Carbon emissions, financial stability and bank profitability in non-crisis years

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Abstract

Carbon emissions, or CO2 emissions, is an important but often overlooked factor affecting financial stability and bank profitability in non-crisis years. The effect of carbon emissions on financial stability and bank profitability in non-crisis years has not been examined in the literature. It is argued that carbon emissions can bring about changes in the environment that create health challenges and financial risks which affect bank profitability and pose a threat to the stability of the financial system in non-crisis years. This study examines the effect of carbon emissions on bank profitability and financial stability in non-crisis years. Twenty-two diverse countries were analysed in non-crisis years. The findings reveal that higher carbon emissions impair financial stability by decreasing banking sector solvency and capital buffer which impair financial stability. Institutional quality mitigates the adverse effect of carbon emissions on financial stability by ensuring greater banking sector solvency in carbon-intensive environments. Institutional quality also reinforces the positive relationship between carbon emissions and bank profitability, particularly banking sector non-interest income. Lagged nonperforming loans, institutional quality, economic growth and regulatory capital ratio are significant determinants of financial stability in non-crisis years while the determinants of bank profitability in non-crisis years are lagged return on asset, the efficiency ratio, institutional quality, inflation rate and unemployment rate.

Keywords: CO2 emissions, carbon emissions, climate change, financial stability, bank profitability, environment, economic growth, unemployment, inflation, pollution.

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1. Introduction

The rise in human activity, since the industrial revolution until now, has given rise to carbon emissions and other greenhouse gas emissions which are impacting the planet's climate (Nong et al, 2021). The United Nations acknowledge that carbon emissions are a cause of climate change, although it is not the only cause (UNFCCC, 1992). There have been calls to limit emissions to the barest minimum to preserve the planet's climate (Nadeau et al, 2022). This led to the Paris Agreement which is an agreement by over 180 countries to limit global warming to 1.5°c or below 2°C, preferably compared to pre-industrial levels. The countries in the Paris Agreement agreed to set legally binding emission targets. The Intergovernmental Panel on Climate Change (IPCC) also recommends that countries should achieve net-zero emissions by 2050 to reduce global warning caused by carbon emissions and greenhouse gas emissions. This development has led banking scholars and economists to investigate the effect of climate change on the financial sector (e.g., Zhou et al, 2023; Wu et al, 2024; Curcio et al, 2023; Dai and Zhang, 2023; Klusak et al, 2023; Takahashi and Shino, 2023).

The recent literature show that climate change, such as carbon emissions and adverse weather conditions, affect financial institutions (Desai et al, 2022; Zhou et al, 2023). Excessive carbon emissions can bring about adverse changes in the environment that create health problems for people including borrowers (Dong et al, 2021). It can also damage the physical infrastructure and human capital that financial institutions rely on to generate profit and to remain financially stable (Mandel et al, 2021; Brunetti et al, 2021). The resulting health problems can adversely affect the ability of debtors to repay loans owed to financial institutions, thereby creating climate-induced credit risk, while the damage to physical infrastructure and human capital can affect the solvency of financial institutions, thereby increasing financial fragility. This hypothesis has not been tested to be valid in non-crisis years.

The few existing studies that examine the effect of climate change on the financial system show a consensus that climate change-induced natural disasters adversely affect banks and stock markets, and they obstruct international financial flows in the financial sector (Zhou et al, 2023). Existing studies also show that carbon emissions increase systemic risk (Wu et al, 2024; Curcio et al, 2023), increase the cost of corporate and sovereign debt (Klusak et al, 2023; Altavilla et al, 2024), and decrease access to loans for firms that emit gaseous pollutants into the environment (Takahashi and Shino, 2023). However, majority of these studies did not focus on non-crisis years. For instance, Dai and Zhang (2023) in their study of the effect of climate policy uncertainty on bank risk in China include the tail-end of the global financial crisis and the start of the COVID-19 pandemic in their sample from 2009 to 2020 period, meaning that they did not focus their study on non-crisis years. Udeagha and Breitenbach (2023) also did not make a distinction between crisis years and non-crisis years in their analysis of the relationship between carbon emissions and financial development from 1960 to 2020. Qayyum et al (2023) did not isolate the non-crisis years when examining the relationship between financial instability and carbon emissions in India from 1980 to 2020. Takahashi and Shino (2023) combine the crisis years and non-crisis years when examining the effect of the greenhouse gas emissions of firms on bank loans from 2006 to 2018. The lack of distinction between crisis years and non-crisis years in the above studies makes it difficult to determine whether their results have positive or negative implications in non-crisis years, given that combining crisis data and non-crisis data can lead to misleading conclusions and implications for non-crisis years. We identify the absence of research that examine the effect of carbon emissions on financial stability and bank profitability in non-crisis years. This is the gap we intend to fill in the literature.

The present study focuses on the effect of carbon emissions from gaseous fuel consumption on financial stability and bank profitability in non-crisis years. By focusing on non-years, we are able to isolate the events of the 2007 to 2009 global financial crisis and the COVID-19 pandemic to focus on the effect of carbon emissions on financial stability and bank profitability in good years. This approach allows us to contribute to the academic and policy literature by providing research insights into how climate change might affect the financial sector in normal times or non-crisis years.

Our study is related to existing studies because it adds to existing knowledge on how climate change events affect the financial sector. However, our study is different from existing studies in several ways. First, we focus on the effect of carbon emissions on financial stability and bank profitability in non-crisis years – a context which have not been examined in the literature. Secondly, our study is distinct from previous studies because we examine the effect of carbon emissions on a non-traditional indicator of bank profitability which is non-interest income. The existing literature has not examined the effect of carbon emissions on bank non-interest income in non-crisis years.

The research design in this study is based on a model that considers financial stability and bank profitability to be a function of bank specific factors, macroeconomic factors and institutional factors. Data for twenty-countries were analyzed and the findings indicate that higher carbon emissions impair financial stability through a decrease in banking sector solvency and bank capital buffer which threaten financial stability. However, this effect is mitigated by high institutional quality.

This study contributes to the existing literature by providing the first evidence on the effect of carbon emissions on financial stability and bank profitability in non-crisis years. We find evidence that carbon emissions impair financial stability. This study also contributes to the carbon emissions and climate change literature that investigate the effect of carbon emissions on the financial sector, but which have not examined whether the effect is stronger or weaker in non-crisis years. This study further contribute to the literature that examine the determinants of financial stability and bank profitability (e.g., Cairó and Sim, 2023; Gržeta et al, 2023; Ozili and Ndah, 2024; Olszak and Kowalska, 2023). We show that carbon emissions are a significant external determinant of financial stability and bank profitability in non-crisis years alongside inflation, economic growth and the level of unemployment.

The remaining sections of this article proceed as follows. The literature review is presented in section 2. It discuss the theoretical framework and the related literature. Section 3 discuss the research methodology. It discuss the sample selection criteria, the model and estimation procedure. The results are discussed in section 4, and this is followed by the conclusion of the study in section 5.

2. Literature review

2.1. Theoretical framework

This study is grounded in the pollution haven hypothesis or theory. The pollution haven hypothesis or theory is the most common theoretical framework used in the literature to explain the consequences of carbon emissions (see, for example, Copeland, 2008; Taylor, 2005; Kearsley and Riddel, 2010). Early theoretical studies, such as Leonard (1988) and Harrison and Eskelund (1994), argue that polluting firms, including financial institutions, will relocate to, or prefer to operate in, jurisdictions or cities that do not have strict environmental regulations or laws so that they can extract environmental resources, utilize environmental resources, release pollutants into the environment and face little or no consequences for their actions (Deng et al, 2023). Firms that produce pollution-intensive goods and services will relocate their production centers to jurisdictions or cities that do not have strict environmental regulations and laws (Shen et al, 2019). Even after relocating to jurisdictions with less stringent environmental laws, polluting firms in such locations can still be required to pay additional taxes whenever their pollution becomes excessive or exceed a certain threshold (Ranocchia and Lambertini, 2021). Despite paying taxes, it has often been argued that the taxes paid by polluting firms to the government are too small compared to the health hazard and damage caused by the pollution. The implication for financial institutions, such as banks, is that financial institutions also want to operate in locations that do not penalize them for emitting carbon pollutants into the environment. If they are allowed to do so, the carbon emitted into the environment will increase climate change risks and could lead to adverse climate change events that affect the ability of debtors to repay their debt. It can also lead to climate change events that damage the physical infrastructure that financial institutions rely on to generate profits and remain financially stable.

2.2. Related literature

The existing literature examined the link between climate change and the financial system. For instance, Zhou et al (2023) review the recent studies on the impact of natural disasters and physical climate change risks on banking, insurance, stock markets, bond markets, and international financial flows in the financial sector. They find that majority of the studies used statistical methods to analyse the historical data of developed countries to identify these impacts. Existing studies show that natural disasters and climate change risks decrease the profitability and risk-sharing capacity of insurers, it decreases bank stability and credit supply, it lowers the returns and stability of stock and bond markets, and it adversely affects foreign direct investment inflows and international lending. Wu et al (2024) focus on climate risk. They examine the impact of climate risk on the systemic risk of banks selected from a global sample. They find that a country's exposure to climate risk increase the systemic risk of its banks, and the increase in bank systemic risk is due to higher climate risk arising from poor credit quality. They also find that the adverse effect of climate risk on bank systemic risk is reduced among profitable and well capitalized banks. In a related study, Curcio et al (2023) investigate the effect of climate change on systemic risk in the US financial sector. They assess whether weather and climate disasters increase systemic risk in the US banking and insurance sector. They find that weather and climate disasters increase financial systemic risk. Dai and Zhang (2023) focus on climate policy uncertainty. They examine the relationship between climate policy uncertainty and bank risks among 210 commercial banks in China from 2009 to 2020. They find that climate policy uncertainty increases the insolvency risks of banks, and the impact of climate policy uncertainty on insolvency risks is lower for listed banks and is more pronounced among rural banks and state-owned banks. Klusak et al (2023) argue that markets need credible and reliable information on how climate change translates into material risks. They examine the effect of climate change on sovereign credit ratings for 109 countries and find that climate-induced sovereign downgrades increase the cost of corporate and sovereign debt.

Several studies examine the effect of carbon emissions on the financial system. A group of studies focus on the effect of carbon emissions on bank loans. For instance, Takahashi and Shino (2023) examine the effect of greenhouse gas emissions of firms on bank loans. They use bank–firm matched data of Japanese listed firms from 2006 to 2018 and find that banks decrease loans to firms with higher greenhouse gas emissions. Also, Japanese banks with greater leverage and a lower return on assets are more likely to decrease loans to firms with high greenhouse gas emissions. In a related study, Altavilla et al (2024) examine the effect of climate risk on bank lending and monetary policy. They analyse Euro-area credit register and carbon emissions data and find that banks charge higher interest rates to firms that have greater carbon emissions and offer lower rates to firms with lower carbon emissions. They also find that contractionary monetary policy induces banks to increase both credit risk premia and carbon emissions premia on lenders and reduce lending to high emission firms more than to low emission firms. Another related study by Ding et al (2023) investigate the effect of firm carbon emissions on their acquisition of new bank loans in listed non-financial companies in China from 2008 to 2018. They find that if the carbon emissions of an enterprise is higher, it will be granted fewer new bank loans. Kanas et al (2023) examine the relationship between carbon emissions and systemic risk in the U.S. They find a positive link between carbon emissions and systemic risk. They also find that carbon emissions reduce the size of bank assets. Qayyum et al (2023) examine the relationship between financial instability and carbon emissions in India from 1980 to 2020 using the autoregressive distributed lag and the vector error correction model. They find that financial instability has an insignificant effect on carbon emissions in India.

Other studies focus on how carbon emissions affect financial development, financial risks and financial inclusion. A study from South Africa by Udeagha and Breitenbach (2023) examine the relationship between financial development and carbon emissions in South Africa from 1960 to 2020 using the dynamic autoregressive distributed lag estimations. They show that financial development reduces the adverse effect of carbon emissions. Their findings imply that countries with higher financial development are less affected by carbon emissions. A related study by Bedendo et al (2023) analyse banks that issue green bonds and find that large banks and banks that already publicly expressed their support for a green transition are more likely to issue green bonds. Larger banks issue green bonds more frequently and for smaller amounts compared to smaller banks which are unlikely to issue green bonds. Hussain et al (2023) investigate the relationship between carbon emissions and financial inclusion in 74 countries from 2004 to 2020 based on the environment kuznets curve. They find an inverted U-shape relationship between carbon emissions and financial inclusion in developed, emerging and frontier economies. Ozili (2025a) argues that excessive carbon emissions can lead to adverse climate change events that have the potential to damage the physical financial access points that financial institutions rely on to accelerate financial inclusion in society. Ozili (2025a) finds evidence that carbon emissions decrease the level of financial inclusion that is achieved through physical financial access points.

2.3. Gap in the literature

The existing literature, reviewed above, have examined (i) the effect of climate change on the financial system, (ii) the effect of carbon emissions on the financial sector, and (iii) the effect of carbon emissions on financial development, financial risks and financial inclusion. However, these studies did not focus strictly on non-crisis years and did not offer any insight into how carbon emissions might affect financial stability and bank profitability in non-crisis years. For example, Dai and Zhang (2023)'s sample include the tail-end of the global financial crisis and the start of the COVID-19 pandemic in their sample from 2009 to 2020 period. Udeagha and Breitenbach (2023) combine both crisis and non-crisis data in their sample from 1960 to 2020. Qayyum et al (2023) and Takahashi and Shino (2023) also combine both crisis and non-crisis data in their sample. The lack of distinction between crisis years and non-crisis years in the literature makes it difficult to determine whether the results of existing studies are relevant to non-crisis years, given that combining crisis data and non-crisis data may offer misleading implications for non-crisis years. Therefore, from the literature review, we identify the absence of research focusing on non-crisis years. We also identify the absence of research on the effect of carbon emissions on bank non-interest income in non-crisis years. These are the gaps in the literature we intend to fill in this study.

3. Methodology

3.1. The Sample

Country-level data was used to examine the impact of carbon emissions on financial stability and bank profitability. Financial/banking sector data were collected from the global financial development indicators (GFDI) database. Macroeconomic data were collected from the world development indicators (WDI) database. Institutional data were collected from the world governance indicators (WGI) database of the World Bank (see table 1). After extracting the data, some countries did not have sufficient reported data for the crucial financial stability, profitability and carbon emissions variables of interest. More than 20 countries had data for only two or three years, while other countries did not have any data entry for the carbon emissions variables. These countries were excluded from the sample. This procedure allowed us to include in our sample only countries that have sufficient data for at least seven consecutive years. This means that the panel data is unbalanced because some countries have missing data for some years. Consequently, the final countries in the sample are Argentina, Brazil, Cote d'Ivoire, Georgia, Ghana, India, Indonesia, Japan, Kenya, Korea Republic, Malaysia, Mexico, Nigeria, Pakistan, Philippines, Russia, Singapore, Tanzania, Thailand, United Kingdom, United States and Vietnam. The selected sample period is from 2011 to 2018. This sample period was selected to isolate the effect of the 2007-2009 global financial crisis and the COVID-19 pandemic which began in late 2019 up until 2022 to ensure that the two crisis events do not contaminate the empirical analysis.

Table 1. Variable description and source

Variable	*Indicator Name*	*Short definition*	*Source*
ZSCORE	Banking sector insolvency risk – a measure of financial stability	Measures the probability of bank insolvency risk. Higher ZSCORE values mean low insolvency risk or greater banking sector solvency and higher financial stability.	GFDI
NPL	Nonperforming loan ratio – a measure of financial stability	Total nonperforming loan to gross loan ratio	GFDI
ROA	Banking sector return on asset	Bank return on assets (%, after tax)	GFDI
ROE	Banking sector return on equity	Bank return on equity (%, after tax)	GFDI
CME	Carbon emissions	Carbon emissions from gaseous fuel consumption (% of total)	WDI
NII	Banking sector non-interest income	Bank noninterest income to total income (%) ratio	GFDI
GDPR	Economic growth	Annual percentage change in real gross domestic product (GDP)	WDI
ISI	Institutional governance index	Average of the six world governance indicators, namely, the voice and accountability index, political stability and absence of violence/terrorism index, government effectiveness index, control of corruption index, regulatory quality index and rule of law index.	WGI, Author
EFF	Efficiency ratio of the banking sector	Total cost to income ratio of the banking sector	GFDI
INF	Inflation rate	Consumer price inflation measured as the annual percentage change in the cost to the average consumer.	IMF International Financial Statistics
UNEMP	Total unemployment rate	Total unemployment refers to the total share of the labor force that is without work but available for and seeking employment.	International Labour Organization

Source: World Bank database

3.2. Justifying the dependent and independent variables

We rely on the empirical literature to justify the variables included in the model. The two financial stability variables used in this study are the banking sector solvency variable (measured by the ZSCORE index) and the nonperforming loans ratio (NPL) variable. These two financial stability variables are widely used in the literature as indicators of country-level financial stability (see, for example, Ali et al, 2023; Do et al, 2023; Ozili and Iorember, 2024). The literature show that the ZSCORE is a potent measure of financial stability because it measures the solvency of the banking sector (Bouvatier et al, 2023). A high ZSCORE is good for the financial system because it indicates that the financial system is solvent and stable (Bouvatier et al, 2023; Horváth and Vaško, 2016). Other studies used the nonperforming loans ratio as an indicator of financial stability because the nonperforming loans ratio signals the asset quality of the banking sector. A high nonperforming loans ratio lowers the asset quality of the banking sector and increases the fragility of the financial system (Jagannath and Maitra, 2023; Horváth and Vaško, 2016).

Regarding the bank profitability variables, the three indicators of banking sector profitability used in this study have been widely used in the literature as indicators of bank profitability (Isshaq et al, 2019; Menicucci and Paolucci, 2016). A high return on assets means that banks generate significant profit from their operational assets while a high return on equity means that banks generate significant profit from utilising shareholders' fund (Ozili and Ndah, 2024; Olszak and Kowalska, 2023). A high non-interest income ratio means that banks earn more income from their non-interest and fee-generating activities.

Regarding the explanatory variables, the CME variable is the main explanatory variable, and it measures the amount of carbon emissions from the use of natural gas as an energy source. High carbon emissions can make people sick and lead to severe health problems in society (Gu et al, 2023). It can lead people to take more private sector debt from the financial system to address their health problems arising from high carbon emissions. As more people take loans from the financial system, they may default on loan repayment if their health condition deteriorates due to rising carbon emissions. This would lead to loan defaults which can threaten the stability of the financial system. Furthermore, if a large number of loan defaults occur, it can adversely affect the profitability of banks. Therefore, a negative relationship between carbon emissions and financial stability is expected. A negative relationship is also expected between carbon emissions and bank profitability.

For the control variables, the economic growth (GDPR) variable controls for the effect of economic fluctuations on financial stability. Prior studies, such as Samad (2015), Ozili and Ndah (2024) and Ozili and Iorember (2024), show that economic growth has a positive effect on financial stability and bank profitability because periods of positive economic growth may lead to higher employment, higher income, and a greater ability of debtors to earn income to repay their debt owed to financial institutions (Buiter and Rahbari, 2012). This, in turn, will lead to fewer loan defaults during times of positive GDP growth and lead to greater bank profitability and greater financial stability. Therefore, the GDPR variable is expected to have a positive relationship with the bank profitability and financial stability variables.

The ISI variable controls for the effect of institutional quality on bank profitability and financial stability. Existing studies, such as Boulanouar et al (2021) and Bermpei et al (2018), show that strong and quality institutions enhance financial stability by strengthening the monitoring, regulation, and supervision of the entire financial ecosystem. The presence of strong governance institutions will lead to the enforcement of laws, policies and regulations that are put in place to safeguard and preserve financial stability (Ozili and Iorember, 2024). Strong legal institutions, such as the courts, will also compel debtors to repay the loans owed to financial institutions. This will reduce loan defaults, improve bank profitability and increase financial stability. Therefore, the ISI variable is expected to have a positive relationship with the bank profitability and financial stability variables.

The EFF variable controls for the effect of banking sector efficiency on bank profitability and financial stability. A low cost-to-income ratio means a high efficiency ratio while a high cost-to-income ratio means a low efficiency ratio. Efficient banks (i.e. banks with a low cost-to-income ratio) will minimise their cost and maximise their income (Chen, 2009). This leads to higher profitability, and it increases the resilience of banks to shocks that threaten bank stability, thereby making banks stable (Gržeta et al, 2023). Therefore, the EFF variable is expected to have a negative relationship with the bank profitability and financial stability variables.

The INF variable controls for the effect of inflation on bank profitability and financial stability. High inflation will compel financial institutions to reprice loans and increase the nominal interest rate on existing or new loans (Caglayan and Xu, 2016). The increase in nominal interest rates will increase the profitability of banks. Therefore, the INF variable is expected to have a positive relationship with bank profitability. However, the increase in nominal interest rate by banks due to high inflation might put a strain on existing borrowers who may default on loan repayment as the nominal interest rate increases. If loan defaults occur in large amounts and at high frequency, it can lead to financial instability (Mishra and Dubey, 2022). Therefore, a negative relationship between the inflation variable and the financial stability variable is expected.

The UNEMP variable controls for the effect of unemployment on bank profitability and financial stability. A high unemployment rate would make it difficult for debtors to find a new job and earn income to repay their debt (Heer and Schubert, 2012). As a result, debtors who cannot find work will likely default on loan repayment and such loan defaults can adversely affect bank profitability. Therefore, the UNEMP variable is expected to have a negative effect on bank profitability. Furthermore, if high unemployment leads to large amounts of loan defaults, it can lead to financial instability (Kabas et al, 2024). Therefore, a negative relationship between unemployment (UNEMP) and financial stability is expected.

3.3. Model specification and estimation procedure

The baseline model used in this study is similar to the model used in existing studies such as Dafermos et al (2018), Fabris (2020) and Ozili and Iorember (2024). The first model estimates financial stability as a function of its bank-specific and external determinants while the second model estimates bank profitability as a function of its bank-specific and external determinants, and each variable in the model vary across country and year. The model is specified below.

$$(Financial\ stability)i,t = \beta1(Financial\ stability)i,t-1 + \beta2CMEi,t + \beta3EFFi,t + \beta4ISIi,t + \beta5INFi,t + \beta6UNEMPi,t + \beta7GDPRi,t + \beta8CARi,t + \mu i + ei,t \dots\dots\dots Eq\ (1)$$

$$(Profitability)i,t = \beta 1(Profitability)i,t-1 + \beta 2CMEi,t + \beta 3EFFi,t + \beta 4ISIi,t + \beta 5INFi,t + \beta 6UNEMPi,t + \beta 7GDPRi,t + \beta 8CARi,t + \mu i + ei,t \ldots\ldots\ldots Eq\ (2)$$

The variables included in the model are described as follows. The financial stability variables include the ZSCORE variable which measures banking sector solvency and the NPL variable which measures the level of nonperforming loan relative to gross loan in the banking sector. The profitability variables include the ROA variable which measures banking sector return on assets, the ROE variable which measures banking sector return on equity, and the NII variable which measures banking sector non-interest income. The explanatory variables include the CME variable which measures carbon emissions from gaseous fuel consumption (% of total), the GDPR variable which measures the rate of economic growth, the ISI variable which measures the quality of institutional governance, the EFF variable which measures the cost to income ratio of the banking sector, the INF variable which measures the annual inflation rate, and the UNEMP variable which measures the total unemployment rate. i, t represents country and year. εit is the error term. µi is the unobserved time-invariant country effect.

3.4. Estimation procedure

The estimation method used to estimate the model is the Arellano and Bond (1991) first difference Generalized Method of Moments (GMM) regression estimator. The GMM first difference estimator addresses the presence of unobserved country-specific effects, which is eliminated by taking the first-difference of all variables. Two, it takes into account the autoregressive process, or the feedback loop, of financial stability and profitability which is addressed by taking the lag of the dependent variables. Three, it addresses endogeneity problems between the explanatory variables and the error term by using instrumental variables. In the first part of the analysis, we use instrumental variables corresponding to the lagged dependent variable. In the second part of the analysis, we use the lagged independent variables as instrumental variables. The Sargan test for the validity of GMM instruments (or the exogeneity of GMM instruments) is reported in each table. The AR(1) and AR(2) test for the presence of first-order and second-order serial correlation in the first-difference residuals.

3.5. Descriptive statistics and correlation analysis

Regarding the data distribution, there is a wide dispersion in the carbon emissions variable (CME). The dispersion is smaller for the ROA, ISI, GDPR, NII and CAR variables. The wide dispersion is attributed to the difference or variation between the maximum and minimum values of the variables. Meanwhile, the Pearson correlation matrix in table 3 shows that the CME variable has a significant negative correlation with the ZSCORE variable, indicating that higher carbon emissions are correlated with lower financial stability. The CME variable also has a significant negative correlation with the NPL variable. The correlation result suggests that higher carbon emissions are correlated with fewer nonperforming loans which indicates greater financial stability. The CME variable has an insignificant correlation with the ROA, ROE and NII variables. The correlation result suggests that carbon emissions are not significantly correlated with return on asset, return on equity and non-interest income. The ISI and INF variables are significantly correlated with the ZSCORE, NPL, ROA and ROE variables. The correlation result suggests that higher institutional quality and high inflation are significantly correlated with higher banking sector solvency, higher nonperforming loans and bank profitability. Meanwhile, the UNEMP variable is not significantly correlated with the financial stability and bank profitability variables.

Table 2. Descriptive statistics

Statistic	ZSCORE	NPL	ROA	NII	ROE	CME	ISI	INF	UNEMP	GDPR	CAR
Mean	15.38	4.43	1.38	35.34	12.07	24.08	-0.05	4.78	4.91	4.01	16.23
Median	15.19	2.82	1.08	31.94	10.80	18.97	-0.24	3.72	3.87	4.18	16.09
Maximum	35.00	21.59	4.50	80	31.22	56.01	1.51	18.67	19.65	14.04	23.15
Minimum	3.76	0.25	-0.34	11.76	-5.10	0.00	-1.17	-0.94	0.24	-5.37	10.48
Std. Dev.	6.72	4.16	1.02	12.99	7.18	19.07	0.70	4.15	3.51	2.72	2.45
Observations	176	168	176	175	175	132	176	168	176	176	168

Source: Author’s computation

Table 3. Pearson Correlation matrix of the variables

Variable	ZSCORE	NPL	ROA	ROE	NII	CME	ISI	INF	UNEMP	GDPR	CAR
ZSCORE	1.000										

NPL	-0.222**	1.000									
	(0.01)	-----									
ROA	-0.071	0.340***	1.000								
	(0.44)	(0.00)	-----								
ROE	-0.031	0.300***	0.917***	1.000							
	(0.74)	(0.00)	(0.00)	-----							
NII	-0.018	0.045	-0.125	-0.189**	1.000						
	(0.84)	(0.62)	(0.17)	(0.04)	-----						
CME	-0.174*	-0.235**	-0.046	-0.121	0.069	1.000					
	(0.05)	(0.01)	(0.61)	(0.19)	(0.45)	-----					
ISI	0.257***	-0.438***	-0.340***	-0.336***	0.038	0.007	1.000				
	(0.00)	(0.00)	(0.00)	(0.00)	(0.67)	(0.93)	-----				
INF	-0.222**	0.631***	0.393***	0.412***	0.024	-0.006	-0.525***	1.000			
	(0.01)	(0.00)	(0.00)	(0.00)	(0.79)	(0.94)	(0.00)	-----			
UNEMP	-0.090	-0.054	0.093	-0.020	0.107	-0.289***	0.241**	-0.061	1.000		
	(0.33)	(0.55)	(0.31)	(0.82)	(0.24)	(0.00)	(0.01)	(0.51)	-----		
GDPR	0.012	0.127	0.271***	0.309***	-0.310***	-0.064	-0.297***	0.076	-0.117	1.000	
	(0.89)	(0.17)	(0.00)	(0.00)	(0.00)	(0.48)	(0.00)	(0.41)	(0.20)	-----	
CAR	-0.111	0.102	0.452***	0.339***	-0.041	0.258***	-0.066	0.081	-0.035	0.119	1.000
	(0.23)	(0.27)	(0.00)	(0.00)	(0.65)	(0.00)	(0.47)	(0.37)	(0.70)	(0.19)	-----

P-values are in parenthesis. ***, **, * denote statistical significance at the 1%, 5% and 10% levels. ZSCORE variable = banking sector solvency. NPL variable = nonperforming loans ratio. ROA variable = banking sector return on assets. ROE variable = banking sector return on equity. NII variable = banking sector non-interest income. CME variable = carbon emissions from gaseous fuel consumption (% of total). GDPR variable = rate of economic growth. ISI variable = quality of institutional governance. EFF variable = the cost to income ratio of the banking sector. CAR = regulatory capital ratio. INF variable = the annual inflation rate. UNEMP variable = the total unemployment rate

Source: Author’s computation

4. Discussion of empirical results

This section discusses the empirical results which are estimated using the first-difference GMM regression method.

4.1. Effect of carbon emissions on financial stability and profitability

The financial stability result is reported in columns 1 and 2 of table 4. The lagged nonperforming loans variable is positively significant, indicating that the size of nonperforming loans in the previous period is a significant determinant of nonperforming loans in the current period in non-crisis years. The carbon emissions variable has a significant negative effect on banking sector solvency in column 1. The carbon emissions variable is statistically significant at the 1 percent level. The result implies that higher carbon emissions decrease banking sector solvency which impair financial stability in non-crisis years. This result supports the findings of Wu et al (2024) and Curcio et al (2023) who show that climate change has an adverse effect on financial stability. In terms of economic significance, the carbon emissions coefficient is not economically significant because a one percent increase in carbon emissions only decreases banking sector solvency by 0.8 percent. The carbon emissions variable is also statistically insignificant in relation to the nonperforming loans variable in column 2, indicating that carbon emissions do not have a significant effect on banking sector nonperforming loans. The significant result shown above indicates that higher carbon emissions impair financial stability in non-crisis years through a decrease in banking sector solvency. The results support our prediction that higher carbon emissions can bring about adverse changes in the environment that adversely affect the solvency of financial institutions, thereby increasing financial fragility.

The profitability result is reported in columns 3, 4 and 5 of table 4. The lagged return on asset variable is negatively significant in column 3, indicating that a high return on asset in the previous period is followed by a low return on asset in the current period in non-crisis years. The lagged return on equity variable is also negatively significant in column 4, indicating that a high return on equity in the previous period is followed by a low return on asset in the current period in non-crisis years. The carbon emissions variable has a significant positive effect on banking sector return on assets. The carbon emissions variable is statistically significant at the 10 percent level in relation to the return on assets variable, but it is not economically significant in column 3. The result implies that higher carbon emissions are significantly associated with higher banking sector return on asset. The carbon emissions variable is also statistically significant at the 10 percent level in relation to the non-interest income variable in column 5. This indicates that carbon emissions have a significant positive effect on bank non-interest income, implying that higher carbon emissions are significantly associated with higher banking sector non-interest income. In terms of economic significance, the carbon emissions coefficient is not economically significant in relation to the non-interest income variable. Meanwhile, the carbon emissions variable is statistically insignificant in relation to the return on equity variable in column 4. This indicates that carbon emissions do not have a significant effect on banking sector return on equity.

Regarding the control variables in table 4, institutional quality significantly improves banking sector solvency in column 1 but it decreases banking sector profitability in columns 3, 4 and 5. This indicates that institutional quality is more beneficial for financial stability than for bank profitability in non-crisis years. A high banking sector efficiency ratio improves banking sector solvency and non-interest income in columns 1 and 5 respectively, but it decreases the return on asset of the banking sector in column 3. A high inflation rate decreases the return on asset and return on equity of the banking sector in columns 3 and 4, but it improves the non-interest income of the banking sector in column 5. A high unemployment rate decreases the return on assets and return on equity of the banking sector in columns 3 and 4. Positive economic growth is associated with fewer nonperforming loans and higher non-interest income in the banking sector in columns 2 and 5. A high capital adequacy ratio improves banking sector solvency, decreases nonperforming loans, and increases both the return on asset and return on equity of the banking sector in columns 1, 2, 3 and 4 respectively. In terms of economic significance, the institutional quality coefficient is economically significant. A one percent increase in institutional quality increases banking sector solvency by 7.2 percent in column 1 and decreases return on assets by 12.84% in column 3. The economic growth coefficient is also economically significant. A one percent increase in economic growth rate decreases return on equity by 5.5% in column 4 but increases non-interest income by 3.47% in column 5. The inflation rate coefficient is also economically significant. A one percent increase in the inflation rate decreases return on equity by 2.6% in column 4 but increases non-interest income by 4.1% in column 5.

Table 4. Effect of carbon emissions on financial stability and bank profitability: panel first-difference-GMM estimations

Variable	ZSCORE	NPL	ROA	ROE	NII
	(1)	(2)	(3)	(4)	(5)
	Coefficient (p-value)	Coefficient (p-value)	Coefficient (p-value)	Coefficient (p-value)	Coefficient (p-value)
$ZSCORE_{lag}$	-0.237 (0.13)				
NPL_{lag}		1.177*** (0.00)			
ROA_{lag}			-0.133* (0.06)		
ROE_{lag}				-0.326* (0.05)	
NII_{lag}					0.275 (0.22)
CME	-0.873*** (0.00)	-0.006 (0.95)	0.248* (0.09)	0.735 (0.21)	1.228* (0.10)
EFF	-0.232*** (0.00)	0.0004 (0.98)	-0.033*** (0.00)	-0.186 (0.27)	1.224*** (0.00)
ISI	7.260* (0.09)	4.806 (0.18)	-12.84*** (0.00)	-113.47*** (0.00)	-51.18*** (0.00)
INF	-0.114 (0.71)	0.017 (0.90)	-0.371*** (0.00)	-2.688*** (0.00)	4.136*** (0.00)
UNEMP	-0.109 (0.87)	-0.264 (0.39)	-0.641*** (0.00)	-3.337* (0.08)	1.249 (0.45)
GDPR	0.536 (0.40)	-0.772*** (0.00)	-0.591*** (0.00)	-5.538*** (0.00)	3.472** (0.01)
CAR	0.764*** (0.00)	-0.493*** (0.00)	0.305*** (0.00)	2.568* (0.05)	1.950 (0.30)
Country fixed effect	Difference	Difference	Difference	Difference	Difference
Year fixed effect?	Yes	Yes	Yes	Yes	Yes
J-statistic	10.933	8.856	6.494	8.016	8.547
P(J-statistic)	0.205	0.355	0.592	0.432	0.382
AR(1)	0.179	0.061	0.563	0.881	0.322
AR(2)	0.343	0.309	0.216	0.573	0.889

P-values are in parenthesis. ***, **, * denote statistical significance at the 1%, 5% and 10% levels.
GMM instruments are only applied to the lagged dependent variable. AR (1) and AR (2) test for the presence of first-order and second-order serial correlation in the first difference residuals, respectively. ZSCORE variable = banking sector solvency. NPL variable = nonperforming loans ratio. ROA variable = banking sector return on assets. ROE variable = banking sector return on equity. NII variable = banking sector non-interest income. CME variable = carbon emissions from gaseous fuel consumption (% of total). GDPR variable = rate of economic growth. ISI variable = quality of institutional governance. EFF variable = the cost to income ratio of the banking sector. CAR = regulatory capital ratio. INF variable = the annual inflation rate. UNEMP variable = the total unemployment rate.

Source: Author's computation

4.2. Moderating role of institutional quality on the relationship between carbon emissions, financial stability and bank profitability

Existing literature on the effect of institutions on financial development show that strong institutions make the business environment conducive for financial institutions to thrive (Law and Azman-Saini, 2012; Law et al, 2013). Strong institutions promote fair competition, discourage excessive risk-taking, ensure rule of law, protect property rights, and promote transparency and accountability in the financial sector, which are essential for improving bank profitability, mitigating systemic risk and preserving financial system stability. In this section, we test whether strong institutions, or institutional quality, moderate the relationship between carbon emissions, financial stability and bank profitability.

The financial stability analysis in table 5 shows that the CME*ISI variable is positive and statistically significant in relation to the banking sector solvency variable in column 1. This indicates that strong institutional quality mitigates the adverse effect of carbon emissions on banking sector solvency in non-crisis years by ensuring greater banking sector solvency in carbon-intensive environments. However, the CME*ISI coefficient is not economically significant in relation to the banking sector solvency variable.

In the profitability analysis in columns 3 to 5 in table 5, the CME*ISI variable is positive and statistically significant at the 1 percent level in relation to the non-interest income variable in column 5 of table 5. This indicates that institutional quality reinforces the positive relationship between carbon emissions and banking sector non-interest income in non-crisis years. In terms of economic significance, institutional quality increases the positive relationship between carbon emissions and banking sector non-interest income by 4.42 percent in non-crisis years.

Table 5. Moderating role of institutional quality on the relationship between carbon emissions, financial stability and bank profitability: panel first-difference-GMM estimation

	ZSCORE	NPL	ROA	ROE	NII
	(1)	(2)	(3)	(4)	(5)
	Coefficient (p-value)	Coefficient (p-value)	Coefficient (p-value)	Coefficient (p-value)	Coefficient (p-value)
$ZSCORE_{lag}$	-0.225 (0.28)				
NPL_{lag}		1.286*** (0.00)			
ROA_{lag}			-0.045 (0.62)		
ROA_{lag}				-0.284 (0.14)	
NII_{lag}					0.343* (0.08)
CME	-1.567*** (0.00)	-0.033 (0.83)	0.155 (0.29)	-0.043 (0.95)	-1.131 (0.31)
CME*ISI	0.790** (0.03)	-0.140 (0.49)	0.085 (0.29)	0.851 (0.14)	4.423*** (0.00)
EFF	-0.189*** (0.00)	0.012 (0.64)	-0.038** (0.02)	-0.329* (0.09)	0.858*** (0.00)
ISI	2.871 (0.80)	10.862 (0.34)	-14.37*** (0.00)	-14.78*** (0.00)	-14.14*** (0.00)
INF	0.521 (0.44)	-0.045 (0.74)	-0.323** (0.01)	-2.491*** (0.00)	3.182*** (0.00)
UNEMP	0.675 (0.16)	-0.322 (0.33)	-0.693*** (0.00)	-2.679 (0.16)	-3.251 (0.11)
GDPR	1.999*** (0.00)	-0.809*** (0.00)	-0.495** (0.04)	-5.286*** (0.00)	1.204 (0.45)
CAR	0.920** (0.02)	-0.541*** (0.00)	0.344** (0.01)	2.000 (0.16)	-0.011 (0.99)
Country fixed effect?	Difference	Difference	Difference	Difference	Difference
Year Fixed effect?	Yes	Yes	Yes	Yes	Yes
J-statistic	6.796	8.407	6.034	6.56	4.658
P(J-statistic)	0.450	0.298	0.536	0.476	0.701
AR(1)	0.215	0.056	0.5004	0.824	0.090
AR(2)	0.308	0.240	0.2804	0.411	0.211

P-values are in parenthesis. ***, **, * denote statistical significance at the 1%, 5% and 10% levels. GMM instruments are only applied to the lagged dependent variable. AR (1) and AR (2) test for the presence of first-order and second-order serial correlation in the first difference residuals, respectively. ZSCORE variable = banking sector solvency. NPL variable = nonperforming loans ratio. ROA variable = banking sector return on assets. ROE variable = banking sector return on equity. NII variable = banking sector non-interest income. CME variable = carbon emissions from gaseous fuel consumption (% of total). GDPR variable = rate of economic growth. ISI variable = quality of institutional governance. EFF variable = the cost to income ratio of the banking sector. CAR = regulatory capital ratio. INF variable = the annual inflation rate. UNEMP variable = the total unemployment rate.

Source: Author’s computation

4.3. Sensitivity and robustness analysis

4.3.1. Instrumental variable (IV) estimation

In this section, the first-difference-GMM model is re-estimated using the one-year lag of the explanatory variables as instrumental variables. The instrumental variables in the estimation address potential endogeneity problems in the dataset. The results are reported in tables 6 and 7.

The financial stability analysis in table 6 shows that the lagged nonperforming loans variable remains positively significant in relation to the nonperforming loans variable in tables 4 and 6, indicating that the size of nonperforming loans in the previous period is a significant determinant of the size of nonperforming loans in the current period. The carbon emissions variable also remains negatively significant in relation to the banking sector solvency variable both in tables 4 and 6, indicating that higher carbon emissions decrease banking sector solvency which impair financial stability in non-crisis years.

In the profitability analysis, the lagged return on asset variable is negatively significant in column 3, indicating that a high return on asset in the previous period is followed by a low return on asset in the current period in non-crisis years. However, the instrumental variable estimations in columns 3 to 5 in table 6 do not report any significant effect of carbon emissions on bank profitability.

Furthermore, in the moderation analysis in table 7, the results show that the CME*ISI variable remains positive and statistically significant in relation to the banking sector solvency variable which indicates that institutional quality mitigates the adverse effect of carbon emissions on banking sector solvency by ensuring greater banking sector solvency in carbon-intensive environments. In the profitability analysis, the CME*ISI variable remains positive and statistically significant in relation to the non-interest income variable in column 5, indicating that institutional quality reinforces the positive relationship between carbon emissions and banking sector non-interest income in non-crisis years.

Table 6. Instrumental Variable (IV) first-difference GMM estimation: Effect of carbon emissions on financial stability and bank profitability in non-crisis years

Variable	ZSCORE	NPL	ROA	ROE	NII
	(1)	(2)	(3)	(4)	(5)
	Coefficient (p-value)	Coefficient (p-value)	Coefficient (p-value)	Coefficient (p-value)	Coefficient (p-value)
$ZSCORE_{lag}$	-0.118 (0.33)				
NPL_{lag}		1.073*** (0.00)			
ROA_{lag}			-0.107* (0.05)		
ROE_{lag}				-0.117 (0.53)	
NII_{lag}					0.264* (0.01)
CME	-0.699*** (0.00)	-0.064 (0.46)	0.069 (0.51)	-0.378 (0.43)	0.662 (0.19)
EFF	-0.087*** (0.00)	0.021 (0.48)	-0.046*** (0.00)	-0.382** (0.02)	1.167*** (0.00)
ISI	2.502 (0.67)	5.307* (0.08)	-6.995** (0.01)	-91.58*** (0.00)	-54.98*** (0.00)
INF	-0.495* (0.10)	0.205*** (0.00)	-0.194** (0.01)	-2.009*** (0.00)	-0.599 (0.65)
UNEMP	-0.053 (0.93)	0.226 (0.21)	-0.243* (0.08)	-0.547 (0.68)	0.573 (0.45)
GDPR	-0.187 (0.77)	-0.494*** (0.00)	-0.217 (0.16)	-2.851* (0.09)	-4.985** (0.03)
CAR	0.602*** (0.00)	-0.373*** (0.00)	0.102 (0.24)	-0.450 (0.62)	0.049 (0.95)
Country fixed effect	Difference	Difference	Difference	Difference	Difference
Year fixed effect?	Yes	Yes	Yes	Yes	Yes
J-statistic	11.371	10.255	9.799	10.27	11.67
P(J-statistic)	0.181	0.247	0.279	0.246	0.166
AR(1)	0.269	0.359	0.927	0.987	0.311
AR(2)	0.568	0.157	0.826	0.936	0.400

P-values are in parenthesis. ***, **, * denote statistical significance at the 1%, 5% and 10% levels. Each IV GMM estimation in this table include instrumental variables made up of one-year lag of all the explanatory variables in the model. AR (1) and AR (2) test for the presence of first-order and second-order serial correlation in the first difference residuals, respectively. ZSCORE variable = banking sector solvency. NPL variable = nonperforming loans ratio. ROA variable = banking sector return on assets. ROE variable = banking sector return on equity. NII variable = banking sector non-interest income. CME variable = carbon emissions from gaseous fuel consumption (% of total). GDPR variable = rate of economic growth. ISI variable = quality of institutional governance. EFF variable = the cost to income ratio of the banking sector. CAR = regulatory capital ratio. INF variable = the annual inflation rate. UNEMP variable = the total unemployment rate.

Source: Author's computation

Table 7. Instrumental Variable (IV) first-difference GMM estimation: Moderating role of institutional quality in the relationship between carbon emissions, financial stability and bank profitability

	ZSCORE	NPL	ROA	ROE	NII
	(1)	(2)	(3)	(4)	(5)
	Coefficient (p-value)	Coefficient (p-value)	Coefficient (p-value)	Coefficient (p-value)	Coefficient (p-value)
$ZSCORE_{lag}$	-0.101 (0.49)				
NPL_{lag}		1.283*** (0.00)			
ROA_{lag}			-0.047 (0.56)		
ROA_{lag}				-0.038 (0.85)	
NII_{lag}					0.177 (0.12)
CME	-1.095*** (0.00)	-0.117 (0.29)	0.029 (0.80)	-0.490 (0.41)	-0.062 (0.91)
CME*ISI	0.619* (0.07)	-0.127 (0.39)	0.076 (0.28)	0.351 (0.46)	2.375*** (0.00)
EFF	-0.066 (0.48)	0.016 (0.61)	-0.050*** (0.00)	-0.483** (0.01)	0.906*** (0.00)
ISI	-2.082 (0.81)	12.437 (0.34)	-8.561*** (0.00)	-103.24*** (0.00)	-94.286*** (0.00)
INF	0.004 (0.99)	0.118 (0.29)	-0.182* (0.10)	-1.915*** (0.00)	0.576 (0.66)
UNEMP	0.129 (0.82)	0.093 (0.71)	-0.325* (0.06)	-0.541 (0.72)	-1.703 (0.15)
GDPR	0.811 (0.30)	-0.616*** (0.00)	-0.160 (0.48)	-2.477 (0.17)	-2.669 (0.19)
CAR	0.867*** (0.00)	-0.380*** (0.00)	0.096 (0.32)	-0.594 (0.54)	0.356 (0.72)
Country fixed effect?	First-Difference	First-Difference	First-Difference	First-Difference	First-Difference
Year Fixed effect?	Yes	Yes	Yes	Yes	Yes
J-statistic	9.259	9.604	9.351	8.448	6.995
P(J-statistic)	0.234	0.212	0.228	0.295	0.429
AR(1)	0.262	0.023	0.921	0.822	0.812
AR(2)	0.949	0.008	0.672	0.787	0.503

P-values are in parenthesis. ***, **, * denote statistical significance at the 1%, 5% and 10% levels. Each IV GMM estimation in this table include instrumental variables made up of one-year lag of all the explanatory variables in the model. AR (1) and AR (2) test for the presence of first-order and second-order serial correlation in the first-difference residuals, respectively. ZSCORE variable = banking sector solvency. NPL variable = nonperforming loans ratio. ROA variable = banking sector return on assets. ROE variable = banking sector return on equity. NII variable = banking sector non-interest income. CME variable = carbon emissions from gaseous fuel consumption (% of total). GDPR variable = rate of economic growth. ISI variable = quality of institutional governance. EFF variable = the cost to income ratio of the banking sector. CAR = regulatory capital ratio. INF variable = the annual inflation rate. UNEMP variable = the total unemployment rate.

Source: Author’s computation

4.3.2. Addressing possible correlation between the bank capitalization and banking sector solvency variables

Furthermore, we address concerns that the regulatory capital ratio variable (CAR) might be correlated with the banking sector solvency variable (i.e. the ZSCORE) since the ZSCORE index is usually computed using return on assets and bank capital ratio. We address this concern by removing the regulatory capital ratio variable from the ZSCORE model and re-estimating the ZSCORE model to check whether the results will change significantly. The results, which are reported in table 8, do not change significantly. It can be observed that the carbon emissions variable remains negatively significant in relation to the banking sector solvency variable in table 8, indicating that higher carbon emissions decrease banking sector solvency which impair financial stability in non-crisis years. However, the CME*ISI variable remained positive but statistically insignificant in relation to the banking sector solvency variable in table 8.

Table 8. Excluding the regulatory capital ratio variable (CAR) to verify the robustness of the ZSCORE estimation result

Variable	Difference GMM with lagged dependent variable	Difference-GMM with lagged dependent variable	Difference-GMM with lagged dependent variable and explanatory variables as instrumental variables (IV)	Difference-GMM with lagged dependent variable and explanatory variables as instrumental variables (IV)
	(1)	(2)	(3)	(4)
	Coefficient (p-value)	Coefficient (p-value)	Coefficient (p-value)	Coefficient (p-value)
$ZSCORE_{lag}$	-0.127 (0.39)	-0082 (0.69)	0.015 (0.86)	-0.002 (0.99)
CME	-1.113*** (0.00)	-1.470*** (0.00)	-1.154*** (0.00)	-0.120*** (0.00)
CME*ISI		0.204 (0.61)		0.065 (0.83)
EFF	-0.076*** (0.00)	-0.252*** (0.00)	-0.237** (0.03)	-0.187* (0.10)
ISI	16.624 (0.31)	16.332 (0.32)	21.038** (0.01)	11.631 (0.33)
INF	-0.316 (0.42)	-0.155 (0.76)	-0.069 (0.79)	-0.291 (0.43)
UNEMP	-1.345** (0.04)	-0.891 (0.28)	-0.144 (0.84)	-0.386 (0.61)
GDPR	-0.587 (0.29)	-0.419 (0.57)	0.057 (0.91)	-0.279 (0.67)
Country fixed effect	First-Difference	First-Difference	First-Difference	First-Difference
Year fixed effect?	Yes	Yes	Yes	Yes
J-statistic	9.45	6.35	11.118	9.011
P(J-statistic)	0.48	0.704	0.348	0.436
AR(1)	0.656	0.296	0.198	0.201
AR(2)	0.458	0.210	0.316	0.261

P-values are in parenthesis. ***, **, * denote statistical significance at the 1%, 5% and 10% levels. In the GMM-IV estimation, each GMM estimation in this table include instrumental variables made up of one-year lag of all the explanatory variables in the model. AR (1) and AR (2) test for the presence of first-order and second-order serial correlation in the first difference residuals, respectively. ZSCORE variable = banking sector solvency. NPL variable = nonperforming loans ratio. ROA variable = banking sector return on assets. ROE variable = banking sector return on equity. NII variable = banking sector non-interest income. CME variable = carbon emissions from gaseous fuel consumption (% of total). GDPR variable = rate of economic growth. ISI variable = quality of institutional governance. EFF variable = the cost to income ratio of the banking sector. INF variable = the annual inflation rate. UNEMP variable = the total unemployment rate.

Source: Author's computation

4.4.3. Capital buffer as an alternative measure of financial stability

Finally, we introduced two alternative measures of financial stability which is the capital buffer variables: "BUFF" and "BUFFER". The BUFF variable is measured as regulatory capital ratio divided by the minimum Basel capital ratio of 8 percent following the approach of De Moraes and Pinto Bandeira de Mello (2024), while the BUFFER variable is measured as regulatory capital ratio minus the minimum Basel capital ratio of 8 percent following the approach of Ozili (2025b). Before re-estimating the result, we observed that the regulatory capital variable is highly or perfectly correlated with the BUFF and BUFFER variables. To address this issue, we removed the regulatory capital ratio variable from the model and re-estimate the results without it as shown in table 9. The result reveals that the carbon emissions coefficient remains negative and statistically significant in most of the estimations in table 9. This indicates that carbon emissions have a significant negative impact on banking sector capital buffer, but the carbon emissions variable is not economically significant. Notwithstanding, the result in table 9 shows that higher carbon emissions decrease bank capital buffer in non-crisis years which is detrimental to financial stability. However, the CME*ISI variable is negatively significant in two out of the eight estimations, indicating that strong institutional quality did not mitigate the adverse effect of carbon emissions on bank capital buffer.

Table 9. Using capital buffer as an alternative measure of financial stability

	Difference-GMM with lagged dependent variable	Difference-GMM with lagged DV and explanatory variables as instrumental variables (IV)	Difference-GMM with lagged dependent variable	Difference-GMM with lagged DV and explanatory variables as instrumental variables (IV)	Difference-GMM with lagged dependent variable	Difference-GMM with lagged DV and explanatory variables as instrumental variables (IV)	Difference-GMM with lagged dependent variable	Difference-GMM with lagged DV and explanatory variables as instrumental variables (IV)
Variable	BUFF	BUFF	BUFF	BUFF	BUFFER	BUFFER	BUFFER	BUFFER
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Coefficient (p-value)	Coefficient (p-value)	Coefficient (p-value)	Coefficient (p-value)	Coefficient (p-value)	Coefficient (p-value)	Coefficient (p-value)	Coefficient (p-value)
$BUFF_{lag}$	-0.124 (0.11)	-0.041 (-0.54)	-0.327* (0.08)	-0.140 (0.22)				
$BUFFER_{lag}$					-0.126 (0.19)	-0.041 (0.55)	-0.281 (0.17)	-0.140 (0.22)
CME	-0.028*** (0.00)	-0.029*** (0.00)	-0.032 (0.39)	-0.031*** (0.00)	-0.240*** (0.00)	-0.238*** (0.00)	-0.322 (0.31)	-0.249*** (0.00)
CME*ISI			-0.087** (0.02)	-0.515 (0.17)			-0.753** (0.02)	-0.412 (0.17)
EFF	0.002 (0.51)	-0.003 (0.57)	-0.014* (0.08)	-0.015 (0.16)	0.020 (0.67)	-0.022 (0.58)	-0.146* (0.06)	-0.125 (0.16)
ISI	0.223 (0.71)	0.148 (0.86)	3.706* (0.09)	2.035 (0.26)	3.578 (0.49)	1.186 (0.86)	28.768* (0.10)	16.284 (0.26)
INF	-0.056*** (0.00)	-0.040** (0.03)	-0.049 (0.16)	-0.033* (0.05)	-0.466*** (0.00)	-0.322** (0.03)	-0.325 (0.27)	-0.262* (0.05)
UNEMP	0.007 (0.93)	0.020 (0.79)	0.107 (0.55)	0.164 (0.22)	0.073 (0.90)	0.161 (0.79)	1.296 (0.41)	1.316 (0.22)
GDPR	-0.033 (0.47)	0.007 (0.83)	-0.047 (0.49)	0.015 (0.60)	-0.221 (0.59)	0.056 (0.83)	-0.217 (0.65)	0.119 (0.60)
Country fixed effect	First-Difference	First-Difference	First-Difference	First-Difference	First-Difference	First-Difference	First-Difference	First-Difference
Year fixed effect?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
J-statistic	10.727	11.85	8.579	10.79	10.99	11.85	7.97	10.793
P(J-statistic)	0.295	0.222	0.379	0.214	0.275	0.222	0.436	0.214
AR(1)	0.096	0.080	0.653	0.167	0.094	0.080	0.464	0.166
AR(2)	0.589	0.341	0.411	0.604	0.438	0.342	0.329	0.604

P-values are in parenthesis. ***, **, * denote statistical significance at the 1%, 5% and 10% levels. In the GMM-IV estimation, each GMM estimation in this table include instrumental variables made up of one-year lag of all the explanatory variables in the model. AR (1) and AR (2) test for the presence of first-order and second-order serial correlation in the first difference residuals, respectively. ZSCORE variable = banking sector solvency. NPL variable = nonperforming loans ratio. ROA variable = banking sector return on assets. ROE variable = banking sector return on equity. NII variable = banking sector non-interest income. CME variable = carbon emissions from gaseous fuel consumption (% of total). GDPR variable = rate of economic growth. ISI variable = quality of institutional governance. EFF variable = the cost to income ratio of the banking sector. INF variable = the annual inflation rate. UNEMP variable = the total unemployment rate. BUFF = regulatory capital ratio divided by the minimum Basel capital ratio of 8 percent. BUFFER = regulatory capital ratio minus the minimum Basel capital ratio of 8 percent.

Source: Author's computation

5. Conclusion

Carbon emissions are important but often overlooked factor affecting financial stability and bank profitability. This study examined the effect of carbon emissions on financial stability and bank profitability in non-crisis years in 22 countries from 2011 to 2018 using several indicators of financial stability and bank profitability.

The findings revealed that higher carbon emissions impair financial stability by decreasing banking sector solvency and bank capital buffer. We also found some evidence that institutional quality mitigates the adverse effect of carbon emissions on financial stability by ensuring greater banking sector solvency in carbon-intensive environments. Institutional quality also reinforces the positive relationship between carbon emissions and bank profitability, particularly banking sector non-interest income. We further found that lagged nonperforming loans, institutional quality, economic growth and regulatory capital requirements are significant determinants of financial stability in non-crisis years while the determinants of bank profitability are lagged return on asset, the efficiency ratio, institutional quality, inflation rate and unemployment rate in non-crisis years.

The implication of the findings is that environmental factors, particularly carbon emissions, adversely affect financial stability and bank profitability. The findings supports the United Nations' SDG13 goal to mobilize policymakers and institutions for collective climate action against man-made environmental (or carbon dioxide) pollution. We demonstrated in this study that such pollution not only affect society, but it also has an adverse effect on financial system stability by increasing bank insolvency risk which impair financial stability.

The findings of the study calls on policymakers to take action to combat climate change arising from excessive carbon emissions from gaseous fuel consumption. It is recommended that policymakers should pay close attention to how carbon emissions affect financial stability and bank profitability. They should identify the areas where policy intervention is needed to minimize the adverse effect of carbon emissions on financial stability and bank profitability. Policymakers should also determine the type of macro-level or micro-level safeguards that should be implemented to preserve financial stability and bank profitability in a carbon-intensive environment. For instance, they should enforce legal and institutional policy measures that reduce carbon emissions, protect the climate and prevent the occurrence of carbon-induced climate change events that could (i) adversely affect the ability of debtors to repay loans owed to financial institutions, and (ii) damage the physical infrastructure and human capital that financial institutions rely on to increase profitability and to remain financially stable. Policymakers also need to develop robust macroprudential and micro prudential policy frameworks that increase the resilience of the financial system to the threat posed by rising carbon emissions.

The limitation of the study is that the study focused on only one determinant of climate change which is carbon emissions. The study did not examine other determinants of climate change that could offer new insights. This was due to the difficulty in finding a good proxy variable for other determinants of climate change. For this reason, this study focused on carbon emissions and its effect on financial stability and bank profitability. However, this limitation creates interesting opportunities for future research.

Future research studies can examine the effect of other climate change variables on financial stability and bank profitability. Future studies can also suggest what financial institutions can do at the micro level to mitigate the adverse effect of carbon emissions on financial stability and bank profitability. Future studies can also investigate the type of macro prudential frameworks that are effective in mitigating the adverse effect of climate change on financial stability and bank profitability.

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