Carbon Emissions and Banking Stability☆

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

[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] *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 (EMDE). 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, 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 Prof. Suk-Joong Kim 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 (CO2) 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 (IMF, 2022; Mertz *et al*., 2009).

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 risk 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 (Sadowski, Wojcieszak-Zbierska and 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 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 EMDE have higher number of poor people who are in the agricultural sector and compete for the 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 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 as to how large such a crisis could be, it could be far bigger than any financial crisis or 'black swan' event that has confronted economies across the world. 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 the asset quality of banks 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 with the aim of better managing how climate risks affect financial systems across the world.

In this paper, we examine the impact of CO2 emissions (our proxy for climate change) on banking stability in emerging market and developing economies and further test whether climate change has non-linear effects on banking stability. We conjecture that, initial increases in CO2 emissions may suggest early stages of industrialization for EMDEs. Firms in these countries would focus their investments on productive capital[1] which would have positive net benefits. This we argue would give borrowers the chance 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 CO2 emissions level should be done with care, taking into account the specific realities of each country especially for emerging market and developing countries. CO2 emissions regulatory decisions will ultimately affect banking stability[3] pushing firms to decide whether to allocate investment to productive capital or adaptation investments.

Specifically, we examine the influence of per capita CO2 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) and Svartzman *et al*. (2020). 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 the stability of the financial sector in the era of climate change. However, none of these studies examine potential non-linear effects of climate change on bank stability in EMDEs.

Consequently, we propose and test the effect of per capita CO2 emissions on banking stability in EMDEs. In particular, we argue that initial emissions of CO2 improve banking stability, while it hurts banking stability after a certain threshold. Our results show an inverted

[1] Productive capital refers to physical capital that can increase output but is vulnerable to climate change.
[2] Adaptive capital entails resources (financial, governance, and infrastructure) that are invested in climate related projects.
[3] For example, when borrowers are exposed to the adverse effects of climate change, banks can suffer from poor asset quality and consequently instability.

U-shaped relationship between per capita CO2 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.

Also, given that we know little about the transmission channels through which CO2 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 CO2 emissions and banking stability. Our empirical evidence shows that industrialization measured by MVA/GDP ratio serves as a channel through which CO2 emissions affect banking stability in EMDEs.

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 estimate the following econometric model:

$$Stab_{i,t} = \beta_1 Stab_{i,t-1} + \beta_2 C02_{i,t} + \beta_3 CO2^2_{i,t} + \gamma \boldsymbol{X}_{i,t} + \varepsilon_{i,t}, \quad (1)$$

where the subscript *i* = 1,2,...,*N* represents countries; *t* = 1,2,...,*T* denotes the time span in years; $Stab_{i,t}$ refers to banking 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; ***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.

To identify the causal effect of carbon dioxide emissions on banking stability, our main empirical strategy is the IV method. In particular, to cater for endogeneity, we adopt an IV approach with the first stage corresponding to Equation (2) below:

$$C02_{i,t} = \delta_0 + \delta_1 Energy_{i,t} + \delta_2 CO2^2_{i,t} + \varphi \boldsymbol{X}_{i,t} + \mu_{i,t} \quad (2)$$

where $Energy_{i,t}$ refers to GDP per unit of energy use; $\boldsymbol{X}$ is a vector of control variables in the structural regressions; and $\mu_{i,t}$ is stochastic error term. Having the predicted values of $\widehat{CO2}_{i,t}$, we estimate the second-stage regression following the same form as Equation (1).

3. Data and Sources

We collect annual data from the year 2000 to 2013 for 81 emerging markets and developing countries.[4] 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. The higher the value of the Z-score, the more stable the banking sector. Carbon emissions are measured by per capita CO2 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

[4] The sample period is limited to 2013 because of data availability on the banking sector variables as provided in the Global Financial Development Database (GFDD) of the World Bank.

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. Our main empirical strategy to identify the causal effect of per capita CO2 emissions on banking stability is the IV method. 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 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 GDP per unit of energy as an instrument is not correlated with the dependent variable in 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 follow 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 column (1) to (9) show that our 2SLS estimate 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 has a significant positive impact on banking stability in EMDE. In particular, on average, 1 unit increase in CO_2 emissions can result in a rise in Z-score in the range of 0.68 to 2.07 units depending on the exact specification. The coefficient of quadratic term is negative and statistically significant with at least 10% level, suggesting that an inverted U-shaped relationship between per capita CO_2 emissions and banking stability. Our IV findings confirm the hypothesis that CO_2 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.

4.2 Robustness checks

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 EMDE 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 subsample analysis. We follow Roodman (2009) and use the lags of the independent variables as instruments. Because this reduces the number of observations, 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. 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 the regions examined are vulnerable to the negative effect of climate change, the impact is largely dependent on the levels of emissions in that geographical region.

[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 CO2 emissions affect banking stability. The data for MVA/GDP ratio is obtained from the World Development Indicators (WDI). As we mentioned earlier, higher CO2 emissions may indicate the level of industrialization in a country. Higher MVA shows 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 CO2 emissions. Panel A of Table 5 presents results for the relationship between per capita CO2 emissions and MVA/GDP ratio. We can see that CO2 emissions raises MVA/GDP ratio. More specifically, MVA/GDP ratio is associated with a 0.005 unit increase in per capita CO2 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 CO2 emissions and banking stability should decrease the magnitude of the coefficient on CO2 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 CO2 emissions falls. Furthermore, column (4) suggests that when assessing the nonlinear effect of CO2 emissions on banking stability, adding MVA/GDP ratio as an extra control variable reduces the coefficient of CO2. Our findings imply that MVA/GDP ratio serves as a potential channel through which per capita CO2 emissions affect banking stability.

We then test whether the impact of per capita CO2 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 CO2 emissions and banking stability. We observe that countries with low levels of MVA/GDP have a per capita CO2 emission of 30.60 compared to the lower 17.50 per capita CO2 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.

[Insert Table 6 Here]

6. Conclusion and Policy Implications

The issue of climate change has gained a lot of 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 CO2 emissions on banking stability at various levels of emissions in emerging market and developing economies across different regions. The results consistently show that there is an inverted U-shaped relationship between CO2 emissions and banking stability. This suggests that, initial levels of CO2 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 into 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 adapt new technologies that will minimize or limit their emissions of greenhouse gases while staying profitable in other to repay their loans.

However, the results showed that after a certain threshold of CO2 emissions, banking stability starts to reduce. Here, regulatory capacity of the government is key in ensuring that the negative impact of CO2 emissions on banking stability after the threshold is mitigated. Particularly, governments are to identify the right balance by ensuring that on one side firms industrialize and on the other side the environment is protected by limiting CO2 emissions. Therefore, governments in different EMDE markets should examine their own realities and fashion out climate related policies that can help mitigate any adverse effects of CO2 on banking stability. Firms on the other hand should also prepare to invest in green technology as they grow. For example, high emitting firms can create a green fund into which they can contribute a certain portion of their profits for future investment in green technology. This would avoid the huge initial outlay of investment into adaptive green technologies that otherwise would be needed for productive capital. The government can also encourage firms to invest in these technologies by offering tax cuts through carbon credits. This will encourage firms to invest these reliefs in green technologies that can limit their greenhouse gas emissions.

At the international level, development agencies like the World Bank with commitment from developed countries can institute incentives for countries especially those in developing countries to help in their commitment to invest in low-carbon technologies. Given that most advanced economies emit higher greenhouse gases compared to other economies, it would not be out of place for these developed countries to provide support to the developing counterparts to help them invest in climate friendly technologies as they are exposed to the vestiges of climate change. The developing countries even though have a lower share of global emission compared to developed countries, are more exposed to the vagaries of climate change. The move towards reducing global warming and hence climate change would need the efforts from both the government, private sector and development organizations.

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.

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.

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.

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

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, res

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.