have significant positive impact on banks' stability for 8 banks during 2008 to 2017 in Ghana. However, policy rate has a significant negative effect on banks stability, while factors such as exchange rates, net government debt, CEO duality, earnings per share, and bank growth do not significantly affect it. Pham et al. (2021) reveals that bank characteristics and

macroeconomic factors such as bank size, equity-to-asset ratio, loans to assets ratio, revenue diversification, foreign investment, GDP growth and inflation positively impact bank stability.

Mkadmi et al. (2021) finds that bank-specific and macroeconomic variables, such as net interest margin, noninterest income, the age and size of the bank, and GDP, positively influence bank stability, though not significantly for 7 commercial banks during 2005 to 2014 in Tunisia. Besides, the return on assets has a positive and significant impact on bank stability, while both the debt ratio and return on equity have a negative and significant effect. Salamat and Al-Kharouf (2021) finds that the inflation rate and debt ratio negatively impact the capital adequacy ratio, while GDP growth positively affects it during 2007 to 2016 for 13 commercial banks in Jordan. Additionally, return on equity and GDP growth significantly negatively influence non-performing loans, whereas the inflation rate has a significant positive effect on them; GDP growth also significantly negatively affects the number of returned checks, while the inflation rate significantly positively impacts that number.

Yitayaw et al. (2023) finds that the effect of banking lending rates, GDP growth, control of corruption, and the effectiveness of the rule of law has a positive impact on the bank's stability during 2014-2020 in Ethiopia. Alfadli and Sahraoui (2024) indicates that banking competition, efficiency, financial inclusion, and banks' performance have a significant positive influence on financial stability, while financial development has a significant negative impact on it during 2011-2020 for 132 commercial banks in 14 MENA-States. This study adds to the exiting literature by determining the potential factors affecting financial fragility in Arab countries since studies on this issue in these countries are scanty. Therefore, this study also aims to investigate the determinants of financial fragility in Arab countries. Accordingly, this study posits hypothesis 2, which can be formulated as follows: Macroeconomic factors have a significant impact on financial fragility in Arab countries. It can be explained as follows:

HO2: There is no significant impact of macroeconomic factors on financial fragility.

HA2: There is a significant impact of macroeconomic factors on financial fragility.

There is a scarcity of literature that may be able to provide evidence on this issue in Arab countries; therefore, this study addresses the research gap related to evaluating the effect of climate risk on financial fragility in these countries over 13 years, considering the macroeconomic factors and income levels across countries.

4. Research Methodology

4.1 Research Data and Variables

The sample includes 177 observations in 18 Arab countries according to data availability during 2007-2019. This study utilized Pooled Ordinary Least Squares (OLS) modeling, as well as the Fixed Effects and Random Effects models, to analyze panel data regression, after conducting several statistical tests to identify the most appropriate model. The counties represent Algeria, Bahrain, Djibouti, Egypt, Iraq, Jordan, Kuwait, Lebanon, Libya, Mauritania, Morocco, Oman, Qatar, Saudi Arabia, Sudan, Tunisia, UAE, Yemen.

4.1.1 Climate Risk

This study defines independent variables as climate risk, represented by the Global Climate Risk Index for each country. The lower the index score, the higher the ranking. This means the higher the climate risk index score, the greater the climate risk of the country. So, this study negatively processes the Global climate risk index scores of countries by multiplying all the scores by -1.

4.1.2 Financial Fragility

This study attempts to construct an aggregate Banking stability index (BSI) by considering both financial strength indicators, such as Return on Assets (ROA), Return on Equity (ROE), and Capital Adequacy Ratio, as well as key risk factors including the Non-Performing Loan (NPL) ratio and Liquidity Ratio. The process involves three steps: first, identifying components by outlining the Financial Soundness Indicators (FSIs) (Swamy, 2011), their weights, and their effects on financial stability (Gadanecz & Jayaram, 2008), as shown in Table 1; second, normalizing the indicators that positively correlate with financial stability using a specified formula as follows:

$$Z_{FSI-i} = {FSI_i - FSI_{min}}/{FSI_{max} - FSI_{min}} \quad (1)$$

Where:

Z_{FSI-i}: The normalized value of the financial soundness indicator for observation i

FSI_i: The value of the financial soundness indicator for observation i

FSI_{max}: The maximum observed value of the financial soundness indicator

FSI_{min}: The minimum observed value of the financial soundness indicator.

However, the indicators that are negatively associated with financial stability were normalized using the following formula:

$$Z_{FSI-i} = {FSI_i - FSI_{max}}/{FSI_{min} - FSI_{max}} \quad (2)$$

The third step involves calculating the index by determining the weighted average of the normalized values using the following formula:

$$\text{BSI} = \sum_{i=1}^{N} Z_{FSI} * \omega_{FSI} \quad (3)$$

Where:

BSI: The Aggregate Banking Stability Index.

Z_{FSI}: The normalized values of the financial soundness indicators.

ω_{FSI}: The weight of the financial soundness indicators.

Ultimately, the index will be used to evaluate financial fragility in Arab countries, focusing on 18 countries over a period of 13 years. The Aggregate Banking Stability Index is a composite index created as a weighted average of partial micro-prudential indicators and consists of four groups of the following indicators: Capital adequacy, Asset quality, Liquidity, and Earnings. Table 1 shows the components of the index as follows:

Table 1. Components of an overall banking stability index

Category	Weight	Indicators	Measurement	Sub-Weight	Impact
Capital adequacy	0.20	Capital adequacy	*Regulatory Capital* / *Risk Weighted Assets*	0.2	+
Asset quality	0.20	Non-Preforming Loans	Non — *Preforming Loans* / *Gross Loans*	0.2	-
Profitability	0.30	Return on Average Assets	*Net Income* / *Average Total Assets*	0.1	+
		Return on equity	*Net Income* / *Average Total Equity*	0.1	+
		Cost to Income	*Cost* / *Operating Income*	0.1	-
Liquidity	0.30	Liquid Assets to Total Deposits	*Liquid Assets* / *Total Deposits*	0.3	+

Source: prepared by the researcher.

Further, this study considers five factors from previous literature as control variables. Table 2 displays a description of all the study variables as follows:

Table 2. Description of all the study variables

	Variables	Abbreviation	Source
Dependent	Aggregate Banking Stability Index	BSI	International Monetary Fund (IMF)
Independent	Climate Risk	Global Climate Risk Index (CR)	Germanwatch
Control	Broad money (% of GDP)	BM	World Bank
	Domestic credit to the private sector by banks (% of GDP)	DCPB	
	GDP growth (annual %)	GDP_G	
	Inflation (annual %) Income	INF Inc	

Source: Prepared by Researcher.

Note. CR is based on the NatCatSERVICE database.

4.2 Research Models

This section provides an overview of the methodology used. The models were estimated to be using EViews

software. Initially, this study employed pooled ordinary least squares regression. Following this, necessary tests were conducted to determine whether the random effects model or the fixed effects model was more suitable for analyzing the relationship between the variables. Ultimately, the study utilized fixed effects modeling for the panel data regression analysis. The following model was estimated in this study.

$$(\widehat{BSI})_{it} = \alpha_0 + \beta_1 CR_{it} + \beta_2 BM_{it} + \beta_3 DCPB_{it} + \beta_4 GDP\_G_{it} + \beta_5 INF_{it} + \beta_6 Inc_{it} + e_{it} \quad (4)$$

Where i represents country, t is year, e_{it} is the error term, and a is the intercept: β_j is the estimated regression coefficient for the variables; j = 1, 2 ,3…6; assuming it follows a normal distribution.

5. Empirical Results

Section 5 introduces descriptive statistics for all the variables included in the analysis, along with a correlation matrix, hypothesis testing, and robustness tests. Table 3 presents the descriptive statistics for the study variables, while the correlation matrix is displayed in Table 4.

5.1 Descriptive Statistics of the Main Variables

Table 3. Descriptive statistics for the study variables

Variable	N	Mean	Median	Minimum	Maximum	Std. Dev.	Skewness	Kurtosis	Jarque-Bera
CR	177	87.14486	92.00000	8.580000	126.1700	27.88810	-0.545215	2.629118	9.783596
Inc	177	2.062147	2.000000	1.000000	4.000000	0.917991	0.142193	1.711936	12.83238
BM	177	76.83562	69.33199	16.93331	260.6183	47.94101	2.029681	8.122382	315.0394
DCPB	177	46.40923	46.67629	2.680275	105.1871	27.49246	0.110430	1.866803	9.830252
GDP_G	177	3.628914	3.400000	-50.33852	86.82675	8.551785	3.714877	60.89063	25123.13
INF	177	4.558179	3.271702	-3.749145	35.55906	5.027089	2.619944	13.65275	1039.414
BSI	177	0.470377	0.478775	0.000000	0.971541	0.170401	0.013982	3.159862	0.194240
Z-score	177	25.58786	21.39767	7.201674	66.63377	12.57542	1.504013	4.867196	92.44297

Source: Outputs of data processing using EViews 12.

Table 3 presents the descriptive statistics for the variables used in the analysis. As indicated, the mean values for BSI and CR are 0.470377 and 87.14486, respectively. The standard deviation of BSI and CR are 0.170401 and 27.88810, respectively. The mean and the standard deviation of the Z-score are 25.58786 and 12.57542, respectively. The mean values of BM, DCPB, GDP_G and INF are 76.83562, 46.40923, 3.628914, and 4.558179, respectively. While the standard deviation of BM, DCPB, GDP_G and INF are 47.94101, 27.49246, 8.551785, and 5.027089, respectively.

Table 4. Correlation Matrix

Variable	**CR**	**Inc**	**BM**	**DCPB**	**GDP_G**	**INF**	**BSI**	**Z-score**
CR	1.000000							

Inc	0.116007	1.000000						
	0.1241	----						
BM	-0.165710	-0.076133	1.000000					
	0.0275	0.3139	----					
DCPB	-0.236845	-0.446198	0.673387	1.000000				
	0.0015	0.0000	0.0000	----				
GDP_G	-0.070814	0.002460	-0.052863	-0.082060	1.000000 ---			
	0.3490	0.9741	0.4847	0.2775				
INF	0.174105	0.348249	-0.192090	-0.360903	-0.140376	1.000000 ----		
	0.0205	0.0000	0.0104	0.0000	0.0624			
BSI	-0.165692	-0.363312	-0.105359	0.098819	-0.106061	-0.073760	1.000000 ---	
	0.0275	0.0000	0.1628	0.1907	0.1600	0.3292		
	-0.091250	0.277287	0.200616	0.177249	-0.039259	0.006202	-0.198450	1.000000
Z-score	0.2271	0.0002	0.0074	0.0183	0.6039	0.9347	0.0081	---

Source: Outputs of data processing using EViews 12.

Note. *p < 0.10; **p < 0.05; ***p < 0.01.

Table 4 presents the results of the correlation analysis for all independent variables. As indicated, there is a

significant negative correlation between the CR and BSI at a 0.05 level of significance. The correlation coefficient of Inc is significantly negatively related to BSI. The correlation coefficients of Inc, BM and DCPB are significantly positively correlated with Z-score. Despite this the correlation matrix does not show a significant correlation between the explanatory variables, as the correlation coefficients are below 0.8. This study observed that the variance inflation factors (VIFs) are less than 10, indicating that there is no multicollinearity problem in the regression model.

5.2 The Effect of Climate Risk on Financial Fragility

To investigate the effect of climate risk on financial fragility, this study initially employed pooled ordinary least squares regression. Following this, necessary tests were conducted to determine whether the random effects model or the fixed effects model was more suitable for analyzing the relationship between the variables. In the case of using BSI as the dependent variable, the study identified fixed effects modeling for the panel data regression analysis, as shown in Table 5. When the study conducted robustness test using an alternative measure of financial fragility, namely Z-score, it identified random effects modeling for analyzing panel data regression, as illustrated in Table 6.

Table 5. Climate risk and financial fragility in Arab countries

Variables Model	**BSI**	
	OLS	**FEM**
Constant	0.566927 **(**0.059252**) *****	0.707375 **(**0.112340**) *****
CR	-0.000995 **(**0.000438**) ****	-0.000857 **(**0.000383**) ****
BM	-0.000606 **(**0.000353**) ***	-0.000976 (0.001668)
DCPB	0.000106 **(**0.000706**)**	0.002221 **(**0.001646**)**
GDP_G	-0.002372 **(**0.001410**) ***	-0.001381 **(**0.001117**)**
INF	0.001273 **(**0.002629**)**	-0.000173 **(**0.002700**)**
Inc	-0.067299 **(**0.015592**) *****	-0.161949 **(**0.032168**) *****
R-squared	0.188212	0.605869
Adjusted R-squared	0.159561	0.546621
S.E. of regression	0.156216	0.114737
F-statistic	6.569055	10.22590
Prob (F-statistic)	0.000003	0.000000

Note. Each cell contains the estimated parameters, with Std. Error between brackets, where * denotes p-value of 10%, ** indicates 5% and *** denotes 1%.

The results indicate that the CR coefficient is negative and statistically significant ($P < 0.05$) with BSI, suggesting that as climate risk increases, financial fragility increases. The coefficient of Inc is significantly negative with respect to BSI. The BM and GDP_G coefficients are negative at a significant level of 10%, indicating the positive effect of BM and GDP_G on financial fragility. The effect of INF isn't noticeable on financial fragility. The results support the view that climate risk reduces financial stability and increases financial fragility, thus aligning with the findings of Liu et al. (2024). These results support the first hypothesis, indicating climate risk led to increase in the financial fragility in Arab region. Also, hypothesis 2 is verified. The results support the second hypothesis, indicating that financial fragility is driven by macroeconomic factors.

5.3 Robustness Tests

The study conducted robustness testing in two ways: first, by using an alternative measure of financial fragility, and second, by changing estimation method to ensure the reliance of the study's results.

5.3.1 Alternative Financial Fragility Measure

The study utilized an alternative measure of financial fragility, which is Z-score, and conducted pooled ordinary least squares regression. Subsequently, the study identified random effects modeling for analyzing panel data

regression based on the necessary statistical tests to determine the appropriate model, as shown in the following table. The Z-score which is calculated as the ratio of return on assets (ROA) plus the equity-to-asset fraction to the standard deviation of ROA. This study adopts the following model to ensure the reliability of the research results.

$$(Z - \widehat{SCORE})_{it} = \alpha_0 + \beta_1 CR_{it} + \beta_2 BM_{it} + \beta_3 DCPB_{it} + \beta_4 GDP\_G_{it} + \beta_5 INF_{it} + \beta_6 Inc_{it} + e_{it} \quad (5)$$

The results are consistent with the previous findings of this study, as shown in Table 6.

Table 6. Climate risk and financial fragility in Arab countries

Variables Model	Z-Score	
	OLS	**REM**
Constant	3.298693 **(**4.328557**)**	16.95328 **(**4.248295**) *****
CR	-0.021389 **(**0.031372**)**	-0.018815 **(**0.009900**) ***
BM	-0.012030 (0.025861)	0.124516 **(**0.039291**) *****
DCPB	0.184730 **(**0.051458**) *****	-0.127007 **(**0.040823**) *****
GDP_G	-0.021737 **(**0.103285**)**	-0.037946 **(**0.029463**)**
INF	-0.004389 **(**0.190661**)**	0.079427 **(**0.071780**)**
Inc	6.197856 **(**1.141810**) *****	1.292226 **(**0.834541**)**
R-squared	0.190266	0.122491
Adjusted R-squared	0.162183	0.092057
S.E. of regression	11.46142	3.066571
F-statistic	6.775061	4.024840
Prob (F-statistic)	0.000002	0.000844

Note. Each cell contains the estimated parameters, with Std. Error between brackets, where * denotes p-value of 10%, ** indicates 5% and *** denotes 1%.

The coefficient of CR is negative and statistically significant with the Z-score, indicating that as climate risks increase, financial fragility rises. The positive and statistically significant coefficients for both BM and Inc with respect to the Z-score suggest that these factors contribute positively to financial stability. Conversely, the significantly negative coefficient for DCPB indicates that it may exacerbate financial fragility. This implies that as DCPB increases, it could lead to heightened risks within the financial system. Regardless of whether the fixed or random effects models are used, the estimated coefficient for climate risk remains significantly negative, indicating that the previous estimation results are consistent. This result confirms the positive effects of climate risk on financial fragility, supporting hypothesis 1.

5.3.2 Panel Generalized Method of Moments

To ensure the reliability of the research results, this study also conducted a robustness check using the Panel Generalized Method of Moments (GMM) through error components, as well as the Generalized Least Squares (EGLS) method and cross-sectional weighting methods.

The results indicate that the climate risk estimated coefficients are significantly negative, suggesting that the positive effect on financial fragility. This finding implies that as climate risk increases, they can contribute to greater financial fragility. Moreover, the robustness of these results strengthens the validity of the study's conclusions. The results of this study are consistent with the findings of Liu et al. (2024). The positive and statistically significant coefficient for BM with respect to the Z-score suggest that this factor contribute positively to financial stability. The significantly negative coefficient for DCPB indicates that it may exacerbate financial fragility to some extent. The results also indicate that Inc has a significant negative impact on financial stability, while INF has a positive effect. These results confirm the first findings.

Table 7. The effect of climate risk on financial fragility

	Model 1 BSI	Model 2 Z-score
Constant	0.707572 **(**0.096974**) *****	16.95328 **(**4.131171**) *****
CR	-0.000566 **(**0.000285**) ****	-0.018815 **(**0.009754**) ***
BM	-0.001088 **(**0.001142**)**	0.124516 **(**0.044128**) *****
DCPB	0.002288 **(**0.001228**) ***	-0.127007 **(**0.041631**) *****
GDP_G	-0.000807 **(**0.000513**)**	-0.037946 **(**0.054259**)**
INF	0.004669 (0.002162) **	0.079427 (0.077506)
Inc	-0.158816 (0.036807) ***	1.292226 (1.265981)
R-squared	0.693991	0.122491
Adjusted R-squared	0.647990	0.092057
S.E. of regression	0.112085	3.066571

Source: Outputs of data processing using EViews 12.

6. Conclusion and Recommendation

This study inquires the effect of climate risk on the financial fragility across 18 Arab countries, divided into four categories based on income levels, during the period 2007-2019. This has been performed using an aggregate banking stability index, as measure of financial fragility. The outcomes reveal the climate risk has significant positive effects on financial fragility. The results indicate the significance of climate-related risks and various factors in explaining financial fragility, such as broad money, GDP growth, domestic credit to private sector by banks, and income have significant effects on financial fragility.

The robustness test was conducted using alternative measures of financial fragility and by changing the estimation method to ensure the reliance of the study's results. The results using both Z-score as the alternative measure and the panel generalized method of moments (GMM) model are consistent with this study's first outcomes. The study contributes to the literature by providing empirical evidence on the impact of climate-related risk on banking stability in Arab countries over 13 years and emphasizing that climate risk is source of risk for the financial system. However, the study has constraints related to data collection from 2007 to 2019 from 18 Arab countries, even though this is due to the availability of data regarding the global climate risk index.

The research insights of this contribution can inform policymakers and central banks to assess climate-related financial risks, highlighting the need for a better understanding of the effect of climate shocks on world financial system across countries. Furthermore, extending the data collection phase to investigate the effect of the other factors on financial fragility and incorporating various social and political contexts could provide additional insights. Further investigations could explore the impact of climate shocks on systemic risks and market risks worldwide.

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