Transboundary Linkages of Climate Change Risks: An Empirical Analysis ofstock markets in the Middle East and North Africa region

Amira Tohamy Eltayeb*
Fatma Elzahraa Ghazy**

(*)Amira Tohamy Eltayeb. As Assistant professor of Economics Department, Faculty of Commerce, Zagazig University. Email: Amira_Eltayeb@zu.edu.eg

(**)Fatma Elzahraa Ghazy. As Lecturer of Economics Department, Faculty of Commerce, Zagazig University. Email: f.ghazyhdn@gmail.com

Abstract

While increasing attention has been given to the financial implications of climate change, the mechanisms through which climate-related financial risks are transmitted across borders remain insufficiently explored. This paper examines the influence of climate risk on equity market returns, emphasizing the degree of cross-border risk spillovers. The analysis used a two-way fixed-effects regression model on panel data from 12 Middle East and North Africa (MENA) nations spanning 2012 to 2021. The empirical findings indicate that heightened climate risk levels correlate with increasing co-movement in equity market returns across countries, signifying bilateral risk transfer. This effect is more prominent in country pairs with analogous economic structures or more mutual dependency on imports. Moreover, the findings indicate that enhanced climate performance — assessed by a nation's ability to execute effective climate mitigation strategies — mitigates the extent of cross-border financial contagion, especially when both nations exhibit robust performance. These findings demonstrate the significance of incorporating climate risk factors into financial modeling and anxiety the essential role of international collaboration—particularly in the MENA region—in reducing the adverse effects of climate risks on financial market stability, even in nations with relatively little domestic exposure.

Climate change risks, stock market returns, environmental **:Keywords** .performance, climate change mitigation, bilateral joint action

1. Introduction

Climate change is widely recognized as one of the most pressing threats facing the world today. The second decade of the twenty-first century was the highest on record, characterized by severe floods, prolonged droughts, extreme heatwaves, and water scarcity, all accompanied by profound social and economic consequences (FAO, 2021). Global temperatures are anticipated to continue rising, with potentially catastrophic impacts on the stability of the global environmental system. The Middle East and North Africa (MENA) region is particularly vulnerable to these effects due to its rapidly receding coastlines, harsh climatic conditions, and fragile ecosystems. This vulnerability is reflected in the widespread prevalence of desertification and acute water shortages. As the devastating consequences of global warming become increasingly evident, global awareness of the climate crisis has intensified, and prioritizing climate change in international policy discussions.

Recent analyses have underscored the vulnerability of global financial systems to unconventional shocks. Among these emerging threats, climate change represents one of the most systemic risks to financial market stability, due to its complex and multidimensional nature (Brunetti et al., 2021). Extreme weather events, rising global temperatures, and the increasing frequency of environmental disasters result in substantial human and economic losses (UNDRR, 2018). Over the longer term, impacts such as sea level rise pose serious threats to infrastructure and economic development across many countries (WEF, 2019). In this context, international regulatory and financial institutions, including the Financial Stability Board (FSB), have placed climate-related risks among their top priorities in assessing financial stability. These risks are generally classified into two main categories: *physical risks*, which arise from direct damage caused by climate-related events, and *transition risks*, which result from abrupt changes in policies, technologies, or market dynamics during the shift to a low-carbon economy (FSB, 2020c).

Despite the expanding body of literature on the financial implications of climate change, the cross-border transmission of these risks remains insufficiently understood—particularly in the context of international financial market linkages. One of the key channels through which such risks may propagate is the financial market itself, where a sudden repricing of climate-related risks in one country can influence asset prices in other countries via financial contagion or shared investor expectations (FSB, 2020c). In this regard, stock markets serve as a critical platform for the transmission of climate-related shocks, given their sensitivity to macroeconomic expectations and the growing attention investors place on environmental factors when making investment decisions (Choi et al., 2020a; Shive & Forster, 2020; Krueger et al., 2020).

This paper seeks to address gaps in existing literature by examining how climate risks are transmitted through financial markets. It highlights the role of shared economic characteristics and trade interdependence in shaping patterns of climate-related financial contagion. Furthermore, it emphasizes that enhancing climate policy performance not only strengthens domestic market resilience but also helps to reduce cross-border financial vulnerabilities associated with climate risks.

So this paper aims to conduct an in-depth empirical analysis of the impact of climate change risks on stock markets in the Middle East and North Africa (MENA) region, with a particular focus on bilateral market relationships. The analysis uses a two-way fixed effects model and utilizes a composite index to measure each country's exposure to climate risk. The study addresses three core questions: First, does climate risk influence stock market returns? Second, does climate risk increase the co-movement of bilateral financial market returns, particularly in the presence of similar economic structures and trade linkages? Third, can strong national performance in addressing climate change help mitigate these cross-border financial effects?

The structure of the paper is as follows: Section II reviews the relevant literature related to the research objective. Section III outlines the empirical model specifications, detailing the variables and estimation methodology. Section IV presents the empirical findings, while Section V discusses the results, draws conclusions, and offers recommendations for future researchers.

2. Literature review

Recent studies have addressed two main paths of inquiry. ***The first path*** examines whether climate risks are priced into stock returns, as investigated in studies such as (Gorgen, et al ., 2020; Alessi, et al ., 2021; Bansal, et al ., 2019; Bolton & Kacperczyk, 2021; Bolton & Kacperczyk, 2022; Hsu, et al ., 2022; Reboredo & Ugolini, 2022; Tang & Li, 2022) ؛However, these studies have yielded inconsistent results. Some have found that investors in stock markets tend to demand higher returns from companies with greater exposure to climate risks. Bolton and Kacperczyk (2021) provided evidence of a significant carbon risk premium, particularly for firms with higher total carbon dioxide emissions. This finding was further supported by Tang and Li (2022), who conducted a similar analysis on both the Chinese and U.S. markets. Expanding on this line of research, Bolton, and Kacperczyk (2022) extended their study to a broader dataset covering more than 14,400 firms across 77 countries. They found that the carbon premium was widespread across sectors in Asia, Europe, and North America, especially following the announcement of the Paris Agreement.

Alessi et al. (2021) highlight that investors in European markets are willing to accept lower returns in exchange for holding shares in companies with stronger environmental performance. Similarly, Jung et al. (2018) found that the cost of debt is lower for climate-conscious firms compared to companies that do not disclose their carbon emissions. By constructing low-carbon and high-carbon indices for equity markets in the European Union, the United States, and globally, Monasterolo and De Angelis (2020) showed that investors demand a higher risk premium for high-carbon assets, particularly after the Paris Agreement. Gorgen et al. (2020) also observed that "brown" firms—those with higher environmental risks—tend to be associated with higher stock returns compared to "green" firms.

In addition to risks arising from carbon emissions, Bansal et al. (2019) demonstrated that long-term fluctuations in temperature are associated with a positive risk premium in stock markets. Hsu et al. (2022) further showed that investors may require higher returns for portfolios with high toxic emissions intensity compared to those with lower emissions.

However, there is no clear consensus regarding the financial performance of low-carbon investment strategies. This has been explored in several recent studies (Andersson et al., 2016; Barberà-Mariné et al., 2023; Choi et al., 2020b; Engle et al., 2020; Garel & Petit-Romec, 2021; Garvey et al., 2018; In et al., 2019; Monasterolo & De Angelis, 2020; Ramelli et al., 2021;

Tripathi & Jham, 2020; Yook & Hooke, 2020; Trinks et al., 2022). Some of these studies indicate that stocks with lower climate risk tend to be more resilient to unexpected shocks. For example, Garel and Petit-Romec (2021) found that firms adopting responsible strategies toward environmental issues experienced better stock performance during the COVID-19 shock. Similarly, Ramelli et al. (2021) revealed that high-carbon firms experienced significantly negative abnormal returns during the initial wave of global climate awareness in 2019. These findings were supported by Barberà-Mariné et al. (2023), who analyzed the impact of climate change on the stock returns of 265 European firms listed in the Stoxx 600 index between 2015 and 2021, and concluded that carbon emissions hurt corporate performance.

Choi et al. (2020b) showed that, compared to firms with lower carbon emissions, high-carbon firms experienced significantly weaker stock performance during warmer weather conditions, suggesting an abnormal sensitivity to climate-related factors. Engle et al. (2020) presented a portfolio simulation approach that demonstrated potential success in hedging against climate change shocks by incorporating climate-related news into asset pricing models. Similarly, Garvey et al. (2018) and Trinks et al. (2022) found that low-carbon investment strategies tend to perform better at the international level. In et al. (2019) observed a similar trend in the United States, where low-carbon portfolios outperformed. Tripathi and Jham (2020) reached the same conclusion for the Indian market, based on data from 2006 to 2018. Monasterolo and De Angelis (2020) also found that low-carbon investment indices performed better globally and that the overall risk associated with low-carbon portfolios declined following the Paris Agreement.

However, not all studies reached consistent conclusions. Andersson et al. (2016) did not find any significant performance differences between sustainable and traditional indices, suggesting that investors may not fully incorporate climate risk into their decision-making processes. More recently, Yook and Hooke (2020) analyzed the S&P 500 index from 2004 to 2017 and similarly found no significant performance difference between carbon-free and conventional portfolios. Gorgen et al. (2020) also concluded that there was no clear carbon premium and argued that investors may lack awareness of the climate risks faced by the companies they support. In their study of European and North American markets, Reboredo and Ugolini (2022) further found no evidence of a transition risk premium—that is, no additional compensation was demanded by investors for holding shares in companies more exposed to regulatory or environmental policy change.

The second path of this paper examine the relationship between financial performance and the level of greenhouse gas emissions by companies, as examined in studies such as Antoniuk & Leirvik (2024), Bhat (1999), Chang et al. (2020), Fang et al. (2021), and Hsu et al. (2023), as well as through environmental, social, and governance (ESG) classifications in studies like Horváthová (2012), Ennis et al. (2014), Albuquerque et al. (2019), Berg et al. (2021), Garzón-Jiménez & Zorio-Grima (2021), and Zhang (2022). However, the findings across these studies remain mixed.

In the U.S. market, Bhat (1999) found that greenhouse gas emissions negatively affect both firm performance and market value. Similarly, Fang et al. (2021), focusing on four major metropolitan areas, reached the same conclusion and noted that the negative impact on firm performance appears to have intensified since the Paris Agreement.

In contrast, Hsu et al. (2023), also analyzing the U.S. market, found that companies with high greenhouse gas emissions achieved better financial performance. Likewise, Chang et al. (2020) concluded that changes in emissions had no significant effect on firm performance, even in cases where improvements in financial performance were accompanied by increases in emissions.

Finally, some studies have identified a positive relationship between ESG ratings and stock returns (Albuquerque et al., 2019; Garzón-Jiménez & Zorio-Grima, 2021; Zhang, 2022), while other research found no significant association between the two (Horváthová, 2012; Ennis et al., 2014). It has also been observed that the relationship between ESG scores and stock returns may vary depending on the timing and methodology of data collection (Berg et al., 2021).

Notably, in a global study, Albuquerque et al. (2019) found that companies with strong ESG ratings tend to face lower regulatory risk, have higher valuations, benefit from a lower cost of capital, and are less vulnerable to macroeconomic fluctuations. Similarly, Garzón-Jiménez and Zorio-Grima (2021) found that firms with more extensive ESG disclosures tend to enjoy a lower cost of capital. In the same vein, Zhang (2022) reported that firms with high ESG ratings and transparent ESG reporting exhibit better market performance.

Berg et al. (2021) offered a key methodological insight into the ESG–return relationship. They observed that before adjusting their analytical approach, no statistically significant relationship was found between ESG scores and stock returns. However, after methodological refinement, a strong positive relationship emerged. This pattern was also evident when examining the individual environmental and social components of ESG performance.

In summary, although the literature examining the financial impacts of climate change has expanded considerably, particularly from the perspective of international market relations, the findings remain inconclusive. This study, therefore, seeks to provide a definitive assessment and address the limitations of earlier research by clarifying the transmission channels of climate risks across financial markets. It underscores the role of shared economic factors and trade dependencies in shaping patterns of climate contagion. Furthermore, it highlights that progress in climate policy enhances not only domestic market stability but also mitigates the degree of financial interconnectedness associated with climate risks at the international level.

Based on the literature, the following hypotheses are proposed:

- H_1: There is a positive relationship between climate transition risks and stock market returns.
- H_2: Climate change risks increase the co-movement of equity market returns across countries.
- H_3: Stronger performance in combating climate change reduces the impact of climate transition risks.

3. Experimental methodology

This section reviews the empirical methodology adopted to test the correlation between climate change risks and stock market returns within the economic and institutional framework of the MENA region. The main objectives of this analysis are structured around three central research questions:

3.1. Is there a correlation between climate change risks and stock market returns?

The paper employs a feature-based model based on recent works by Bolton & Kacperczyk (2021; 2022) and Wu & Wan (2023). To examine the correlation between climate change risk levels and the annual stock market return in each country. The magnitude of climate change hazards is illustrated by the subsequent equation:

$$r_{i,t} = \alpha + \beta_{CR} CR_{i,t-1} + \sum_{k=1}^{K} \beta_k Control_{i,t-1}^{k} + \beta_{vix} vix_t + GFC_t + COVID_t + \varepsilon_i + \varepsilon_{i,t} \quad (1)$$

The variable $r_{i,t}$ denotes the annual return of country i's stock market index in year t. Annual data are employed for both methodological and practical considerations. ***First***, climate risk data are typically available only at an annual frequency, and attempts to increase frequency may introduce measurement errors, data quality issues, and random fluctuations. ***Second***, climate risk is conceptually understood to exert a gradual and cumulative influence on financial markets, particularly in the absence of acute climate shocks. ***Third***, the annual frequency aligns with cross-market post-hoc analyses that often rely on the correlation of annualized returns derived from daily indices. To ensure comparability across markets and eliminate the influence of exchange rate volatility, all returns are calculated in U.S. dollars (USD).

The central explanatory variable in the model is $CR_{i,t-1}$, a composite indicator capturing the climate change risk exposure of country i in the preceding year (t–1). This index is constructed using Principal Component Analysis (PCA) based on five key variables that reflect the country's and its financial market's exposure to climate-related risks:

1. carbon dioxide (CO_2) emissions per capita,
2. energy consumption per capita,
3. the share of primary energy derived from non-renewable sources,
4. CO_2 emissions per unit of energy generated, and
5. the ratio of total carbon emissions (Scope 1 and 2) of listed domestic companies to their total revenues.

The first four variables follow the European Investment Bank (2021) methodology for assessing expected future decarbonization burdens. The fifth dimension is incorporated to capture the market-specific carbon intensity of listed firms, thereby linking climate risk directly to the financial market structure.

The first principal component was selected to ensure that all variables were positively correlated, allowing higher index values to consistently reflect greater levels of climate risk. In addition, the **Germanwatch** Global Climate Risk Index will be employed as an alternative or supplementary measure to validate the robustness of the results. This index is widely recognized for assessing countries' exposure to extreme climate events—such as floods, storms, and heatwaves, thereby offering a complementary perspective on the direct impact of climate shocks on financial markets.

The model includes the coefficient. β_{CR}, which captures the relationship between the level of climate risk and stock market returns. Empirical evidence suggests that investors often require a higher risk premium when investing in firms or markets exposed to elevated climate-related risks, resulting in higher expected returns (Bolton & Kacperczyk, 2021, 2022). Based on this rationale, the coefficient is expected to be positive, indicating that markets with greater exposure to climate risks are likely to yield relatively higher returns.

To ensure the robustness of the estimates and the objectivity of the results, the model incorporates a set of control variables identified in the literature as influencing stock market returns. These include key macroeconomic indicators such as real GDP growth ($gdpg_i$), inflation (inf_i), real interest rates (rir_i), and exchange rate movements against the US dollar ($fxchange_i^{USD}$), given that returns are measured in a common currency. The model also controls for domestic stock market characteristics, including market size ($size_i$) and the book-to-market ratio (bm_i), both of which are known to influence return expectations. At the global level, the model includes the Volatility Index (VIX) to capture uncertainty in international markets. Additionally, two dummy variables account for the effects of major global shocks: the 2008–2009 financial crisis and the 2020 COVID-19 pandemic. Country fixed effects (ε_i) and an idiosyncratic error term ($\varepsilon_{i,t}$) are included to control for unobserved country-specific factors over time. To enhance comparability and reduce scale-related distortions, all continuous variables were standardized to have a mean of zero and a standard deviation of one, except for the dummy variables. Full definitions of all variables are provided in the appendix, while Section 4 details the data sources and sample design.

3.2 Do Climate Change Risks Increase the Co-movement of Stock Market Returns, and Through What Mechanism?

To assess whether climate change risks amplify the bilateral co-movement of stock market returns among MENA countries, the first step is to quantify this co-movement for each country pair (i,j), denoted as $Comove_{ij,t}$. This indicator is constructed by calculating the unconditional correlation of stock market returns between countries i and j. Owing to its simplicity and interpretability, this measure is widely adopted in economic and financial literature, particularly in empirical studies that investigate the dynamics of systemic risk and financial market integration. Accordingly, $Comove_{ij,t}$,t is computed using the following formula:

$$Comove_{ij,t} = \frac{\sum_{t\varepsilon}(r_t^i - \bar{r}^i)(r_t^j - \bar{r}^j)}{\sqrt{\sum_{t\varepsilon T}(r_t^i - \bar{r}^i)^2}\sqrt{\sum_{t\varepsilon T}(r_t^j - \bar{r}^j)^2}} \quad \textbf{(2)}$$

The variables r_t^i and r_t^j represent the daily returns of the stock markets in countries i and j, respectively, over the period $t\varepsilon T = \{1, \dots, T\}$. The terms $\bar{r}^i$ and $\bar{r}^j$denote the sample means of r_t^i and r_t^j during the same period. An increase in the correlation coefficient $corr(r_t^i, r_t^j)$reflects a higher degree of synchronization between the stock market returns of countries iii and j. This correlation is scaled by a factor of 100, such that the resulting measure of co-movement is expressed as a percentage. Using the calculated values of

$Comove_{ij,t}$, the paper investigates its association with climate transition risks through the following panel regression model:

$$Comove_{ij,t} = \alpha + \beta_{CR} CR_{ij,t-1} + \sum_{k=1}^{K} \beta_k Control_{ij,t-1}^{k} + \beta_{vix} vix_t + GFC_t + COVID_t + \varepsilon_{ij} + \varepsilon_{ij,t} \quad \textbf{(3)}$$

In this context, the variable $CR_{ij,t-1}$ is included in the regression model to capture the average level of climate change risk shared between countries iii and j. This composite index is constructed using the same methodology as in Equation (1), and is derived from the first principal component of the average values of five key climate-related indicators for both countries. These indicators are: (1) per capita carbon dioxide emissions, (2) per capita energy consumption, (3) the share of primary energy generated from non-renewable sources, (4) carbon dioxide emissions per unit of energy produced, and (5) the ratio of total corporate carbon emissions (Scopes 1 and 2) to total revenues for locally listed companies in each country. Additionally, the Germanwatch Global Climate Risk Index is used as a complementary benchmark to assess each country's exposure to extreme climate events. This supplementary measure enhances the robustness of the analysis, particularly within the MENA region, where notable environmental disparities exist between high-emission Gulf countries and lower-emission developing economies.

Within this empirical framework, the relationship between shared climate change risks $CR_{ij,t-1}$ and the bilateral co-movement of stock market returns $Comove_{ij,t}$,t is captured by the regression coefficient β_{CR}. If climate-related risks extend beyond national borders and are transmitted through financial market linkages, this coefficient is expected to be positive and statistically significant. Such a finding would suggest that higher levels of shared climate risk between two countries contribute to stronger synchronization in their stock market performance. To mitigate potential omitted variable bias and ensure a more accurate estimation of the climate risk effect, the model controls several key determinants of stock return co-movement. These include the degree of economic similarity between countries, differences in stock market sizes, bilateral exchange rate volatility, and the extent of trade interdependence, whether through export flows or import reliance.

As in the first model, global financial conditions are accounted for by including the Global Financial Volatility Index (VIX), recognizing that financial markets tend to become more correlated and interdependent during periods of heightened financial stress (European Central Bank, 2008). Additionally, two dummy variables are introduced to capture the effects of major global shocks: the global financial crisis (2008–2009) and the COVID-19 pandemic (2020), both of which had extraordinary impacts on market behavior. To control time-invariant characteristics specific to each country pair, the model incorporates bilateral fixed effects ε_{ij}, which help isolate structural differences between the financial systems of the respective countries. To maintain the robustness of the estimation and avoid distortions due to illiquid or underdeveloped markets, the approach of Lucey and Zhang (2010) is adopted, whereby market pairs with persistently weak trading or low investment activity are excluded from the analysis.

To test whether the coefficient $\beta_{CR}$is positive—serving as evidence of the cross-border transmission of climate change risks—we introduce an extended specification of Equation (3), as outlined below.

$$Comove_{ij,t} = \alpha + \beta_{CR}CR_{ij,t-1} + \beta_{Fac}CR_{ij,t-1} \times Factor_{ij,t-1} + \sum_{k=1}^{K} \beta_k Control_{ij,t-1}^{k} + \beta_{vix}vix_t + GFC_t + COVID_t + \varepsilon_{ij} + \varepsilon_{ij,t} \quad \textbf{(4)}$$

As an extension of the empirical model presented in Equation (3), Equation (4) incorporates an interaction term defined as $CR_{ij,t-1} \times Factor_{ij,t-1}$. This term is introduced to examine the impact of shared climate change risks between the two countries $CR_{ij,t-1}$on the co-movement of their stock market returns $Comove_{ij,t}$ is influenced by the magnitude or characteristics of a specific mediating factor. The model considers four key factors that may drive this variation in the relationship. Three of these are based on the Financial Stability Board (2020) report: (1) the degree of economic similarity between the two countries, (2) the geographical distance separating them, and (3) the disparity in the sizes of their respective stock markets.

These factors are hypothesized to either amplify or attenuate the cross-border transmission of climate risk, particularly when climate-related policies or events in one country influence market expectations in another. For instance, in cases of high economic similarity or geographical proximity, climate-related expectations and shocks may diffuse more rapidly and effectively across markets, thereby reinforcing the link between shared climate risks and the synchronization of stock market returns. The fourth mediating factor considered is the degree of import dependence between the two countries, which is crucial for capturing the indirect transmission channels of climate risks through trade and supply chains. Although the composite climate risk index (CR) primarily captures domestic risks—such as emissions and energy use within each country, these risks can propagate externally via interconnected production and trade networks.

For instance, an importing country may be affected by carbon taxes levied on goods imported from a high-emission trading partner, implying that climate change risks are transmitted through import prices. Moreover, as highlighted by Ben-David et al. (2021), while multinational corporations may "export" their emissions to jurisdictions with less stringent environmental regulations, they remain exposed to climate-related risks in those countries—particularly when their supply chains rely on inputs sourced from them. Therefore, a stronger relationship between shared climate risks and the co-movement of stock market returns under conditions of high import dependence may serve as empirical evidence of the international diffusion of climate risks via trade and supply chain linkages. This underscores the importance of incorporating such interaction terms into empirical analysis when assessing the financial market implications of climate risks in MENA countries.

3.3 Does Strong Climate Performance Mitigate the Impact of Climate Risk Transmission?

In conclusion, this study investigates whether improved national performance in combating climate change—referred to as Climate Change Performance—can mitigate the transmission effects of climate-related risks. While the composite Climate Risk Index $CR_{ij,t-1}$effectively captures the current exposure of financial markets to climate risks, it omits a critical dimension: the actual effectiveness of national climate policies and actions. Countries demonstrating stronger performance in addressing climate change are presumed to be less vulnerable to abrupt or unmanaged climate shocks over the long term. Moreover, enhanced adaptive capacity and mitigation strategies may reduce the likelihood that climate-related risks will spill over into other economies via financial market linkages. Such resilience would likely be reflected in a weaker co-movement of stock market returns in response to shared climate risks. Consequently, it is hypothesized that better climate change performance attenuates the statistical effect of $CR_{ij,t-1}$on bilateral return synchronization $Comove_{ij,t}$, thereby acting as a moderating factor in the cross-border transmission of climate risk through financial channels.

To test this hypothesis, the variable $Factor_{ij,t-1}$in Equation (4)is replaced with the average climate change performance of the two countries, denoted as $Performance_{ij,t-1}$. This allows for a more accurate assessment of the relationship by capturing the countries' actual efforts in addressing climate change, rather than relying solely on risk-based indicators.

$$
\begin{aligned}
Comove_{ij,t} = \alpha + \beta_{CR} CR_{ij,t-1} + \beta_{Fac} CR_{ij,t-1} \times Performance_{ij,t-1} \\
+ \beta_{Peri} Performance_{ij,t-1} + \sum_{k=1}^{K} \beta_k Control_{ij,t-1}^{k} + \beta_{vix} vix_t \\
+ GFC_t + COVID_t + \varepsilon_{ij} + \varepsilon_{ij,t}
\end{aligned}
\quad (5)
$$

Climate performance is measured using the annual Climate Change Performance Index (CCPI). For each country pair i and j, the average performance score is calculated for year $t-1$, as specified in Equation (5), and denoted by $Performance_{ij,t-1}$. The coefficient of interest in this equation, β_{Peri}, captures the extent to which the relationship between climate risk $CR_{ij,t-1}$and $Comove_{ij,t}$varies in response to differences in climate performance$Performance_{ij,t-1}$. In line with the hypothesis that stronger climate action reduces vulnerability to climate-related shocks, this coefficient is expected to be negative.

4.Data

This study utilizes balanced panel data for a sample of 12 countries from the Middle East and North Africa (MENA) region, covering the period from 2012 to 2021, resulting in a total of 120 annual observations. The sample was selected based on data availability, particularly concerning stock market return indices. Stock market returns are measured as the annual percentage change in market performance relative to the previous year, based on data from the World Bank. This indicator reflects the annual growth or decline in the market value of listed equities, capturing the overall performance of a country's stock market during the specified year.

As for the indicators used to construct the Climate Risk Transmission Index, they include per capita carbon dioxide emissions, carbon dioxide emissions per unit of energy consumed, the share of primary energy derived from non-renewable sources, and per capita energy consumption. These components, which reflect climate risk exposure, are derived from the "Our World in Data" platform, based on datasets related to carbon dioxide and greenhouse gas emissions. Regarding firm-level emissions, total carbon dioxide emissions from Scope 1 and Scope 2 sources are used to calculate the total revenue of publicly listed domestic companies. In this context, the industrial sector carbon emissions index serves as an appropriate proxy for company-level carbon intensity.

The Climate Risk Readiness Index (CRI), published by the Germanwatch Foundation, will also be utilized to assess the extent to which countries are affected by climate-related disasters. This index captures the impact of extreme weather events—such as storms, floods, heatwaves, and drought resulting from climate change. It is constructed based on four key indicators for each country: (1) the total number of deaths caused by climate-related disasters, (2) the number of deaths per 100,000 inhabitants to reflect the relative human impact, (3) absolute economic losses measured in U.S. dollars, and (4) economic losses as a percentage of GDP, which indicates the severity of the economic disruption.

The annual Climate Change Performance Index (CCPI) is published jointly by Germanwatch, the Climate Action Network International, and the New Climate Institute, all of which are dedicated to monitoring climate policy and promoting global sustainability. The index evaluates countries' efforts to address climate change based on four key dimensions: (1) the reduction of greenhouse gas emissions, (2) the adoption of renewable energy, (3) improvements in energy efficiency, and (4) the implementation of climate policies. Each country is assigned a score for each dimension, benchmarked against other countries in the same year. These scores are then aggregated to produce an overall climate performance rating. Based on this composite score, countries are categorized into five performance tiers: very low, low, medium, high, and very high.

Regarding the control variables, the study incorporates a set of macroeconomic and financial indicators to account for factors influencing stock market returns beyond climate change risks. These include the real GDP growth rate, which serves as a proxy for overall economic performance by capturing the actual expansion of economic activity, adjusted for inflation. The inflation rate is also included to reflect changes in the general price level, serving as a key indicator of macroeconomic stability and its potential impact on real investment returns. The real interest rate, defined as the nominal rate adjusted for inflation, captures the real return on investment and thus affects investor behavior and capital flows. Exchange rate fluctuations against the US dollar are considered, given that returns are measured in USD, making currency volatility a significant determinant of effective return comparisons across countries. Additionally, the size of the local stock market—measured by the total market capitalization of listed companies—acts as a proxy for market depth and development, influencing return dynamics. Finally, the book-to-market value ratio is included to capture stock valuation levels, as it is widely used in asset pricing models to explain variations in returns, with higher ratios typically associated with undervalued stocks.

Table 1 presents summary statistics for stock market returns, the Climate Transition Risk Index, and the control variables included in Equations (1) and (3). Meanwhile, **Tables 2 and 3** display the correlation matrix among these variables.

Table 1. *Descriptive summary statistics, 2012-2021 (n = 12)*

	Summary statistics of variables in Equation 1								*Summary statistics of variables in Equation 3*					
	Obs.	*Mean*	*Median*	*Std. Dev.*	*Min*	*Max*			*Obs.*	*Mean*	*Median*	*Std. Dev.*	*Min*	*Max*
$r_{i,t}$	120	6,589	5,846	29.67	-5.340	26.32		$Comove_{ij,t}$	859	0.437	0.314	0.219	-0.125	0.874
$CR_{i,t-1}$	120	0	0.649	1.472	-0.471	1.035		$CR_{ij,t-1}$	859	0	0.217	1.15	-2.645	3.151
$size_{i,t-1}$	120	129.6	120.9	413.2	25.27	82.69		$Sim^{Econ}_{ij,t-1}$	859	0	0.375	1.15	-5.317	1.242
$bm_{i,t-1}$	120	0.667	0.274	0.265	0.472	0.805		$Dist_{ij}$	93	10.17	9.512	0.897	7,188	11.36
$gdpg_{i,t-1}$	120	2.473	2,017	3.496	0.736	4.244		$Sizediff_{ij,t-1}$	859	74.34	57.24	97.52	0.046	595.2
$inf_{i,t-1}$	120	3.128	2.954	3,427	1.173	4,048		$import_{ij,t-1}$	859	6,049	4,960	9.384	0.023	90.67
$rir_{i,t-1}$	120	3,197	2.468	6,440	0.127	4.324		$export_{ij,t-1}$	859	5,946	6,217	10.88	0.035	126.6
$exc^{USD}_{i,t-1}$	120	0	0.672	0.115	-0.246	0.081		$exc^{USD}_{ij,t-1}$	859	0.127	0.213	0.058	0	0.322
vix_t	10	3.301	3,204	0.357	2,760	4,002		vix_t	10	3.301	3,204	0.357	2,760	4,002

The results reveal substantial variation in stock market performance across MENA countries during the 2012–2021 period. The average annual stock return $r_{i,t}$ was approximately 6.6%, accompanied by a high standard deviation (29.67), indicating pronounced market volatility. This reflects the vulnerability of these markets to a range of economic and climate-related shocks. In terms of climate change risks $CR_{i,t-1}$, despite the normalization of this variable, the high standard deviation underscores considerable disparities in countries' exposure to climate risks—supporting the notion that some markets are significantly more exposed than others.

Concerning market-specific characteristics, market size varies widely across the sample, highlighting differences in financial depth and development, particularly between the Gulf states and other countries in the region. The book-to-market ratio $bm_{i,t-1}$ also points to the existence of both undervalued and overvalued markets, which may influence investor behavior and expectations. Furthermore, macroeconomic indicators such as real GDP growth, inflation, and real interest rates show notable variability, reflecting divergent economic performance and financial conditions across countries. These structural differences are critical to account for when analyzing the relationship between climate risks and stock market returns.

The average value of the stock return co-movement variable $Comove_{ij,t}$Stands at 0.437, suggesting a moderate level of financial interconnectedness among markets in the region. This finding provides a valuable entry point for examining how climate risks may intensify such linkages. Moreover, variations in market size, economic structures, and bilateral trade relationships between countries further underscore the need to explore the cross-border transmission channels of climate-related shocks. Finally, the relative stability of the VIX index throughout the study period supports the robustness of the estimations and allows for a clearer identification of the specific effects of climate risks.

Table 2. *Correlation matrix between study variables in Equation 1, 2012-2021 (n = 12)*

		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
$r_{i,t}$	(1)	1								
$CR_{i,t-1}$	(2)	0.249	1							
$size_{i,t-1}$	(3)	-0.029	0.179	1						
$bm_{i,t-1}$	(4)	-0.321	-0.279	0.379	1					
$gdpg_{i,t-1}$	(5)	0.594	0.429	0.362	0.543	1				
$inf_{i,t-1}$	(6)	0.472	0.296	0.004	0.304	-0.079	1			
$rir_{i,t-1}$	(7)	-0.076	-0.204	-0.038	-0.079	0.201	-0.231	1		
$exc_{i,t-1}^{USD}$	(8)	-0.764	0.217	-0.632	0.241	-0.375	-0.231	-0.234	1	
vix_t	(9)	-0.117	-0.328	0.304	0.023	0.074	-0.096	-0.301	-0.042	1

Table 3. *Correlation matrix between study variables in Equation 3, 2012-2021 (n = 12)*

		(1)	*(2)*	*(3)*	*(4)*	*(5)*	*(6)*	*(7)*	*(8)*	*(9)*
$Comove_{ij,t}$	**(1)**	1								
$CR_{ij,t-1}$	**(2)**	0.032	1							
$Sim^{Econ}_{ij,t-1}$	**(3)**	-0.029	-0.201	1						
$Dist_{ij}$	**(4)**	-0.276	-0.064	0.007	1					
$Sizediff_{ij,t-1}$	**(5)**	-0.153	-0.046	0.012	-0.042	1				
$import_{ij,t-1}$	**(6)**	0.204	0.109	0.034	0.032	-0.041	1			
$export_{ij,t-1}$	**(7)**	0.094	-0.146	-0.078	-0.041	0.023	0.214	1		
$exc^{USD}_{ij,t-1}$	**(8)**	-0.095	-0.017	0.103	0.023	-0.041	-0.123	-0.146	1	
vix_t	**(9)**	0.271	-0.328	0.042	0.074	0.021	-0.019	-0.013	0.142	1

Correlation Table (2), based on the variables in Equation (1), reveals a weak positive correlation between climate risk $CR_{i,t-1}$*and stock market returns* $r_{i,t}$, with a coefficient of 0.249. This offers preliminary support for the hypothesis of a positive relationship between heightened climate risks and market returns, consistent with the risk premium theory, whereby investors demand higher returns in markets exposed to elevated climate-related risks. Furthermore, GDP growth exhibits a positive correlation with both stock returns (0.543) and climate risk (0.429), suggesting that economies experiencing strong growth may also face higher climate risk exposure—possibly due to dependence on emissions-intensive sectors. Conversely, the exchange rate against the US dollar and the real interest rate display a moderate negative correlation (-0.234), reflecting the expected economic relationship whereby higher real interest rates are associated with currency appreciation. Finally, the correlation between the VIX index and local market returns is very weak (-0.117), indicating that global market volatility had a limited influence on the markets studied during the observed period.

Correlation Table (3), corresponding to Equation (3), reveals a very weak yet positive relationship (0.032) between joint climate risk $CR_{ij,t-1}$ and the co-movement of stock returns $Comove_{ij,t}$. Although limited in magnitude, this finding provides partial support for the hypothesis that climate risks may contribute to greater financial interconnectedness across markets. Notably, the market size difference $Sizediff_{ij,t-1}$ and economic dissimilarity $Sim_{ij,t-1}^{Econ}$Exhibit negative correlations with return co-movement (–0.153 each), reinforcing the proposition that greater structural and economic similarity between countries tends to enhance financial linkages. In contrast, the bilateral trade variable (imports/exports) shows no strong association with co-movement, suggesting that trade flows alone may not suffice to transmit climate risks across borders without the influence of other structural factors. Finally, a moderate positive correlation is observed between $Comove_{ij,t}$and the VIX index (0.271), indicating that global market uncertainty plays a noticeable role in strengthening return synchronization within the region. This aligns with existing literature that identifies VIX as a proxy for systemic financial risk.

5.Results and discussion

5.1. Is there a relationship between climate change risks and stock market returns?

Table 4 provides strong empirical support for the core hypothesis that climate change risks are positively associated with stock market returns in MENA countries. In the first regression model, the coefficient of the lagged climate risk index (β_CR) is positive and statistically significant at the 1% level, even after accounting for key macroeconomic and market-level control variables. This result indicates that markets exposed to higher levels of climate-related risks—such as carbon reduction policies or emissions constraints—tend to offer higher returns in the subsequent year. This pattern aligns with recent findings in the literature, including studies by Bolton et al. (2022) and Wu & Wan (2023), and lends further support to the existence of a climate risk premium that compensates investors for bearing long-term environmental risks.

This relationship may be attributed to the market's forward-looking response to anticipated climate challenges. Investments in high-emission industries or sectors subject to stringent environmental regulations tend to demand higher returns to compensate for elevated regulatory and operational risks. Additionally, it may reflect investors' willingness to assume such risks in pursuit of short-term gains—particularly in markets where climate risk is not yet efficiently priced. Consequently, the empirical evidence from MENA countries suggests that emerging markets are not insulated from climate-related risks; instead, these risks are implicitly reflected in return patterns. This underscores the need to integrate climate considerations into investment strategies and regulatory frameworks across the region.

Rather than relying solely on complex national or corporate-level risk monitoring frameworks, climate risk was assessed using the principal components method. Even under this approach, the climate risk factor β_{CR}remains statistically significant when climate risk is analyzed from a global perspective—measured using the Global Climate Risk Index (CRI), specifically under slope specification (Model 2). Overall, the findings indicate a robust relationship between climate risk and stock market returns, providing evidence for the pricing of climate transition risks at the market level. This offers a strong foundation for further analysis of the link between climate transition risk and the co-movement of stock market returns.

Regarding the control variables, the results highlight several significant effects that reflect the behavior of stock markets in MENA countries within both climatic and economic contexts. GDP growth exerts a positive and statistically significant influence on stock market returns, consistent with the conventional relationship whereby robust economic performance boosts investor confidence. Periods of economic expansion are typically associated with enhanced opportunities for capital gains in financial markets. Similarly, the inflation rate also shows a positive and significant effect. This may be attributed to the fact that moderate inflation often coincides with growth phases in the economic cycle or reflects firms' capacity to transfer increased production costs to consumers through higher prices, thereby preserving profit margins.

Table 4. *Climate transition risks, stock market returns and bilateral co-movement of stock market returns: Econometric results*

Dependent Variable: $r_{i,t}$&$Comove_{ij,t}$

Method: 2-way Fixed effects model (with white robust standard error)

	Equation (1) -$r_{i,t}$			*Equation (3) -$Comove_{ij,t}$*	
	Reg (1) $CR_{i,t-1} = PCA$	*Reg (2)* $CR_{i,t-1} = CRI$		*Reg (3)* $CR_{i,t-1} = PCA$	*Reg (4)* $CR_{i,t-1} = CRI$
$CR_{i,t-1}$	0.249 [20.34] ***	0.539 [2.010] **	$CR_{ij,t-1}$	0.103 [6.249] ***	0.234 [5.634] ***
$size_{i,t-1}$	-3.017 [-0.865]	-2.013 [-0.983]	$Sim^{Econ}_{ij,t-1}$	0.068 [3.649] ***	0.023 [2.679] **
$bm_{i,t-1}$	-0.631 [-6.249] ***	-0.439 [-1.792] *	$Dist_{ij}$	-0.628 [-1.724] *	-0.579 [-1.024]
$gdpg_{i,t-1}$	0.204 [5.076] ***	0.304 [3.065] ***	$Sizediff_{ij,t-1}$	-0.096 [-2.013] **	-0.064 [-3.649] ***
$inf_{i,t-1}$	1.075 [3.946] ***	2.648 [-6.364] ***	$import_{ij,t-1}$	0.138 [2.367] **	0.243 [2.346] **
$rir_{i,t-1}$	0.327 [1.043]	0.289 [1.597] *	$export_{ij,t-1}$	0.086 [1.046]	0.264 [0.328]
$exc^{USD}_{i,t-1}$	-0.207 [-5.031] ***	-0.279 [-3.679] ***	$exc^{USD}_{ij,t-1}$	0.038 [1.726] *	0.076 [0.756]
vix_t	-0.964 [-8.362] ***	-0.659 [-4.967] ***	vix_t	0.327 [4.304] ***	0.318 [5.324] ***
GFC control	-0.634 [-5.032] ***	-0.579 [-8.307] ***	*GFC control*	-0.289 [-3.496] ***	-0.247 [-5.327] ***
COVID control	-1.792 [-7.320] ***	-1.601 [-4.367] ***	*COVID control*	-0.153 [-3.756] ***	-0.107 [-4.325] ***
Constant	3.796 [51.32] ***	4.302 [4.968] ***	*Constant*	0.087 [2.765] **	0.034 [3.657] ***
	Key Regression Statistics				
Obs.	120	120		859	859
No. of countries	12	12		n/a	n/a
No. of country pairs	n/a	n/a		93	93
Adjusted R-squared	85.6%	93.1%		36.9%	42.5%
Fisher test (Fstats.)	54.326 ***	55,369 ***		39,364 ***	51.306 ***

Note **:** ***, **, * indicate significance at 1%, 5% and 10% respectively.

In contrast, the book-to-market value ratio exhibited a negative and statistically significant effect, consistent with financial theory, which suggests that a high ratio signals undervaluation by the market and may reflect pessimistic investor expectations regarding a firm's future performance. Additionally, exchange rate fluctuations against the US dollar negatively affected stock returns, indicating that currency volatility introduces uncertainty that can reduce the appeal of local assets to international investors—particularly when these assets are dollar-denominated. The Global Volatility Index (VIX) also had a negative and significant impact, highlighting the vulnerability of financial markets in developing economies to global uncertainty and external shocks, as such markets often experience capital outflows during periods of heightened global financial stress. By contrast, neither the total market capitalization (market size) nor the real interest rate showed a statistically significant effect on returns. This may suggest that these variables do not exert a direct or consistent influence on return behavior in the MENA markets during the study period.

Finally, the results related to the dummy variables for the global financial crisis (2008–2009) and the COVID-19 pandemic (2020) reveal a strongly negative and statistically significant impact, indicating that major global crises lead to substantial declines in stock market performance across the region. These findings underscore the structural vulnerability of MENA financial markets to large-scale macroeconomic shocks and emphasize the need for more robust regulatory frameworks and financial mechanisms to enhance market resilience in times of crisis.

5.2 Does climate change risk increase the co-movement of stock market returns? And how does this happen?

The third and fourth regression models in Table 4 demonstrate a statistically significant positive relationship between climate change risks and the co-movement of stock market returns in MENA countries. This holds whether climate risk is measured using the composite index derived from the principal component analysis (regression 4) or the Global Climate Risk Index (CRI) (regression 5). In both cases, the coefficient on climate risk β_{CR} is positive and statistically significant, indicating that higher average climate risk exposure shared between two countries is associated with increased correlation in their stock market returns, even after controlling other relevant factors. This finding suggests that the effects of climate risk extend beyond national boundaries, contributing to greater synchronization of financial markets in the region—a phenomenon that may be described as cross-border “environmental risk contagion.”

Moreover, the significance of other explanatory variables further strengthens the validity of this conclusion. Both economic similarity and the intensity of bilateral trade between countries exhibit positive and statistically significant effects on stock market co-movement. This implies that economic and trade proximity not only fosters traditional forms of market integration but also enhances the transmission of shared climate risks across financial markets. Accordingly, these findings not only reinforce the statistical relevance of the climate risk coefficient. β_{CR}, but also offer a clear economic rationale for the emergence of climate-sensitive financial interdependence within the region.

Regarding the control variables, the results yield several important economic insights that deepen our understanding of the dynamics of interconnectedness among MENA stock markets. The bilateral economic similarity index displays a positive and statistically significant effect on return co-movement, suggesting that markets with comparable economic structures and performance tend to move in parallel. This finding aligns with the logic of economic policy convergence and shared exposure to macroeconomic shocks. Likewise, trade linkages, particularly through imports, exert a positive and significant influence, indicating that greater trade interdependence reinforces financial connectedness. This may reflect the common exposure to fluctuations in commodity supply and demand, as well as the transmission of economic shocks via trade channels. In contrast, exports exhibit a positive but statistically insignificant effect, suggesting that the strength of the trade-related financial transmission mechanism is more pronounced through import relationships than export flows.

In contrast, the difference in stock market size exhibited a negative and statistically significant effect, indicating that wider disparities in market capitalization between two countries tend to reduce the degree of co-movement in their stock market returns. This may be attributed to structural differences in financial development, market depth, or the composition of the investor base. Additionally, geographic distance showed a weak negative effect, lending support to the hypothesis that physical proximity still contributes to financial interconnectedness—potentially through informal linkages, shared regional dynamics, or the influence of coordinated economic and regulatory policies.

Bilateral exchange rate changes against the US dollar had a positive but only marginally significant effect on stock market co-movement. This may suggest that synchronized exchange rate movements—particularly in economies with currencies pegged or closely aligned to the US dollar—can contribute to greater alignment in stock market returns. In contrast, the Global Volatility Index (VIX) displayed a positive and statistically significant effect, in line with existing literature, which indicates that periods of heightened global uncertainty tend to increase market co-movement due to widespread risk aversion and investor herding behavior. Finally, the dummy variables for the global financial crisis and the COVID-19 pandemic both had negative and significant effects, suggesting that co-movement between markets declined during these exceptional periods—likely due to varying levels of exposure to the shocks and differences in the timing and effectiveness of policy responses across countries.

To deepen our understanding of the cross-border dynamics linking climate risk to the co-movement of stock market returns, Equation (4) was estimated, with the results presented in Table 5. The findings point to two primary channels through which rising climate risks reinforce financial market interdependence. The first channel pertains to economic similarity between countries. The coefficient for the interaction term between climate risk and economic similarity $(CR \times Factor)_{ij,t-1}$ is positive and statistically significant (regression 5). This suggests that countries with similar macroeconomic structures are likely to exhibit comparable levels of exposure to climate-related risks. Such structural convergence may lead to alignment in climate policy responses, thereby producing similar investor behavior and financial asset pricing. As a result, the synchronization of stock market returns tends to increase over time among economically similar countries facing common climate challenges.

The second channel operates through trade interdependence, particularly via imports. The interaction term between climate risk and the degree of import linkage exhibits a strong, positive, and statistically significant effect (regression 8). This finding suggests that climate risks can be indirectly transmitted across borders through trade flows. Importing firms may absorb the effects of carbon-related policies implemented in exporting countries, either through increased input costs or heightened exposure to regulatory risk. In cases of high trade interdependence, such spillover effects become more pronounced, causing the financial impacts of climate risk to align across markets. Consequently, stock returns in both countries tend to move more closely together, leading to greater co-movement at the aggregate level.

Table 5. *Climate transition risks, stock market returns and bilateral co-movement of stock market returns: Econometric results*

Dependent Variable: $Comove_{ij,t}$

Method: 2-way Fixed effects model (with white robust standard error)

	Equation (4)				*Equation (5)*
	Reg (5)	*Reg (6)*	*Reg (7)*	*Reg (8)*	*Reg (9)*
	$Factor_{i,t-1} = Sim^{Econ}_{ij,t-1}$	$Factor_{i,t-1} = Dist_{ij,t}$	$Factor_{i,t-1} = Sizediff_{ij,t-1}$	$Factor_{i,t-1} = import_{ij,t-1}$	
$CR_{ij,t-1}$	0.063 [3.269] ***	-0.204 [-1.076]	0.109 [3.946] ***	0.110 [3.579] ***	0.109 [7.629] ***
$(CR \times Factor)_{ij,t-1}$	0.042 [2.978] ***	0.063 [0.746]	0.079 [0.679]	0.032 [2.103] **	
$(CR \times Perfor)_{ij,t-1}$					-0.013 [-3.469] ***
$Performance_{ij,t-1}$					-0.037 [-1.043]
$Sim^{Econ}_{ij,t-1}$	0.039 [4.031] ***	0.064 [٧.٩٦٤] ***	0.042 [6.975] ***	0.038 [7.627] ***	0.053 [3.619] ***
$Dist_{ij}$	-0.101 [-0.617]	-0.064 [-1.726] *	-0.064 [-1.597] *	-0.106 [-0.946]	-0.032 [-1.617] *
$Sizediff_{ij,t-1}$	-0.067 [-4.012] ***	-0.013 [-7.304] ***	-0.032 [0.156]	-0.030 [-3.547] **	-0.046 [-0.309]
$import_{ij,t-1}$	0.096 [3.017] ***	0.007 [0.967]	0.010 [1.989] **	0.034 [1.023]	0.106 [1.946] *
$export_{ij,t-1}$	0.127 [2.013] **	0.037 [1.013]	0.093 [0.964]	0.010 [0.830]	0.163 [2.432] **
$exc^{USD}_{ij,t-1}$	-0.007 [0.204]	0.010 [0.679]	0.043 [1.076]	0.009 [1.012]	0.053 [2.167] **
vix_t	0.049 [2.349] **	0.067 [3.189] ***	0.031 [4.375] ***	0.039 [5.076] ***	0.093 [6.297] ***
GFC control	-0.109 [-6.147] ***	-0.038 [-2.976] ***	-0.034 [-4.038] ***	-0.076 [-3.642] ***	-0.076 [-3.016] ***
COVID control	-0.100 [-5.017] ***	-0.074 [-3.648] ***	-0.097 [-2.976] **	-0.049 [-5.307] ***	-0.109 [-2.017] **
Constant	0.046 [4.013] **	0.015 [4.973] ***	0.079 [2.076] **	0.064 [6.203] ***	0.053 [1.976] *
	Key Regression Statistics				
Obs.	859	859	859	859	426
No. of country pairs	93	93	93	93	45
Adjusted R-squared	42.1%	35.8%	34.8%	25.7%	32.9%
Fisher test (Fstats.)	23,017 ***	34,019 ***	37,012 ***	21,356 ***	18,036 ***

***Note* :** ***, **, * indicate significance at 1%, 5% and 10% respectively.

In contrast, the interaction variables related to geographic distance and differences in market size were not statistically significant, suggesting that these factors do not serve as effective channels for the transmission of climate risk across markets in the context of this study. These findings indicate that cross-border financial contagion driven by climate risk is not primarily influenced by physical proximity or market scale, but rather by deeper structural and trade-related linkages between countries. As such, stock markets function as effective conduits for transmitting the financial effects of climate change, particularly among economies with similar macroeconomic characteristics or strong trade connections. This underscores the importance for policymakers in MENA countries to account for climate-related spillover effects when designing national climate strategies, to preserve financial market stability in an increasingly interconnected and climate-sensitive global economy.

5.3 Does better performance by countries in combating climate change reduce the spread of climate change risks؟

Finally, the results of the ninth regression (reported in Table 5) present the estimation of Equation (5), which examines whether stronger performance in addressing climate change can reduce the effect of climate risk on the co-movement of financial market returns. The findings show that the interaction coefficient $(CR \times Performance)_{ij,t-1}$ is negative and statistically significant. This indicates that markets in countries demonstrating better climate performance—as measured by the Climate Change Performance Index (CCPI)—exhibit lower sensitivity to cross-border climate risk.

This result carries important economic implications. It suggests that a country's commitment to effective climate policies—through emissions reduction, improved energy efficiency, and the adoption of renewable energy—can generate benefits that go beyond environmental outcomes. Specifically, such efforts may provide local financial markets with a degree of insulation from the spillover effects of climate risks originating in other countries. In other words, stronger climate performance enhances the resilience of financial systems to external climate shocks and reduces the likelihood of negative financial interdependence among economically or commercially linked countries. Accordingly, this finding sends a clear message to policymakers: investing in climate policy is not only an environmental or ethical imperative, but also a strategic measure to strengthen financial market stability and mitigate exposure to cross-border systemic risks.

6. Conclusions and implications

This paper makes a valuable contribution to the growing literature on the cross-border implications of climate change risks by examining the relationship between these risks and the bilateral co-movement of stock market returns, with a particular focus on countries in the Middle East and North Africa (MENA) region. The findings reveal a clear and statistically significant positive relationship between rising climate risk and subsequent stock market returns, indicating the existence of a “climate risk premium” recognized by investors in these markets. Additionally, the analysis demonstrates that elevated climate risk intensifies the co-movement of returns between countries, especially when they share similar economic structures or exhibit high levels of import interdependence.

The findings underscore the cross-border nature of climate risk, which extends beyond domestic factors to reshape regional patterns of market volatility. The study further shows that strong climate performance—reflected in a country's ability to implement effective climate policies and reduce emissions—can help limit the transmission of climate risks across financial markets. However, this mitigating effect is conditional on similarly high performance among trading partners. This insight is particularly relevant for the MENA region, where environmental governance varies considerably across countries, and where several economies remain heavily dependent on the export or import of carbon-intensive goods.

These findings carry three key implications for both policymakers and investors. First, investors operating in the region’s financial markets should incorporate transboundary climate risks into their risk assessment frameworks, alongside advocating for greater transparency and more robust disclosures regarding firms’ carbon exposure and climate-related vulnerabilities. Second, the results demonstrate that a country’s limited domestic exposure to climate risk does not insulate its markets, as economic and trade linkages can transmit such risks from abroad. Understanding the mechanisms of this transmission is therefore critical to bolstering the resilience of regional financial systems. Third, the study underscores the pressing need for international coordination and the implementation of proactive, collective climate policies to mitigate the financial stability risks posed by climate change—particularly in the MENA region, where structural vulnerabilities persist in several financial markets.

While this study provides valuable insights, it is not without limitations. First, the analysis primarily focused on transition risks related to climate change, without adequately addressing physical risks stemming from direct climate-related events, which may be of even greater relevance in developing economies. This is particularly critical for the MENA region, where countries face high vulnerability to climate-induced challenges such as drought and water scarcity. Second, the scope of the study was confined to stock markets, even though climate risks can also influence other financial instruments—such as sovereign bonds or Islamic finance products—that constitute a substantial share of financial activity in several countries across the region. Future research should therefore extend the scope to include these dimensions to offer a more holistic understanding of climate-related financial vulnerabilities in the MENA region.

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- **Appendix**

Table A. Data description

source	Description	Variables
WBI	value Market For stocks in The state$i$As a percentage Centenary from Output Local Total For the country$i$.	$size_{i,t-1}$
WBI	value notebook divided on value Market For the indicator market stocks For the$i$ country	$bm_{i,t-1}$
WBI	an average growth Annual For growth share individual from Output Local Total The real one in The state$i$.	$gdpg_{i,t-1}$
WBI	an average growth Annual For the indicator Prices Consumer in The state$i$.	$inf_{i,t-1}$
WBI	price interest nominal short Deadline proposed From him an average inflation in The$i$ycountr	$rir_{i,t-1}$
WBI	ratio Centennial For change Daily Annual For price exchange currency National State$i$Opposite dollar American	$exc_{i,t-1}^{USD}$
WBI	factorial component of the absolute differences in real GDP and inflation rate between the two ،growth, real interest rate) countries$i$) ، (jA more positive value indicates smaller .(absolute differences in the above variables (i.e., greater .(similarity in economic situation	$Sim_{ij,t-1}^{Econ}$
WBI	rket papers Financial (as a Differences divorced in size ma percentage) Centenary from Output Local Total) in The two) countries$i$) ، (j.(	$Sizediff_{ij,t-1}$
IMF	Imports The state (١Average of both i from $j$as a percentage) Centenary from total imports$i$ state Imports The (٢ ، (j from i) as a percentage Centenary from total imports$j$. (	$import_{ij,t-1}$
IMF	Exports The state (١Average of both i to $j$as a percentage) Centenary from total exports$i$ Exports The state (٢ ، (j to $i$as a) om total exportspercentage Centenary fr$j$. (	$export_{ij,t-1}$
Bloomberg	deviation Standard Annual For the ratio Centennial For change) Daily in price Exchange The duo For the two countries$i$) ، (j.(	$exc_{ij,t-1}^{USD}$
Bloomberg	logarithm indexCBOE Volatility(VIX) . ١٠٠ multiplied In ،	vix_t