Carbon Emissions and Banking Stability☆

Elikplimi Kolma Agbloyor[a,b], Richard Adjei Dwumfour[c], Lei Pan[c,d,e], Alfred Yawson[f] *

[a] *University of Ghana Business School, Ghana*

[b] *University of Stellenbosch Business School, South Africa*

[c] *School of Accounting, Economics and Finance, Curtin University, Australia*

[d] *Centre for Development Economics and Sustainability, Monash University, Australia*

[e] *Centre for Global Finance,, SOAS University of London, United Kingdom*

[f] *University of Adelaide Business School, Australia*

Abstract

This paper examines the impact of per capita CO2 emissions on banking stability in emerging markets and developing economies. To identify the causal effect of carbon emissions on the stability of banking system, we use plausibly exogenous source of variations in energy use as an instrumental variable (IV) for CO2 emissions. Our results show an inverted U-shaped relationship between per capita CO2 emissions and banking stability. We also find that industrialization can be a potential channel through which per capita CO2 emissions affect banking stability. Our results are robust to alternative specifications and sample-splitting and have important implications for policy on banking stability.

Keywords: CO2 emissions; Banking stability; Energy use; Nonlinearity; Emerging market and developing economies (EMDE)

JEL Classifications: G21, Q50, Q53

☆ We would like to thank the editor (Prof. Samuel Vigne), the guest editor (Prof. Suk-Joong Kim), and two anonymous referees for the invaluable comments and feedback. All errors are our own. Authors are ordered alphabetically according to surnames – all authors contributed equally to the study.

* Corresponding author.

E-mail address: ekagbloyor@ug.edu.gh (E.K. Agbloyor), r.dwumfour@postgrad.curtin.edu.au (R.A. Dwumfour), lei.pan@curtin.edu.au (L. Pan), alfred.yawson@adelaide.edu.au (A. Yawson)

1. Introduction

Climate change has been on the development agenda for many years and more so recently due to its increased threats and potential adverse effects on the global economy. There is an undeniable environmental effects of greenhouse gases (hereafter GHG). Carbon dioxide (CO_2) in particular, constitute the biggest share (76%) of the total greenhouse gases that contribute to global warming and climate change (IPCC, 2014; World Bank, 2019). Climate change has become even more important because it represents an existential threat to humanity. For emerging markets and developing economies (EMDE), the consequences of climate change could even be more dire given the vulnerabilities of these countries to climate risks with most global climate hazard hot spots identified to be in EMDE (Mertz, Halsnæs, Olesen, & Rasmussen, 2009, IMF, 2022).

For these economies to achieve net-zero greenhouse emissions by 2050, they would need a projected $1 trillion dollars in renewable energy investments by 2030 (IEA, 2021). Reaching the net-zero global goal as set by the Paris Agreement is critical for EMDEs otherwise their need for climate adaptation finance could rise sharply (Chapagain et al. 2020). It is becoming increasingly obvious that important linkages may exist between climate change and the stability of the financial system. Climate risks, such as rises in temperature levels, can lead to undesirable consequences such as irregular weather patterns, droughts, floods, and the like. This risk can manifest through both physical and transition risks. Physical risks represent the damage that climate change can cause to the assets of economic agents – particularly those in the agriculture sector. For EMDEs, these physical impacts can be larger due to their economic structure. In most of these countries, agriculture – which is directly impacted by climate change – is a large employer and a major contributor to the national income of these countries (Sadowski, Wojcieszak-Zbierska, & Zmyślona, 2024). Moreover, the physical damage can lead to climate-related financial risks, which include non-repayment of loans by economic agents who have borrowed from banks.

Transition risks, on the other hand, refer to the changes that would have to take place regarding resource allocations to various sectors of the economy in the transition to a low-carbon economy. This requires substantial climate-mitigating investments (IEA and IFC, 2023). Indeed, IEA and IFC (2023) estimate that EMDEs need about $2 trillion in annual climate mitigation investments by 2030, mostly in the energy industry, to achieve the net-zero goal by 2050. This will certainly lead to winners and losers. Of major potential concern is the fact that most EMDEs have a higher number of poor people who are in the agricultural sector and compete for limited public resources. Given the limited public resources of these countries, about 80% to 90% of the investments would need to come from the private sector (IEA and IFC, 2023). Meanwhile, for EMDEs, aside from the known challenges of raising private finance, the challenge with private climate finance is that it does not usually generate enough financial returns (IMF, 2021). Hence, there is potential that these economies could be less prepared for the consequences of climate change.

Meanwhile, the scale of any financial crisis resulting from climate change could exceed that of the global financial crisis in 2007/09 and the effects of a pandemic such as COVID-19. Though we are not aware of reliable estimates of how large such a crisis could be, it could be far bigger than any financial crisis or 'black swan' event that has confronted economies worldwide. The potential negative consequences of climate change on financial stability have been referred to as 'green swan' events (see for example, Svartzman et al., 2020). Meanwhile, the potential failure of losers could impact banks' asset quality and lead to potential bank failures. Physical and transition risks could have malign interactions sparking a systemic crisis in the banking industry on a scale that has not been seen before. Indeed, recognizing the potential for climate risk to affect banking stability, a number of regulators known as the Central Banks and Supervisors Network for Greening the Financial System (NGFS) was formed to better manage how climate risks affect financial systems across the world.

In this paper, we examine the impact of CO_2 emissions (our proxy for climate change) on banking stability in emerging market and developing economies. We further test whether climate change has non-linear effects on banking stability. We conjecture that initial increases in CO_2 emissions may suggest the early stages of industrialization for EMDEs. Firms in these countries would focus their investments on productive capital[1] which would have positive net benefits. We believe this would allow borrowers to grow and increase their ability to repay their loans. Later, when firms attain certain levels of development, investments could be more focused on adaptive alternatives. 2 Consequently, the current discourse on regulating CO_2 emissions level should be done with care, considering the specific realities of each country, especially for emerging markets and developing countries. CO_2 emissions regulatory decisions will ultimately affect banking stability[2], pushing firms to decide whether to allocate investment to productive capital or adaptation investments.

Our study makes important contributions to the literature in the following ways. We examine the influence of per capita CO_2 emissions on banking stability and the extent to which this can help to engender a balanced climate regulatory framework considering the level of industrialization of the country. Thus far, very few empirical investigations have been undertaken to identify the impact of climate change on financial stability. The exceptions to the best of our knowledge are International Monetary Fund (2020), Svartzman et al. (2020) and Stolbova et al. (2018). The International Monetary Fund (IMF) study shows that climate change has had modest effects on equity markets across the globe and that sovereign financial strength and insurance penetration mitigate the negative consequences of climate change on financial stability. Svartzman et al. (2020) provide a framework for understanding how central banks ensure financial sector stability in the era of climate change. Moreover, Batten et al. (2016) review and provide a conceptual framework for the implication of climate change for central banks in managing the financial sector. The authors note that climate change can have a severe impact on the stability of the financial system and, hence, affect the conduct of monetary policy. Moreover, Klomp (2014) examined the impact of large-scale natural disasters on banking stability and found that, natural disasters increase the likely of default of banks. Dafermos et al. (2018) also used simulation in a global sample and examined the effect of climate change on financial stability using temperature levels in a general equilibrium model.

Our study differs from these studies in four ways. First, we argue that the impact of climate change on banking stability may be non-linear. We therefore test the non-linear relationship between CO_2 and bank stability, which has been ignored in the literature. Unlike previous studies that used temperature levels, we use CO_2 as a proxy for climate change. Given that different GHGs can contribute to temperature levels and that CO_2 emissions are projected to show the level of industrialization, our paper is able to estimate how the major contributors to GHGs, such as CO_2, affect banking stability. This is important because most energy policies and regulatory requirements have been on limiting CO_2 emission levels given that CO_2 is the most important anthropogenic greenhouse gas (IPCC, 2007). At lower emissions levels of CO_2, financial stability may be improved, given that it may signal the early stages of industrialization. This is crucial given that a general conclusion has been made about climate-related financial stability risks, which could suggest a wholesale policy approach without considering the cross-country and regional peculiarities that may hinder the adoption of climate-mitigating policies. By providing evidence to this conjecture, essentially, we add to the body of literature and policy debate that countries that

[1] Productive capital refers to physical capital that can increase output but is vulnerable to climate change.

[2] For example, when borrowers are exposed to the adverse effects of climate change, banks can suffer from poor asset quality and consequently instability.

are emitting comparatively low levels of CO_2 may relent on their commitment to climate mitigating policies such as The Paris Agreement.

Second, given that we know little about the transmission channels through which CO_2 emissions impact banking stability, we further contribute to the existing studies by examining the role of manufacturing value added to GDP (MVA/GDP) ratio as a potential channel of the relationship between CO_2 emissions and banking stability. To the best of our knowledge, no study has examined this potential channel. Higher emissions may suggest higher industrialization or manufacturing expansion. When banks finance these expansions, many manufacturing firms will have their loans on the books of these banks. The physical risks of climate change—such as extreme weather events, rising sea levels, and temperature fluctuations—pose substantial threats to these manufacturing firms and their operations. These climate-related risks can disrupt production, damage infrastructure, and reduce output, directly impacting the firms' revenue streams and their ability to service their loans. If these firms face difficulties in meeting their debt obligations due to climate-induced disruptions, the incidence of non-performing loans (NPLs) in the banking sector is likely to rise. Higher NPLs reduce the profitability of banks, impair their balance sheets, and increase financial instability. Consequently, the stability of banks is closely tied to the financial health of the manufacturing sector they finance, making MVA a crucial channel through which the effects of CO_2 emissions and climate change can be transmitted to banking stability. MVA is a plausible and insightful channel to explore how climate change, driven by CO_2 emissions, can affect banking stability. It encapsulates the interconnectedness of industrial growth, financing needs, and the physical risks associated with climate change, providing a comprehensive framework for understanding the broader economic impacts on the banking sector. Our empirical evidence shows that industrialization, measured by MVA/GDP ratio, serves as a channel through which CO_2 emissions affect banking stability in EMDEs. Moreover, we explore the heterogenous impact ofCO_2 on banking stability in low and high MVA countries. If our argument holds, then countries with higher MVA levels are likely to be more exposed to banking instability, given the high levels of bank exposure to these firms. We provide empirical support for these arguments.

Third, methodologically, we use a novel instrument for CO_2 emissions and apply our analysis to a larger sample of EMDEs. Specifically, we use energy consumption as an instrument for CO_2 emissions to address any possible endogeneity of CO_2 emissions in an Instrumental Variable (IV) framework to examine the causal impact of CO_2 on banking stability. It is important to note that banks are needed to finance investments to drive industries, leading to higher CO_2 emissions, and at the same time, the level of industrialization may also determine the level of finance needed and, thus, the stability of banks. The IV approach helps us to account for these issues. In doing so, we employ a large sample of 81 emerging markets and developing countries (EMDEs) and provide robustness with sub-sample analysis of different regions to examine the impact of CO_2 emissions on bank stability. This approach helps us to estimate the different CO_2 thresholds across different regions beyond which banking stability begins to fall. This is the first study in the climate-finance literature that covers a large number of countries and provides causal evidence of the heterogeneous impact of CO_2 on banking stability across different regions.

Therefore, we propose and test empirically a novel framework that is used to examine the effect of per capita CO_2 emissions on banking stability. More specifically, we argue that initial emissions of CO_2 improve banking stability while it hurts banking stability after a certain threshold. Our results show an inverted U-shaped relationship between per capita CO_2 emissions and banking stability. In our estimations, we use an innovative identification strategy to tackle the endogeneity issue. In particular, we propose an identification strategy that utilises a plausibly exogenous source of variations in energy use as an instrumental variable (IV) for carbon dioxide emissions. Energy consumption is a strong predictor of CO2 emissions as high energy demand is a major contributor to the rising CO2 emissions: energy demand outpaces the speed at which decarbonisation of the energy system is taking place. Hence, our instrument is likely to be valid and satisfies both the relevance and exclusion restriction that energy use affects banking stability only through CO2 emissions.

The remainder of the paper is structured as follows. Section 2 presents the empirical approach undertaken in this study. In section 3, we discuss the data set. Section 4 reports empirical findings, section 5 conducts channel analysis. Section 6 concludes with policy implications provided.

2. Empirical Methodology

In order to relate banking stability with the level of per capita carbon dioxide emissions, we follow the basic econometric model below:

$$Stab_{i,t} = \beta_1 Stab_{i,t-1} + \beta_2 C02_{i,t} + \beta_3 CO2_{i,t}^2 + \gamma \boldsymbol{X}_{i,t} + \varepsilon_{i,t}, \tag{1}$$

where the subscript $i = 1,2,...,N$ represents countries; $t = 1,2,...,T$ denotes the time span in years; $Stab_{i,t}$ refers to the stability measured by Z-score; the introduction of lagged stability $Stab_{i,t-1}$, for instance, is necessary because previous year's stability is likely to influence the following period's stability levels; $C02_{i,t}$ is per capita carbon dioxide emissions; $\boldsymbol{X}$ denotes a vector of control variables including: net interest margin (*NIM*); ratio of non-interest income to total income (*NONIM*); bank asset concentration measured as the assets of the five largest banks as a share of total assets of all commercial banks (*CONCEN*); percentage of foreign banks of the total banks in each country (*Foreign*); level of competition as measured by the Boone indicator (*Boone*); average consumer price index (*Inflation*); and institutional quality proxied by regulatory quality index (*Quality*), and $\varepsilon_{i,t}$ is the idiosyncratic error term. Our variable of interest is CO2, thus, β_2 captures the effect of per capita carbon emissions on banking stability. The quadratic term in Equation (1) helps to approximate the nonlinear relationship between carbon dioxide emissions and banking stability. That is, the quadratic term in CO2 emissions allows for the nexus between CO2 emissions and banking stability to be non-monotonic.

Our main empirical strategy is the 2SLS-IV method to identify the causal effect of carbon dioxide emissions on banking stability. To cater for endogeneity, we adopt an IV approach where we employ energy use as a valid instrument for CO2 emissions. Energy use is an excellent instrumental variable for CO2 emissions because it directly influences the amount of carbon dioxide released into the atmosphere through the combustion of fossil fuels. The primary sources of CO2 emissions—coal, oil, and natural gas—are integral to energy production and consumption in industries, transportation, and households. Energy use captures the intensity and scale of economic activities that rely on these carbon-intensive energy sources. Consequently, variations in energy consumption reflect changes in economic output and energy efficiency, making it a robust proxy for CO2 emissions. Moreover, by using energy use as an instrument, we assume that while energy consumption impacts CO2 emissions, it does not directly affect banking stability. This assumption is plausible because the mechanisms linking energy use to banking stability—such as through environmental regulations, climate change impacts, or economic disruptions—primarily operate through the intermediary variable of CO2 emissions. Thus, energy use serves as a valid instrument, isolating the variation in CO_2 emissions needed to accurately assess its causal impact on banking stability.

3. Data and Sources

We collect annual data from the year 2000 to 2013 for 81 Emerging markets and developing countries (EMDE). The sample period is limited to 2013 because of data availability on the banking sector variables as provided in the World Bank, Global Financial Development Database (GFDD) and our instrument, Energy use. We acknowledge that extending the dataset beyond 2013 would potentially capture more recent economic dynamics and environmental policies, providing a more comprehensive analysis. This limitation is based purely on data availability from the GFDD. The use of the World Bank data provides is rooted in its established accuracy, consistency, and extensive coverage. The World Bank's data is widely recognized for its open access, wider coverage and reliability. While our data ends in 2013, we have employed robust econometric techniques to ensure the validity of our results. These methods, including sensitivity analyses and robustness checks, affirm the stability and reliability of our findings within the given timeframe. Additionally, the period covered includes significant economic and environmental events like the 2007/2008 global financial crisis (GFC), the 2000 Mozambique Floods, 2003 European Heatwave, 2004 Indian Ocean Tsunami, 2005 Hurricane Katrina, 2008 Cyclone Nargis, 2010 Pakistan Floods, 2011 East Africa Drought and 2013 Typhoon Haiyan among others, providing a substantial basis for our analysis and the observed relationships. We believe our study offers valuable insights and serves as a solid foundation for future research that may incorporate more recent data as it becomes available.

The banking stability data used in this paper is Z-score. Z-score is calculated as (ROA+(equity/assets))/sd(ROA). In essence, Z-score compares the capitalization and returns – which shows the strength of the banking system – to how volatile those returns are. As defined by Roy, (1952), Z-score measures the distance from insolvency where insolvency is where losses exceed equity. Hence, as a measure of the probability of insolvency, Z-score has largely been used in the literature to measure banking stability (Shabir et al. 2024; Samet et al., 2018; Klomp, 2014; Laeven, & Levine, 2009; Roy, 1952). The higher the value of the Z-score, the more stable the banking sector. Carbon emissions are measured by per capita CO_2 emissions (in metric tons).

On the controls, the study adds net interest margin (*NIM*) of the banks as a proxy for how banking spread affects the banking stability. This is calculated as the ratio of banks' net interest revenue to their average interest-bearing assets. We also include non-interest margin (*NONIM*) calculated as the ratio of non-interest income to total income. This captures how the income from banks' "nontraditional activities" affect the stability of the banking industry. Another variable that is added as a control is the bank asset concentration (*CONCEN*). This is measured as the assets of the five largest commercial banks as a share of total commercial banking assets. We also include foreign bank presence as a control variable. We proxy foreign presence as the percentage share of the total banks that are foreign banks. A bank that has majority (50% or more) shares owned by foreigners is classified as a foreign bank. The study also adds the Boone indicator as a measure of banking competition. This is calculated as the elasticity of bank profits to marginal costs. The intuition is that more efficient banks are those that can achieve higher profits. Hence, there is more competition when the indicator becomes more negative while more positive values show less competition in the banking system. We also include Inflation which is measured as the log of the average consumer price index per year. As noted in Perry (1992), the impact of inflation on banking stability will depend on how banks anticipate inflationary changes and factor them in their pricing. Thus, inflation could improve banking stability when banks anticipate inflationary increases and hence correctly price their loans. A negative effect on stability may however happen when the increase in inflation is unanticipated. Hence, the impact of inflation on banking stability is therefore expected to be ambiguous. The data on *NIM*, *NONIM*, *CONCEN*, *Boone* and inflation are sourced from the World Bank Global Financial Development Database (GFDD). To capture the role of institutional quality, we use the regulatory quality index from the World Development Indicators (WDI). The index is such that, higher values connote quality institutional framework in a country. These may include the quality of the regulations in relation to property rights where there is ease of securing property and enforcing property rights at the law courts. This also includes the ability of banks to engage in contractual or financial arrangements that help them to adjust their balance sheets. This can help to improve banking stability. The variables description and data sources are presented in Table 1, and the summary statistics are reported in Table 2.

[Insert Tables 1 & 2 Here]

4. Empirical Results and Discussion

4.1 Instrumental variable (IV) estimation

A proper identification of the causal effect of CO2 emissions on banking stability requires an exogenous source of variation in carbon dioxide emissions. The IV method is our main empirical strategy to identify the causal effect of per capita CO2 emissions on banking stability. In particular, we use variation in energy consumption across countries as the primary instrument for CO2 emissions. Energy use is a natural instrument for CO2 emissions because it is theoretically rooted, is highly correlated with CO2 emissions, and plausibly satisfies the exclusion restriction.

Table 3 reports the results from the two-stage least square (2SLS) estimation together with the first stage results and diagnostic tests. In column (1), we regress the Z-score on only the per capita CO2 emissions, while other columns increasingly add more variables, concluding with column (9), which includes the full set of control variables. The first-stage regression outcome indicates that the coefficient of GDP per unit of energy use is statistically significant at the 1% level, and the first-stage F-test is well above 10. These results suggest that energy use is sufficiently correlated with CO2 emissions variable to serve as a potentially good instrument.

[Insert Table 3 Here]

We also use GDP per unit of energy as an instrument for the exclusion restriction in our IV estimates. Here, we assume that this instrument is not correlated with the second-stage regression, which is another important identifying assumption. We are unable to calculate the Sargan test of over-identification restrictions given that our model is exactly identified. We therefore test the endogeneity assumption by following the approach of Altonji et al. (2005): this approach tests the sensitivity of the estimates to the exclusion and inclusion of control variables. The incremental addition of control variables across columns (1) to (9) shows that our 2SLS estimates are not sensitive to the inclusion and exclusion of control variables.

From Table 3, we see that the coefficient on CO2 emissions is positive and statistically significant at the 5% level or better in all regressions, suggesting that rising CO2 emissions have a significant positive impact on banking stability in EMDE. In particular, on average, 1 unit increase in CO2 emissions can result in a rise in Z-score in the range of 0.68 to 2.07 units depending on the exact specification. Again, the coefficient of the quadratic term is negative and statistically significant with at least a 10% level, suggesting an inverted U-shaped relationship between per capita CO2 emissions and banking stability. Our IV findings confirm the hypothesis that CO2 emissions is positively related to banking stability below a threshold level of CO_2 emissions. Here, the average threshold of per capita CO_2 emissions, after which banking stability begins to fall, is 49. This threshold is within the global emissions level even though above the global average of 6.

4.2 Robustness checks

In this section, we perform robustness checks. Specifically, we divide our sample countries into five regional groups based on the World Bank's classification.

One main concern of our analysis is that differences in regional performance may reflect differences in the stability of the banking system. It is in fact a stylized fact that there are substantial regional differences in banking sector fragility. For instance, De Haas and van Lelyveld (2006, 2010) find that, due to the presence of foreign banks, the financial stability in Eastern Europe is enhanced during the periods of financial distress. In contrast, according to Arena et al. (2007), the stabilising effect is more subdued and diverse in Latin America and Asia. Hence, without considering such potential difference in regional disparities, the IV estimation results may not be precise. To address this concern, we divide our sample into five regional groups according to the World Bank's classification: European and Central Africa (ECA), Latin America (LAC), Middle East and North Africa (MENA), Sub Saharan Africa (SSA) and East Asia and Pacific (EAP).

As our data exhibited relatively large cross-sectional units compared to time-series periods, we use the system GMM (sys-GMM) method: this method combines both the difference and level regressions in a system making it suitable for the study's dataset. We follow Roodman (2009) and use the lags of the independent variables as instruments. Because this reduces the number of obversions, we limit the number of instruments by employing the collapsing method of Holtz-Eakin et al. (1988) and the forward orthogonalization procedure of Arellano and Bover (1995). Results are reported in Table 4. We can see that, in most of our regressions, the coefficients of carbon dioxide emissions are positive and statistically significant at 10% significance level or better, indicating that a rise in per capita CO_2 emissions leads to higher banking stability. As discussed earlier, initial increase in CO_2 emissions may suggest industrialization in the country which would mean borrowers are able to grow their businesses from the loans and consequently their ability to repay their loans. Also, from the table, coefficients on the quadratic term are all negative and statistically significant at the 10% significance level or better. This suggests that a nonlinear relationship exists between CO_2 emissions and banking stability. This is consistent with our baseline estimation results. Looking at the turning points of per capita CO_2 emissions, we see that the MENA region has the highest turning point of around 53 followed by the LAC region with a turning point of 17. The SSA and EAP regions have the same turning point of 5, while the ECA region had a turning point of 7. These results present an interesting outlook given that MENA being the highest emitter of CO_2 emissions requires the highest emissions level to affect the stability of the banking system in the region. Thus, even though all countries are vulnerable to the negative effect of climate change, the impact is largely dependent on the levels of emissions in that country.

[Insert Table 4 Here]

5. Channel Analysis

In this section, we explore whether manufacturing value added (MVA) as percent of GDP (MVA/GDP ratio) can be a potential channel through which CO_2 emissions affect banking stability. The data for MVA/GDP ratio is obtained from the World Development Indicators (WDI). As we mentioned earlier, higher CO_2 emissions may indicate the level of industrialization in a country. Higher MVA show the increasing capacity and manufacturing level of a country, hence the corresponding financing for this expansion. If banks finance these expansions, most of these firms will have their loans on the books of the banks. Therefore, the physical risk of climate change to these manufacturing firms and their products would affect their ability to service their loans as they fall due. This will likely increase the non-performing loans of banks, hence their stability. MVA is, therefore, a plausible channel to explore how climate change can affect banking stability.

To examine whether MVA/GDP ratio is a channel, we follow the method in the existing studies such as Alesina and Zhuravskaya (2011) and Awaworyi Churchill et al. (2019). Two conditions need to be satisfied for MVA/GDP ratio to qualify as a potential channel. First, MVA/GDP ratio is required to be correlated with CO_2 emissions. Panel A of Table 5 presents results for the relationship between per capita CO_2 emissions and MVA/GDP ratio. We can see that CO_2 emissions raises MVA/GDP ratio. More specifically, MVA/GDP ratio is associated with a 0.005 unit increase in per capita CO_2 emissions.

[Insert Table 5 Here]

The second condition is that the inclusion of MVA/GDP ratio as an additional control variable in the regression that relates per capita CO_2 emissions and banking stability should decrease the magnitude of the coefficient on CO_2 emissions or render it insignificant. Panel B of Table 5 reports the results. Column (2) shows that when MVA/GDP ratio is included as an additional control, the scale of the coefficient on per capita CO_2 emissions falls. Furthermore, column (4) suggests that when assessing the nonlinear effect of CO_2 emissions on banking stability, adding MVA/GDP ratio as an extra control variable reduces the coefficient of CO_2. Our findings imply that MVA/GDP ratio serves as a potential channel through which per capita CO_2 emissions affect banking stability.

We then test whether the impact of per capita CO_2 emissions on banking stability through MVA/GDP is dependent on the level of MVA/GDP. We provide estimates for MVA/GDP below and above the 50th percentile. The results in Table 6 further confirm the inverted U-shaped relationship between CO_2 emissions and banking stability. We observe that countries with low levels of MVA/GDP have a per capita CO_2 emission threshold of 30.60 compared to the lower 17.50 per capita CO_2 emissions for countries with high MVA/GDP. This seems to suggest that it takes more emissions for low industrialized EMDC to reach a threshold, after which banking stability begins to fall.

6. Conclusion and Policy Implications

The issue of climate change has gained significant attention from various stakeholders in recent years due to its adverse effects. For governments, there is an increasing need and pressure to implement climate-friendly regulations to limit greenhouse gas emissions as they seek to work towards Goal 13 (Climate Action) of the Sustainable Development Goals (SDGs) and the Paris Agreement to limit global warming to 2°C or even 1.5°C. For firms, the issue of being environmentally responsible is gradually affecting their assessment by consumers and equity investors alike. Consequently, green finance is gaining some traction as investors become environmentally conscious. While a number of studies have looked at the growth impact of climate change, this study is unique as we look at the impact of CO_2 emissions on banking stability at various emissions levels in emerging markets and developing economies across different regions. The results consistently show that there is an inverted U-shaped relationship between CO_2 emissions and banking stability. This suggests that initial levels of CO_2 emissions may show initial levels of industrialization in an economy. As countries industrialize, firms rely on banks to finance their growth and expansion. At this stage, firms need to reinvest in their business and remain profitable to be able to meet their loan obligations as they fall due. It may, therefore, be costly for industries, especially young firms, to adopt new technologies that will minimize or limit their greenhouse gas emissions while staying profitable to repay their loans.

However, the results showed that banking stability starts to decline after a certain threshold of CO_2 emissions is reached. This inflection point underscores the critical role of government regulatory capacity in mitigating the negative impact of CO_2 emissions on banking stability. We propose the following policy recommendations to address this complex challenge:

1. Tailored Climate Policies: Governments should develop climate-related policies that consider their specific economic contexts, balancing industrialization needs with environmental protection. This may involve a) Implementing progressive carbon pricing mechanisms that increase stringency as economies develop. b) Establishing sector-specific emission reduction targets that align with national development goals. c) Creating incentive structures for low-carbon innovations in key industries.

2. Green Technology Investment Strategies: Firms should prepare for the transition to a low-carbon economy by: a) Creating dedicated green funds and allocating a portion of profits for future investments in green technology. b) Developing long-term sustainability strategies that incorporate climate risk assessments. c) Collaborating with research institutions to develop industry-specific green technologies.

3. Government Incentives: To encourage green technology adoption, governments can: a) Offer tax credits or deductions for investments in approved green technologies. b) Implement a carbon credit system that rewards emissions reductions and penalizes excess emissions. c) Provide grants or low-interest loans for small and medium-sized enterprises (SMEs) to adopt clean technologies.

4. International Support Mechanisms: Given the global nature of climate change, we recommend: a) Establishing a global green technology transfer fund, managed by institutions like the World Bank, to facilitate the adoption of low-carbon technologies in EMDEs. b) Creating a tiered system of support where developed countries provide technical and financial assistance to EMDEs based on their vulnerability to climate change and emission levels. c) Implementing a global carbon pricing mechanism with proceeds directed towards climate adaptation and mitigation in vulnerable countries.

5. Banking Sector Reforms: To enhance banking stability in the face of climate-related risks: a) Central banks should incorporate climate stress tests into their regulatory frameworks. b) Banks should be required to disclose climate-related risks in their loan portfolios. c) Regulatory bodies should incentivize green lending practices through preferential capital requirements for low-carbon investments.

6. Research and Development: To support evidence-based policymaking: a) Governments should increase funding for climate-related research, particularly in EMDEs. b) International collaborations should be fostered to share best practices in climate policy and

green technology. c) Regular assessments of the effectiveness of climate policies on banking stability should be conducted.

The transition towards reducing global warming and mitigating climate change requires coordinated efforts from governments, the private sector, and development organizations. While EMDEs have a lower share of global emissions compared to developed countries, they are often more exposed to the impacts of climate change. Therefore, a global approach that considers equity and differentiated responsibilities is crucial.

Further research incorporating more recent data and covering global economies is needed to provide a comparative analysis between advanced economies and EMDEs. This would enable a more comprehensive understanding of the relationship between CO2 emissions and banking stability across different stages of economic development and regulatory environments.

References

Alesina, A. and Zhuravskaya, E. (2011). Segregation and the quality of government in a cross section of countries. *American Economic Review*, 101(5), 1872-1911.

Altonji, J.G., Elder, T.E. and Taber, C.R. (2005). An evaluation of instrumental variable strategies for estimating the effects of catholic schooling. *Journal of Human Resources*, 40(4), 791-821.

Arellano, M. and Bover, O. (1995). Another look at the instrumental variable estimation of error components models. *Journal of Econometrics*, 68(1), 29-51.

Arena, M., Reinhart, C. and Vázquez, F. (2007). The lending channel in emerging economies: Are foreign banks different? IMF Working Paper No. 07/48.

Awaworyi Churchill, S. Farrell, L. and Smyth, R. (2019). Neighbourhood ethnic diversity and mental health in Australia. *Health Economics*, 28(9), 1075-1087.

Chapagain, D., Baarsch, F., Schaeffer, M., & D'haen, S. (2020). Climate change adaptation costs in developing countries: insights from existing estimates. *Climate and Development*, 12(10), 934-942.

Dafermos, Y., Nikolaidi, M. and Galanis, G. (2018). Climate change, financial stability and monetary policy. *Ecological Economics*, 152, 219-234.

De Haas, R. and I. van Lelyveld (2006). Foreign banks and credit stability in Central and Eastern Europe: A panel data analysis. *Journal of Banking & Finance*, 30, 1927-1952.

De Haas, R. and I. van Lelyveld (2010). What determines the composition of banks' loan portfolios? Evidence from transition countries. *Journal of Banking & Finance*, 34, 388-398.

Haug, A. A. and Ucal, M. (2019). The role of trade and FDI for CO2 emissions in Turkey: nonlinear relationships. *Energy Economics*, 81, 297-307.

Holtz-Eakin, D., Newey, W. and Rosen, H.S. (1988). Estimating vector autoregressions with panel data. *Econometrica*, 56(6), 1371-1395.

International Energy Agency (IEA) (2021). Financing Clean Energy Transitions in Emerging and Developing Economies. World Energy Investment 2021 Special Report, Paris.

IEA and IFC. (2023). Scaling up Private Finance for Clean Energy in Emerging and Developing Economies. Paris: IEA.

International Monetary Fund (2020). Climate Change: Physical Risk and Equity, Global Financial Stability Report: Markets in the Time of COVID-19, available online at: https://www.imf.org/en/Publications/GFSR/Issues/2020/04/14/global-financial-stabilityreport-april-2020#Chapter5

International Monetary Fund (2022). Global Financial Stability Report - Navigating the High-Inflation Environment, Washington, DC, October.

IPCC (2014). Climate change 2014: Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Edenhofer, O., Pichs-Madruga, R., Sokona, Y., Farahani, E., Kadner, S., Seyboth, K., Adler, A., Baum, I., Brunner, S., Eickemeier, P., Kriemann, B., Savolainen, J., Schlömer, S., von Stechow, C., Zwickel, T. and Minx, J.C. (eds.) Cambridge University Press, Cambrdige, United Kingdom and New York, NY, USA.

Klomp, J. (2014). Financial fragility and natural disasters: An empirical analysis. *Journal of Financial stability*, *13*, 180-192.

Laeven, L., and Levine, R. (2009). Bank governance, regulation and risk taking. *Journal of financial economics*, *93*(2), 259-275.

Milliner, A. and Dietz, S. (2015). Adaption to climate change and economic growth in developing countries. *Environment and Development Economics*, 20(3), 380-406.

Perry, P. (1992). Do banks gain or lose from inflation? *Journal of Retail Banking*, 14(2), 25-31.

Ripple, W. J., Wolf, C., Newsome, T. M., Galetti, M., Alamgir, M., Crist, E., ... and 15,364 scientist signatories from 184 countries. (2017). World scientists' warning to humanity: a second notice. *BioScience*, 67(12), 1026-1028.

Roodman, D. (2009). How to do xtabond2: An introduction to difference and system GMM in Stata. *The Stata Journal*, 9(1), 86-136.

Roy, A. D. (1952). Safety first and the holding of assets. *Econometrica: Journal of the econometric society*, 431-449.

Sadowski, A., Wojcieszak-Zbierska, M. M., & Zmyślona, J. (2024). Agricultural production in the least developed countries and its impact on emission of greenhouse gases–An energy approach. Land Use Policy, 136, 106968.

Safarzyn´ska, K. and van den Bergh, J.C. (2017). Financial stability at risk due to investing rapidly in renewable energy. *Energy Policy*, 108, 12-20.

Samet, A., Boubakri, N., and Boubaker, S. (2018). Does public–private status affect bank risk taking? Worldwide evidence. *Journal of International Financial Markets, Institutions and Money*, *53*, 287-306.

Schelling, T.C. (1992). Some economics of global warming. *American Economic Review*, 82(1), 1-14.

Shabir, M., Jiang, P., Shahab, Y., Wang, W., Işık, Ö., and Mehroush, I. (2024). Diversification and bank stability: Role of political instability and climate risk. *International Review of Economics & Finance*, *89*, 63-92.

Stolbova, V., Monasterolo, I. and Battiston, S. (2018). A financial macro-network approach to climate policy evaluation. *Ecological Economics*, *149*, 239-253.

Svartzman, R., Bolton, P., Despres, M., Pereira Da Silva, L. A. and Samama, F. (2020). Central banks, financial stability and policy coordination in the age of climate uncertainty: a three-layered analytical and operational framework. *Climate Policy*, 1-18.

World Bank. (2019). World Development Indicators, The World Bank, avaiable online at: https://databank.worldbank.org/source/world-development-indicators

LIST OF TABLES

Table 1: Description of variables and data sources

Variable	Description	Source
Z-score	It captures the probability of default of a country's commercial banking system. Z-score compares the buffer of a country's commercial banking system (capitalization and returns) with the volatility of those returns.	Global Financial Development Database (GFDD)
CO2	Per capita CO2 emissions (in metric tons) which include carbon dioxide produced during consumption of solid, liquid, and gas fuels and gas flaring.	Global Financial Development Database (GFDD)
Energy use	GDP per unit of energy use (constant 2017 PPP) is the PPP GDP kilogram of oil equivalent of energy use per constant PPP GDP	World Development Indicators (WDI)
Institutional quality	Regulatory quality institutional quality index	World Governance Indicators
Net interest margin	Accounting value of bank's net interest revenue as a share of its average interest bearing (total earning) assets.	Global Financial Development Database (GFDD)
Non-interest income	Bank's income that has been generated by non-interest related activities as a percentage of total income (net-interest income plus non-interest income).	Global Financial Development Database (GFDD)
Bank asset concentration	Assets of five largest commercial banks as a share of total commercial banking assets	Global Financial Development Database (GFDD)
Foreign entry	Percentage of the number of foreign owned banks to the number of the total banks in an economy.	Global Financial Development Database (GFDD)
Boone indicator	Elasticity of profits to marginal costs.	Global Financial Development Database (GFDD)
Inflation	Log of the average consumer price index per year.	Global Financial Development Database (GFDD)
MVA/GDP	Manufacturing value added as a percent of GDP	World Development Indicators (WDI)

Table 2: Summary statistics

Variable	Obs.	Mean	Std.Dev	Min	Max
Z-score	927	15.189	9.561	1.131	60.437
CO2 emissions per capita	927	4.902	7.869	0.049	63.354
GDP per unit of energy use	927	133.195	78.329	35.195	673.845
Institutional quality	927	-0.036	0.703	-2.071	2.142
Net interest margin	927	0.054	0.025	0.005	0.170
Non-interest income	927	0.370	0.128	0.064	0.929
Bank asset concentration	927	0.660	0.178	0.208	1
Foreign entry	927	0.426	0.263	0.000	1
Boone indicator	927	-0.071	0.139	-2.000	0.420
Consumer price index	927	0.066	0.084	-0.098	1.089
MVA/GDP	927	0.144	0.072	0.014	0.500

Table 3: Main (IV) Results

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
CO2	0.683**	1.741*	1.985**	1.958**	2.070**	1.865**	1.735**	1.923**	1.804**
	(0.324)	(0.908)	(0.951)	(0.947)	(0.893)	(0.874)	(0.872)	(0.945)	(0.910)
CO2sq		-0.018***	-0.020**	-0.020*	-0.021**	-0.019**	-0.017*	-0.020*	-0.018*
		(0.010)	(0.010)	(0.010)	(0.010)	(0.009)	(0.009)	(0.010)	(0.010)
Nim			48.543***	44.540***	45.259***	49.306***	49.053***	48.197***	48.691***
			(9.429)	(9.186)	(9.048)	(9.409)	(9.312)	(9.618)	(9.540)
Boone				-4.870***	-4.925***	-5.024***	-4.961***	-5.032***	-5.019***
				(1.877)	(1.891)	(1.799)	(1.740)	(1.752)	(1.733)
Quality					0.338	0.477	0.544	0.006	-0.004
					(0.628)	(0.621)	(0.633)	(0.743)	(0.737)
Nonim						2.233	2.176	2.411	2.616
						(1.777)	(1.770)	(1.782)	(1.805)
Concen							0.777	0.626	0.672
							(1.227)	(1.229)	(1.221)
Foreign								4.480**	4.477**
								(2.085)	(2.071)
Inflation									-1.239
									(1.119)
First-stage regressions									
Energy	0.009***	0.003***	0.003***	0.003***	0.003***	0.004***	0.004***	0.004***	0.004***
	(0.002)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
1st stage F-test	19.47	13.86	13.43	13.44	15.53	16.01	16.67	16.21	16.99
Threshold (CO2)	-	48	50	49	49	49	51	48	50
R2	0.92	0.91	0.91	0.91	0.91	0.92	0.92	0.92	0.92
Obs.	927	927	927	927	927	927	927	927	927
No. of countries	81	81	81	81	81	81	81	81	81

Note: Robust standard error in parenthesis. *, ** and *** indicate significance at the 10%, 5% and 1% level, respectively.

Table 4: Impact of CO2 emissions on banking stability – System GMM results across regions

	SSA		MENA		EAP		ECA		LAC	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
L.dependent	0.610***	0.751***	0.928***	0.571***	0.730***	1.255**	1.016***	0.765***	0.739***	0.937***
	(0.099)	(0.185)	(0.044)	(0.736)	(0.087)	(0.568)	(0.135)	(0.095)	(0.046)	(0.040)
CO2	0.495***	2.943**	0.138***	0.736**	0.527**	2.160**	0.110*	0.546**	0.186*	1.495***
	(0.159)	(1.221)	(0.035)	(0.295)	(0.239)	(0.867)	(0.064)	(0.227)	(0.097)	(0.503)
CO2sq		-0.313***		-0.007*		-0.233*		-0.037***		-0.044***
		(0.055)		(0.004)		(0.124)		(0.015)		(0.014)
Controls	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Obs.	187	187	132	179	103	103	165	165	201	201
No. of countries	19	19	14	14	10	10	17	17	21	21
Threshold (CO2)	-	4.70	-	52.57	-	4.60	-	7.38	-	16.99
AR(2)	0.38	0.42	0.71	0.72	0.21	0.27	0.11	0.10	0.47	0.97
Hansen J *p*-value	0.83	0.83	0.99	0.81	0.83	1.00	0.97	0.98	0.91	0.90

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

Table 5: Channel analysis results

Panel A: Effect of per capita CO2 emissions on MVA/GDP ratio

Dependent Variable:	MVA/GDP
CO2	0.005***
	(0.0005)
Controls	YES
R2	0.94
Obs.	927
Countries	81

Panel B: Effect of per capita CO2 emissions on banking stability controlling for MVA/GDP ratio – GMM estimates

Dependent Variable (Z-score)	(1)	(2)	(3)	(4)
CO2	0.043***	0.041***	0.099***	0.095***
	(0.012)	(0.009)	(0.010)	(0.011)
CO2sq			-0.002***	-0.002***
			(0.0001)	(0.0001)
MVA/GDP		0.950**		0.893*****
		(0.447)		(0.380)
Controls	Yes	Yes	Yes	Yes
Obs.	788	788	788	788
No. of countries	81	81	81	81
Threshold (CO2)	-	-	24.75	23.75
AR(2)	0.761	0.812	0.836	0.849
Hansen J p-value	0.895	0.909	0.935	0.904

Note: Robust standard error in parenthesis. *, ** and *** indicate significance at the 10%, 5% and 1% level, respectively.

Table 6 Effect of per capita CO2 emissions on banking stability based on Low and High MVA/GDP ratio – GMM estimates

Dependent Variable (Z-score)	Low MVA/GDP		High MVA/GDP	
	(1)	(2)	(3)	(4)
CO2	0.147***	0.306***	0.014**	0.035***
	(0.007)	(0.016)	(0.005)	(0.013)
CO2sq		-0.005***		0.001***
		(0.0002)		(0.0001)
Controls	Yes	Yes	Yes	Yes
Obs.	401	401	387	387
No. of countries	52	52	48	48
Threshold (CO2)	-	30.60	-	17.5
AR(2)	0.970	0.971	0.427	0.408
Hansen J p-value	0.878	0.987	0.971	0.996

Note: Robust standard error in parenthesis. *, ** and *** indicate significance at the 10%, 5% and 1% level, respectively.