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Climate Risk and Financial Stability: Some Panel Evidence for the European Banking Sector

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CLIMATE RISK AND FINANCIAL STABILITY:
SOME PANEL EVIDENCE FOR THE EUROPEAN BANKING SECTOR

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Abstract

This study provides new panel evidence on the effects on climate risk on financial stability in the European banking sector using yearly data over the period 2000-2021. More specifically, the impact of a number of climate risk indices on the Z-score (capturing the probability of default of a country's banking system) is assessed after controlling for various macro and bank-related factors. The estimation is carried out using the GMM method. The analysis is also performed for two subsets of countries, namely EU (European Union) and non-EU ones. Finally, the role of governance quality is investigated. The results suggest that higher emissions growth tends to be associated with lower Z-scores, which indicate lower financial stability. However, the size of this effect differs between EU and non-EU European countries, suggesting that differences in policies, regulatory environments, and economic structures may influence how emissions growth affects financial stability across these areas. Our analysis also shows that the climate risk–financial stability relationship is affected by the quality of governance since the WGI (World Governance Index) does not appear to have a mitigating effect in non-EU countries with poorer governance.

Keywords: climate risk, financial stability, Z-score, Europe, panel data, GMM (Generalized Method of Moments) estimator

JEL Classification: C33, G12, G18

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1. Introduction

Climate change, namely the long-term shift in average temperatures and weather conditions, has come to the fore in recent decades as a fundamental threat to the planet Earth. The world is currently warming at a faster rate than ever before, mainly as a result of greenhouse gas emissions, with 2023 having turned out to be the hottest year since records began and this upward trend being expected to continue in 2024 and beyond (WMO, 2024). Such developments have taken place despite the actions taken by national governments to tackle global warming and its negative impact. In particular, a breakthrough was made at the UN Climate Change Conference (COP21) in Paris on 12 December 2015 when the Paris Agreement was signed by 195 parties (194 countries as well as the European Union). This treaty set some long-term goals including the commitment to reduce greenhouse gas emissions to keep the global temperature increase below 2°C above pre-industrial levels and possibly to limit it to 1.5°C above them. It required individual countries to develop Nationally Determined Contributions (NDCs), which are national climate action plans to reduce greenhouse gas emissions, in order to achieve the targets specified in the treaty. The NDCs are updated every five years, the third round being expected to take place in 2025, as the current commitments are clearly insufficient and more wide-ranging and effective measures are required to deal with global warming.

Climate change not only affects the physical environment and natural and human systems, but also has implications for the economy as a whole as well as for financial markets (Dafermos et al., 2018). In particular, three types of climate risk can affect financial stability (FSB, 2020): (i) "physical risk" reflecting the increasing impact on financial assets and liabilities of extreme weather events related to climate change; (ii) "transition risk" arising from policies designed to promote an adjustment towards a low-carbon economy, which can also decrease the value of financial assets and increase liabilities (OECD, 2021); (iii) "liability risk" for parties whose actions or omissions have caused environmental damage. A number of empirical studies have provided evidence concerning the significant impact of climate change on financial assets and risk (Dietz et al., 2016; Cevik and Jalles, 2022; Chenet et al. 2021; Roncoroni et al., 2021) and have also analysed the various transmission channels (King and Levine, 1993; Stolbova et al., 2018).

Some recent papers suggest that physical risk has become relatively more important for financial markets over time. For instance, Le Tran et al. (2023) showed that the return premium for this type of risk has been increasing compared to that for the transition risk. Further evidence was provided by Pagnottoni et al. (2022), who used a tailored event study methodology to investigate the effects of natural disasters in 104 countries on 27 global market indices. Their results indicate that climatological and biological hazards have a stronger impact on financial markets than meteorological and hydrological disasters.

The effects of physical risk specifically on financial stability is also the focus of a recent contribution by Liu et al. (2024). Their study investigates this issue by using panel data from 2007 to 2019 for 53 countries. More specifically, their model examines the impact of climate risk, measured by the Global Climate Risk Index constructed by German Watch, on the Z-score, which captures the probability of default of a country's banking system, after controlling for various bank-related and macro factors. Different estimation methods (Fixed effects – FE; random effects – RE; Generalized Method of Moments - GMM) and alternative measures of bank risk are used as a robustness check, and heterogeneity is also analysed by considering subsets of countries on the basis of their economic or financial development as well as of their competition level. Finally, the possible roles of macroprudential policies and governance quality are examined. Their findings indicate that physical risk has a negative impact on financial stability. However, its effects appear to vary across countries, being less severe in developed ones with a more advanced financial system, more effective macroprudential policies and better governance.

The present study is related to the Liu et al. (2024) one but differs from it in several respects. *First,* it provides more extensive evidence on a specific geographical area, namely Europe, which is more homogeneous. However, it includes both EU (European Union) and non-EU members, countries with some different features and legislation. This enables us to assess the effectiveness of EU climate-related policies and targets (Horn, 2024), as well as the possible role of membership in terms of reducing the impact of climate change on financial stability. In particular, the Europe 2020 Strategy was launched in 2010 to achieve sustainable growth by reducing greenhouse gas emissions by 20%, increasing the share of renewable energy to 20% of total energy consumption, and enhancing energy efficiency by 20% relative to 1990. More ambitious targets were then set by the 2020 Climate and Energy Package and the 2030 Climate and Energy Framework (introduced in 2008 and 2014 respectively), which aimed for a 40% reduction in greenhouse gas emissions, a 32% level for renewable energy, and a 32.5% improvement in energy efficiency compared to 1990.

Following the signing of the Paris Agreement, the European Green Deal (2019), which was incorporated into the European Climate Law (2021), set the target of making Europe the first climate-neutral continent by 2050 by reducing greenhouse gas emissions by at least 55% by 2030 compared to 1990 levels, investing in clean technologies, reducing pollution, promoting the circular economy, and safeguarding biodiversity. Finally, the Climate Adaptation Strategy (2021) has introduced measures to enhance the EU's resilience to climate change, with the Recovery and Resilience Facility providing financial support for this purpose.

Second, this study uses six different climate risk indices (emission growth rates for various greenhouse gases) that provide more detailed information on how climate change can affect financial stability. The existing literature mainly uses physical risk indices based on both acute and chronic risk. The former denotes sudden, episodic events causing substantial physical harm, such as wildfires, river and ocean flooding, and tropical storms. The latter instead refers to on-going processes such as sea level rise and increases in global mean temperature (Buhr et al., 2022). Both can result in financial losses or higher costs (Bua et al., 2022). It should be noted that that there is a lack of consensus concerning the most appropriate physical risk measures to use. For instance, both greenhouse emissions (Ciccarelli et al., 2024), precipitation (Muntaz et al., 2024) or indicators based on textual analysis (e.g., Bua et al., 2022; Ardia et al., 2023) have been proposed. The latter measures have the limitation of being specific to the set of news and reports considered. Our analysis instead uses climate change indices reflecting both physical and transition climate risks. This approach yields more comprehensive evidence on the impact of climate change on financial stability.

Third, this paper uses the system GMM (Generalized Method of Moments) estimator developed by Arellano and Bover (1995). This approach is more efficient than alternative ones and yields consistent parameter estimates in the context of dynamic panel data models.

The layout of the paper is the following: Section 2 outlines the econometric framework and describes the data; Section 3 presents the empirical results; Section 4 offers some concluding remarks.

2. Econometric Framework and Data

As already mentioned, the aim of the analysis is to provide panel evidence on the effects of climate risk on financial stability in the European banking sector. For this purpose, first the impact of various climate change indices on financial stability is investigated by estimating a dynamic panel data model for a sample of 41 European countries over the period 2000-2021. Next, the analysis is also performed for two subsets of countries, namely EU (European Union) and non-EU economies. Finally, an assessment is made of whether or not this relationship is affected by quality of governance by using an interaction term which sheds light on the possible role of this variable in mitigating the effects of climate change.

2.1 The impact of climate change indices on financial stability

To study the impact of climate change on financial stability we estimate a model of the following form:

$$\text{Z-score}_{i,t} = \alpha + \beta_{1,k}\text{CLI}_{i,t}^{k} + \text{CV}_{i,t}^{n} + \varepsilon_{i,t} \qquad (1)$$

where $\text{Z-score}_{i,t}$ is a measure of financial stability in the banking sector; $\text{CLI}_{i,t}^{k}$ stands for various climate change measures in turn, $\text{CV}_{i,t}^{n}$ represents a set of control variables, and $\varepsilon_{i,t}$ is the error term

The Z-score calculates the probability of bankruptcy as follows:

$$Z\text{-}score = \frac{Roa + \frac{Equity}{Assets}}{\sigma Roa} \qquad (2)$$

where Roa is the bank's return on assets, σRoa is the standard deviation of Roa (the volatility of returns), Equity stands for the bank's share capital, Assets denotes the bank's total assets, and Equity/Assets is Equity-to-assets ratio (the capital buffer).

The Z-score is a standard measure of financial stability which is widely used in the empirical literature, and thus is the most appropriate choice for our purposes. It enables us to evaluate the resilience of banks under different conditions and provides a consistent basis for comparison with existing research in the field. Higher Z-scores indicate greater stability and a lower bankruptcy risk, and thus characterize banks which are more resilient to shocks. By contrast, lower Z-scores indicate a higher risk of insolvency, implying that even relatively small shock can make the bank's equity go negative. These data can be obtained from the World Bank's Global Financial Development Databases.

In our analysis we examine the impact on financial stability of a number of climate change indices, namely the adjusted emissions growth rates for (i) carbon dioxide, (ii) methane, (iii) F-gases, (iv) nitrous oxide, (v) black carbon, and also (vi) greenhouse gas (GHG) emissions per capita. Using various climate change indices in our context is essential to obtain more comprehensive evidence since different indices capture different aspects of climate change as well as the corresponding risks. CO_2 is the biggest overall contributor to climate change because it is emitted in much greater quantities than other greenhouse gases and remains in the atmosphere for centuries. For this reason, the adjusted emissions growth rate for carbon dioxide is especially important for understanding the impact of climate change.

The GHG emissions per capita variable takes into account all major greenhouse gases that contribute to climate change. It is an aggregate index including Carbon Dioxide (CO_2), Methane (CH_4), Nitrous Oxide (N_2O), and Fluorinated Gases (F-gases). These greenhouse gases come from different sources, specifically: Carbon Dioxide (CO_2) from burning fossil fuels, deforestation, and industrial activities; Methane (CH_4) from agriculture (livestock, rice production), landfills, and fossil fuel extraction; Nitrous Oxide (N_2O) from fertilizers, industrial processes, and biomass burning; Fluorinated Gases (F-gases) from refrigerants, air conditioning, and industrial applications. These series are taken from a database constructed by Yale University.

As previously mentioned, there are three types of climate risks that can affect financial stability. The first is Physical Climate Risk, which includes climate-related extreme weather events such as hurricanes, floods, and heatwaves. The second is Transition Risk, arising from changes in policies, regulations, and market preferences related to carbon pricing, shifts in climate policy, and the transition to green energy. The third is Liability Risk, which involves potential legal actions and financial losses from climate-related litigation and stranded assets. Together, these risks capture the different ways in which climate change can affect financial systems.

The climate change indices selected for our study are linked to both Physical and Transition Climate Risks: to the former, because rising emissions lead to more frequent extreme weather events and to greater environmental degradation, thereby worsening the impact of climate change; to the latter, as changes in emissions are often linked to evolving policies, regulations, market dynamics, and technological advancements. The Adjusted Emissions Growth Rates we use specifically measure how a country's or industry's emissions are changing over time, which reflects economic activity, policy measures, and efficiency improvements. Thus, they are valuable indicators of the exposure to transition-related climate risks. Their definitions are provided in Table A1 in the Appendix.

The model also includes a set of control variables (CV), encompassing both macroeconomic and bank-specific factors, their selection being based on the theoretical and empirical literature discussed before. Specifically, the variables included are the following: GDPC - Growth Domestic Product per Capita; INFL – inflation rate (CPI growth rate); DCPS – Domestic credit to the private sector as a percentage of GDP; WUI– Word Uncertainty Index; WGI – World Governance Index. These data are extracted from the World Bank's Global Financial Development Databases and World Development Indicators; further details are provided in Table A2.

The World Governance Indicator (WGI) is a country-level index developed by Kaufmann et al. (2010) and is available from the World Bank's World Governance Indicators Data Bank. It includes six key dimensions of governance: voice and accountability, political stability and absence of violence or terrorism, government effectiveness, regulatory quality, rule of law, and control of corruption. The index scores range from −2.5 to 2.5, with higher values indicating stronger governance and better institutional quality.

The World Uncertainty Index (WUI), developed by Ahir et al. (2022), is a proxy for political and economic uncertainty. It is available on a quarterly basis from 1996 onward for 143 countries, with values ranging from 0 (indicating no uncertainty) to 1 (indicating maximum uncertainty). By relying on a single consistent data source across countries, the WUI facilitates comparative analysis of uncertainty levels globally. It effectively captures uncertainty related to economic and political events, reflecting concerns over both short- and long-term developments. This index is particularly valuable for analysing how different levels of uncertainty influence economic variables and for identifying the underlying drivers of uncertainty.

The general specification of the dynamic panel data model employed for the empirical analysis is the following:

$$\text{Z-score}_{\text{i,t}} = \alpha + \beta_0 \text{Z-score}_{\text{i,t}-1} + \beta_1 CLI_{i,t}^{k} + \sum_{n=1}^{N} \beta_{n+1} CV_{i,t}^{n} + \mu_i + \gamma_t + \varepsilon_{i,t} \quad (3)$$

The model is used first to assess the impact of various climate change indices on financial stability in Europe as a whole, and then in the EU and non-EU countries separately to establish whether there are any differences reflecting different climate policies. This approach provides a more thorough understanding of and new insights into the impact of climate change on financial stability in the banking sector. Analysing Europe as a whole allows us to assess the broader impact of climate change on financial stability in this geographical area. Specifically, a continental perspective enables us to identify risks that could propagate throughout the European financial system, regardless of national policy boundaries. Conducting the analysis for the EU versus non-EU subsets of countries is also important because these groups differ significantly in terms of climate policies, regulatory frameworks, economic structures, and institutions, and therefore this additional evidence yields further insights that are crucial for shaping resilient and forward-looking financial systems across the continent.

More specifically, the following regression, which includes various measures of climate change in turn and a set of control variables, is estimated:

$$\text{Z-score}_{\text{i,t}} = \alpha + \beta_0 \text{Z-score}_{\text{i,t}-1} + \beta_2 CLI_{i,t}^{k} + \beta_3 GDPC_{i,t} + \beta_4 INFL_{i,t} + \beta_5 DCPS_{i,t} + \beta_6 WUI_{i,t} + \varepsilon_{i,t} \quad (4)$$

The above is our benchmark specification to analyse the impact of climate change on financial stability in Europe. It is subsequently augmented to incorporate institutional quality in the European countries, with the aim of gaining deeper insights into the relationship of interest.

2.2. The Climate Change-Financial stability relationship and the quality of governance – can the latter play a role in mitigating the impact of climate change on financial stability?

To assess whether the climate change-financial stability relationship is affected by the quality of governance we introduce an interaction term between the various climate change indices and the World Governance Index (WGI), which is a proxy for institutional quality, with higher values indicating stronger governance and better institutions.

More precisely, the benchmark model is extended by adding an interaction variable, which results in the following specification:

$$\text{Z-score}_{\text{i,t}} = \alpha + \beta_0 \text{Z-score}_{\text{i,t}-1} + \beta_1 CLI_{i,t}^{k} + \sum_{n=1}^{N} \beta_{n+1} CV_{i,t}^{n} + \beta_{n+1} CLI_{i,t}^{k} \times WGI_{i,t}^{n} + \mu_i + \gamma_t + \varepsilon_{i,t} \quad (5)$$

where $CLI_{i,t_i}^{k} \times WGI_{i,t}$ is the interaction term between WGI and the measures of climate change indices used (CLI^{k}).

More explicitly, the estimated model including the control variables can be written as follows:

$$Z\text{-}score_{i,t} = \alpha + \beta_1 \text{Z-score}_{\text{i,t}-1} + \beta_2 CLI_{i,t}^{k} + \beta_3 GDPC_{i,t} + \beta_4 INFL_{i,t} + \beta_5 DCPS_{i,t} + \beta_6 WUI_{i,t} + \beta_7 WGI_{I,t} + \beta_8 CLI_{i,t}^{k} \times WGI_{i,t} + \varepsilon_{i,t} \quad (6)$$

As already mentioned, our panel contains yearly data for 41 European countries over the period 2000-2021.[1] For the econometric analysis, we employ the system GMM estimator developed by Arellano and Bover (1995), which combines a regression in differences with one in levels. This approach results in greater efficiency and consistent parameter estimation in dynamic panel data models. The consistency of the GMM estimator depends on two key conditions, namely the validity of the instruments used in the model as well as the assumption that the error term does not exhibit serial correlation. We select the instruments from the set of lagged endogenous and explanatory variables and use the Sargan test of over-identifying restrictions proposed by Arellano and Bond (1991) to test their validity.

As a first step, we perform a battery of panel unit root tests to examine the stationarity properties of the series. Specifically, we carry out the tests developed by Levin, Lin, and Chu (LLC, 2002), Harris and Tzavalis (1999), and Breitung (2000), which are widely used for detecting unit roots in panel data. These tests differ in their assumptions regarding cross-sectional independence and individual effects, providing a robust framework for establishing the integration order of the variables. Their results (not reported) imply that all the series used for the analysis are stationary in first differences, and thus are entered in this form into the estimated models.

3. Empirical Results

3.1 Estimates of the effects of climate change indices on financial stability

The GMM estimates for the impact of the various climate change indices on financial stability in Europe as a whole, and also on EU and non-EU countries separately, are displayed in Tables 1-3. Each column corresponds to a different climate change index. Various diagnostic tests (not reported) confirm that all the estimated models (including the expanded ones discussed later) are data congruent.

[1] EU countries: Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, United Kingdom.
Non-EU Countries: Albania, Bosnia and Herzegovina, Belarus, Iceland, Macedonia, Moldova, Montenegro, Norway, Russia, Serbia, Switzerland, Turkey, Ukraine.

Table 1: The impact of various climate change indices on financial stability in the case of the European countries

Index	CDA	CHA	FGA	NDA	BCA	GHP
	(1)	(2)	(3)	(4)	(5)	(6)
Z-score lagged	-0.484	-0.480	-0.479	-0.510	-0.485	-0.437
	(8.56)***	(7.90)***	(7.24)***	(8.97)***	(7.85)***	(8.74)***
CLI^k	-0.065	-0.113	-0.062	-0.132	-0.128	-0.480
	(2.24)**	(5.03)***	(3.50)***	(4.26)***	(7.44)***	(5.54)***
GDPC	0.190	0.196	0.143	0.264	0.082	0.203
	(6.33) ***	(8.69)***	(5.26)***	(7.26)***	(3.07)***	(7.66)***
INFL	-0.084	-0.035	-0.025	-0.093	-0.062	-0.057
	(4.12) ***	(2.46)**	(1.87)*	(4.19)***	(3.58)***	(3.44)***
DCPS	-0.114	-0.099	-0.096	-0.175	-0.061	-0.146
	(8.46) ***	(9.34) ***	(8.61) ***	(7.92) ***	(4.79) ***	(9.66) ***
WUI	-0.029	-0.196	-0.194	-0.051	-0.122	-0.236
	(0.20)	(1.75) *	(1.92) *	(0.31)	(1.68) *	(2.07) **
Constant	-0.180	-0.166	-0.206	-0.319	-0.145	-0.272
	(3.12) ***	(2.78) ***	(3.90) ***	(4.07) ***	(2.45) **	(3.79) ***
Observations	861	861	861	861	861	861
Ar (1)	-3.45	-3.47	-3.18	-3.37	-2.65	-2.26
	(0.001)	(0.000)	(0.002)	(0.001)	(0.008)	(0.024)
Ar(2)	0.71	-0.85	-0.82	1.02	-1.77	-1.43
	(0.476)	(0.397)	(0,413)	(0.308)	(0.076)	(0.152)
Sargan	1.61	6.72	2.86	0.03	1.43	2.71
	(0.447)	(0.152)	(0.239)	(0.641)	(0.49)	(0.258)

Note: Absolute value of the t statistics in parentheses; * significant at 10%; ** significant at 5%; * significant at 1%.**

Table 2: The impact of various climate change indices on financial stability in the case of the EU countries

Index	CDA	CHA	FGA	NDA	BCA	GHP
	(1)	(2)	(3)	(4)	(5)	(6)
Z-score lagged	-0.408	-0.407	-0.513	-0.420	-0.402	-0.335
	(8.48)***	(8.45)***	(9.41)***	(8.54)***	(8.83)***	(7.97)***
CLI^k	-0.041	-0.019	-0.053	-0.031	-0.078	-0.238
	(2.40)**	(0.77)	(3.56)***	(1.42)	(4.29)***	(2.53)**
GDPC	0.193	0.183	0.132	0.209	0.159	0.315
	(4.30) ***	(3.86)***	(2.93)***	(4.42)***	(2.77)***	(6.43)***
INFL	-0.009	-0.008	-0.003	-0.005	-0.034	-0.013
	(1.71) *	(1.68)*	(0.49)	(1.65)*	(2.18)**	(1.91)*
DCPS	-0.080	-0.072	-0.059	-0.102	-0.053	-0.128
	(4.18) ***	(3.38) ***	(3.30) ***	(5.47) ***	(5.45) ***	(6.95) ***
WUI	-0.031	-0.171	-0.089	-0.042	-0.105	-0.193
	(1.66) *	(2.53) **	(1.96) *	(1.78) **	(2.06) **	(2.75) ***
Constant	-0.177	-0.170	-0.182	-0.201	-0.252	-0.296
	(6.71) ***	(6.54) ***	(4.17) ***	(7.27) ***	(6.62) ***	(8.73) ***
Observations	588	588	588	588	588	588
Ar (1)	-2.68	-2.81	-2.79	-2.80	-2.72	-2.82
	(0.007)	(0.005)	(0.005)	(0.005)	(0.007)	(0.004)
Ar(2)	-0.42	-0.36	-0.37	-0.38	-0.34	-0.37
	(0.678)	(0.718)	(0.710)	(0.991)	(0.737)	(0.711)
Sargan	6.71	1.03	1.14	2.86	0.1	2.73
	(0.152)	(0.794)	(0.768)	(0.239)	(0.952)	(0.144)

Note: Absolute value of the t statistics in parentheses; * significant at 10%; ** significant at 5%; * significant at 1%.**

Table 3: The impact of various climate change indices on financial stability in the case of the non-EU members

Index	CDA	CHA	FGA	NDA	BCA	GHP
	(1)	(2)	(3)	(4)	(5)	(6)
Z-score lagged	-0.268	-0.197	-0.187	-0.200	-0.255	-0.194
	(4.99)***	(3.86)***	(4.23)***	(4.26)***	(5.31)***	(4.04)***
CLI^k	-0.222	-0.101	-0.112	-0.073	-0.094	-0.355
	(5.62)***	(3.97)***	(6.33)***	(2.86)***	(5.58)***	(9.70)**
GDPC	0.186	0.053	0.137	0.124	0.136	0.084
	(4.79) ***	(1.68)*	(3.40)***	(3.00)***	(3.87)***	(2.57)**
INFL	-0.056	-0.019	-0.089	-0.078	-0.064	-0.168
	(1.89) *	(1.78)*	(3.35)***	(2.42)**	(2.25)**	(4.02)***
DCPS	0.012	-0.039	-0.008	0.009	0.017	-0.010
	(1.69) *	(2.23) **	(0.46)	(0.65)	(1.85) *	(1.62)
WUI	-0.167	-0.274	-0.106	-0.204	-0.150	-0.261
	(2.06) **	(3.54) **	(1.65) *	(2.59) **	(1.73) *	(3.01) **
Constant	0.217	0.109	0.285	0.248	0.254	0.214
	(3.04) ***	(2.28) **	(3.85) ***	(3.42) ***	(4.01) ***	(2.96) ***
Observations	273	273	273	273	273	273
Ar (1)	-4.37	-5.71	-3.22	-3.56	-4.64	-4.01
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Ar(2)	-1.14	-0.94	-1.29	-0.97	-1.51	-1.08
	(0.252)	(0.346)	(0.197	(0.331)	(0.131)	(0.282)
Sargan	0.35	0.1	1.03	0.35	2.42	2.28
	(0.838)	(0.952)	(0.794)	(0.838)	(0.298)	(0.32)

Note: Absolute value of the t statistics in parentheses; * significant at 10%; ** significant at 5%; * significant at 1%.**

As can be seen from the reported results, the estimated impact of climate change on financial stability varies depending on the specific measure used, both for the full set of countries and for the two subsets considered. In particular, CDA (Adjusted emissions growth rate for carbon dioxide) and GHP (Greenhouse gas emissions per capita) have a negative and statistically significant impact, with relatively higher coefficient estimates. As previously discussed, CDA is one of the most important climate change indices, carbon dioxide emissions being one of the main causes of atmospheric pollution, and it is also closely linked to transition climate risk, since climate policies often respond to changes in CO_2 emissions performance. GHP, on the other hand, is an aggregate measure that captures more broadly greenhouse gas emissions, making it a more comprehensive indicator of climate change. Thus, both indices play a key role in explaining the link between climate risk and financial stability.

The effects of the adjusted emissions growth rate for all greenhouse gases on financial stability (measured by the Z-score) in Europe as a whole (including both EU and non-EU countries) are generally negative, namely higher emissions growth tends to be associated with a lower Z-score and thus to lower financial stability. However, the size of this effect differs between EU and non-EU European countries, suggesting that differences in policies, regulatory environments, and economic structures can influence how emissions growth affects financial stability in these two sets of countries.

Higher emissions growth reduces financial stability (as indicated by a lower Z-score) owing to both physical and transition climate-related risks. They contribute to climate change by increasing physical risks such as extreme weather events (including floods and heatwaves) that disrupt economic activity and increase loan defaults. These climate-related disasters result in higher insurance claims and real estate devaluations, negatively affecting bank balance sheets. Moreover, rising emissions increase economic uncertainty through extreme weather events, supply chain disruptions, and infrastructure damage, further exposing the financial sector to potential losses. This greater exposure to climate risks translates into lower overall bank stability. Thus, higher climate risks lead to greater financial sector exposure to losses, resulting in lower bank stability.

In addition to physical risks, transition risks also play a role. As governments implement stricter carbon regulation (such as carbon taxes or emissions trading schemes) companies in high-emission sectors (e.g., oil, coal, and heavy manufacturing) may face rising costs or asset devaluations. This increases the likelihood of credit risk and non-performing loans (NPLs), especially for banks heavily exposed to carbon-intensive industries. Additionally, higher CO_2 emissions growth can lead to lower investor confidence, capital flight, and increased volatility, particularly in economies reliant on fossil fuels. As governments adopt more stringent climate policies to accelerate the transition toward low-carbon economies, the financial sector becomes increasingly vulnerable to these adjustments, which further affects stability.

When comparing the results for the EU and non-EU countries (Table 2 and 3 respectively) significant differences can be noted between them regarding the impact of the various climate change indices on financial stability. Specifically, in the case of the EU countries, the negative effects of climate change on financial stability appear to be weaker. This can be attributed to several factors, including the presence of more effective climate policies, such as the EU Green Deal and the Emissions Trading System, which help mitigate both physical and transition risks. Additionally, EU countries tend to have more diversified economies, which reduces their dependence on high-emission industries. Well-regulated banking sectors are more likely to integrate climate risks into their lending practices, supported by frameworks such as the EU Sustainable Finance Taxonomy. Furthermore, EU banks have greater access to green finance instruments, which enhances their resilience. By contrast, non-EU countries exhibit a stronger negative impact of climate change on financial stability. This can be explained by weaker climate policies, higher dependence on fossil fuels, and financial institutions that are less equipped to handle climate-related shocks. These countries also generally have lower access to green finance, making them more vulnerable to both physical and transition risks, thereby increasing financial instability. On the whole, there is clear evidence that the impact of emissions on financial stability differs between EU and non-EU countries, primarily owing to differences in regulations, economic structures, and financial resilience.

Note that, as discussed by Liu et al. (2024), physical climate risk can be transmitted to financial markets through various channels including: (i) the underwriting risk channel – this reflects the impact of climate disasters and the resulting insurance claims on insurance companies that face increasing liabilities threatening financial stability: (ii) the credit risk channel – this is the consequence of the higher default risk for companies affected by climate disasters, which leads to an increase in the number of non-performing loans for banks: (iii) the operational risk channel – this results from the disruption to business and financial operations caused by climate change; (iv) the market risk channel – this is related to the higher uncertainty caused by global warming and extreme weather events; (v) the reputation and liability risk channel – this arises when companies have poor ESG scores and their reputation suffers, making them less attractive to investors; (vi) the liquidity risk channel – this occurs when as a result of climate change assets used as collateral become less valuable and thus businesses find it more difficult to obtain loans and become more likely to default. It is also noteworthy that these channels are interlinked, which can magnify the effects of climate shocks (Chenet et al., 2021). Further amplification of their impact can result from the possibility of pro-cyclical behaviour of market participants, who might sell assets simultaneously when facing widespread higher climate-related risk (FSB, 2020). All these channels are likely to play a role in the case of the set of countries under investigation,

Finally, the coefficients on the control variables are mostly significant and exhibit the expected signs. In particular, GDP per capita (GDPC) has a positive sign, indicating that higher levels of economic development are associated with greater financial stability. By contrast, both the inflation rate and the uncertainty index have negative signs, suggesting that higher inflation and greater economic or political uncertainty are detrimental to financial stability.

3.2 Estimates for the climate change–financial stability relationship taking into account governance quality

Tables 4 and 5 reports the estimates for the EU and non-EU countries respectively from the model including an interaction term (CLI x WGI) between the various climate change measures (CLI) used and a proxy for the quality of institutions (WGI).

Table 4. The climate change – financial stability relationship and the level of governance in the EU countries

Index	CDA	CHA	FGA	NDA	BCA	GHP
Z-score lagged	0.579	0.589	0.561	0.481	0.461	0.588
	(4.42)***	(3.56)***	(3.83)***	(7.16)***	(4.65)***	(7.22)***
CLI^k	-0.043	-0.040	0.032	-0.030	-0.075	-0.125
	(1.68)*	(1.66)*	(1.48)	(1.45)	(1.98)*	(2.45)**
GDPC	0.043	0.028	0.036	0.035	0.021	0.034
	(3.10)***	(2.50)**	(4.42)***	(3.27)***	(2.10)**	(3.56)***
INFL	0.083	-0.078	-0.033	-0.038	-0.014	-0.042
	(1.95)*	(1.72)*	(0.67)	(0.79)	(0.21)	(1.67)*
DCPS	-0.028	-0.024	-0.015	0.018	-0.007	0.031
	(1.71)*	(0.68)*	(1.10)	(1.31)	(1.07)	(1.89)*
WUI	-0.042	-0.006	-0.026	-0.050	-0.014	0.007
	(1.93)*	(0.34)	(1.67)	(2.09)**	(0.67)	(0.14)
WGI	0.098	0.091	0.039	0.047	0.031	0.107
	(2.91)***	(2.87)***	(1.81)*	(1.92)*	(1.39)	(3.72)***
CLI^k x WGI	-0.008	-0.001	0.015	0.008	-0.023	-0.029
	(1.16)	(0.02)	(0.34)	(0.07)	(1.53)	(1.51)
Constant	-0.266	-0.174	-0.159	-0.164	-0.086	-0.247
	(2.81) ***	(2.49) **	(4.19) ***	(2.44) **	(1.83) *	(4.56) ***
Observations	588	588	588	588	588	588
Ar(1)	-2.68	-2.80	-2.72	-2.69	-2.81	-2.71
	(0.007)	(0.005)	(0.006)	(0.007)	(0.005)	(0.007)
Ar(2)	-0.42	-0.38	-0.36	-0.36	-0.36	-0.38
	(0.678)	(0.991)	(0.722)	(0.717)	(0.718)	(0.707)
Sargan	6.71	2.86	0.03	5.51	1.03	4.55
	(0.152)	(0.239)	(0.641)	(0.138)	(0.794)	(0.208)

Note: Absolute value of the t statistics in parentheses; * significant at 10%; ** significant at 5%; * significant at 1%.**

Table 5. The climate change – financial stability relationship and the level of governance in the non-EU countries

Index	CDA	CHA	FGA	NDA	BCA	GHP
Z-score lagged	0.325	0.126	0.658	0.201	0.546	0.230
	(1.70)	(0.52)	(3.71) ***	(1.03)	(3.13) ***	(0.98)
CLI^k	-0.154	-0.116	-0.095	-0.065	-0.081	-0.307
	(2.64) **	(2.32) **	(1.72) *	(1.13)	(1.45)	(3.00) ***
GDPC	0.040	0.090	0.030	0.007	0.038	0.011
	(1.86) *	(2.64) **	(1.66) *	(0.80)	(1.74) *	(1.01)
INFL	-0.014	-0.015	-0.009	-0.007	-0.005	-0.022
	(1.80) *	(1.91) *	(1.65) *	(0.76)	(0.60)	(2.13) **
DCPS	-0.025	-0.052	-0.045	-0.023	-0.004	-0.021
	(1.78) *	(2.49) **	(2.13) **	(1.67) *	(1.08)	(1.30)
WUI	-0.184	0.271	-0.387	0.110	-0.126	0.013
	(3.08) ***	(3.34) ***	(3.61) ***	(2.35) **	(2.63) **	(1.05)
WGI	0.032	0.046	0.051	-0.015	-0.023	-0.029
	(1.74) *	(1.85) *	(2.13) **	(0.21)	(0.71)	(1.66) *
CLI^k x WGI	-0.139	-0.109	-0.083	-0.058	-0.069	-0.285
	(2.61) **	(2.43) **	(1.89) *	(0.88)	(1.42)	(3.58) ***
Constant	0.228	0.469	0.128	0.072	-0.103	0.092
	(1.04)	(1.27)	(0.49)	(0.55)	(0.71)	(0.44)
Observations	273	273	273	273	273	273
Ar(1)	-4.37	-3.22	-2.08	-3.14	-3.39	-4.01
	(0.000)	(0.000)	(0.037)	(0.000)	(0.000)	(0.000)
Ar(2)	-1.14	-1.25	1.83	-1.29	-0.99	-1.08
	(0.252)	(0.212)	(0.068)	(0.197	(0.323)	(0.282)
Sargan	0.35	1.43	5.51	1.03	2.71	2.42
	(0.838)	(0.49)	(0.138)	(0.794)	(0.258)	(0.298)

Note: Absolute value of the t statistics in parentheses; * significant at 10%; ** significant at 5%; * significant at 1%.**

The key finding emerging from these tables is that the coefficient on the interaction term is negative and significant for the non-EU countries but becomes insignificant for the EU member states. This suggests that climate change has a greater negative impact on financial stability in countries with lower governance quality, regulatory gaps and financial vulnerabilities, namely the non-EU ones, whilst the presence of better institutions in the EU countries appears to be effective in mitigating the effects of climate change, which confirms the important role of governance in this context.

4. Conclusions

This paper investigates the impact of a number of climate change indices on financial stability in the banking sector in a set of 41 European countries by estimating a dynamic panel data model over the period 2000-2021. The analysis is conducted for both the full set of countries and two subsets including the EU and non-EU ones respectively. The climate change indices are generally found to have a negative effect on financial stability, namely higher climate risk is typically associated with lower financial stability of banks as indicated by lower Z-scores. However, the impact is smaller in EU countries compared to non-EU ones.

The weaker negative impact found in the case of the EU countries can be largely attributed to the implementation of stronger climate policies, regulatory frameworks, and financial mechanisms aimed at mitigating climate-related risks. Measures such as the EU Green Deal, the Emissions Trading System, and the EU Sustainable Finance Taxonomy have supported the integration of climate risk into financial decision-making, enhanced the resilience of financial institutions, and facilitated greater access to green finance.

The more pronounced effects of climate risk on financial stability in the banking sector of non-EU countries indicates greater vulnerability which can be linked to less effective climate policy frameworks, and greater economic dependence on carbon-intensive industries. These factors not only increase exposure to physical risks—such as extreme weather events and natural disasters—but also amplify transition risks associated with potential policy shifts, technological disruptions, and market reallocation in the move toward a low-carbon economy. In these countries, financial institutions are often less prepared to assess and manage climate-related risks, and access to sustainable finance remains limited.

Finally, our analysis also suggests that the climate risk–financial stability relationship is affected by the quality of governance: the comparison between the two sets of countries implies that there are no mitigating effects in the case of the non-EU countries, which are characterized by weaker governance, regulatory gaps, and financial vulnerabilities, whilst better designed institutions appear to be a more effective tool to combat the effects of climate change in the case of the EU countries. Overall, this study highlights the importance of strong institutional frameworks and proactive climate policies to enhance the resilience of financial systems in the face of increasing climate risks across Europe.

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APPENDIX

Table A1: Climate Change Indices: Definitions

Code	Variable definitions
CDA	Adjusted emissions growth rate for carbon dioxide
CHA	Adjusted emissions growth rate for methane
FGA	Adjusted emissions growth rate for F-gases
NDA	Adjusted emissions growth rate for nitrous oxide
BCA	Adjusted emissions growth rate for black carbon
GHP	Greenhouse gas emissions per capita

Table A2: Control Variable Definitions and Data Sources

Code	Variable	Data Source
Z- Score	Bank Z Score	World Bank-World GFDD Indicators
GDPC	Real GDP per capita	World Bank-World Development Indicators (WDI)
INFL	Inflation rate (CPI growth rate)	World Bank-World Development Indicators (WDI)
WUI	Word Uncertainty Index	World Uncertainty Index https://worlduncertaintyindex.com
DCPS	Domestic Credit to the private sector as share of GDP	World Bank-World Development Indicators (WDI)
WGI	World Governance Index	World Bank-World Development Indicators (WDI) Authors' calculations based on the WDI database