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Examining the Impact of Financial Development on Carbon Emissions: Insights from Emerging Economies

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Abstract This study investigates the impact of financial market development on the environmental quality of emerging countries through an analysis of panel data from 21 Emerging Countries covering the period from 2001 to 2023. To accomplish this objective, we constructed stock market-based and banking sector-based indices to measure the level of financial market development using principal component analysis. We then identified the cross-sectional dependence and employed unit root testing to ensure accurate estimation. By employing a panel ARDL bound test, we demonstrate that financial development positively impacts environmental quality in emerging countries. The findings provide new insights for researchers and policymakers who seek to develop comprehensive energy supply and economic policies to alleviate the adverse effects of pollution.

Keywords Financial development · Environmental quality · CO2 Emissions · Panel ARDL bound test · Emerging countries

Jel Codes O1, O13, F6, F64

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Examining the Impact of Financial Development on Carbon Emissions: Insights from Emerging Economies

Environmental risks resulting from economic models and policies that prioritise economic growth—EG—have become a global concern. This issue is highly contentious, as it lies at the connection of sustainable development and environmental economics, affecting both developed and developing countries. A developed financial sector that facilitates access to financial resources and eliminates investment barriers has increasingly become a vital component of economic growth and development. However, it should be noted that financial development—FD—also has related costs. An increase in CO2 emissions has been linked to economic growth accelerated by financial development, resulting in global warming and its wide-ranging effects.

According to Khan and Ozturk (2021), the prioritisation of EG in economic models has generated global concerns regarding environmental risks. This matter is highly debated and at the convergence of sustainable development and environmental economics, impacting all countries. The establishment of a well-developed financial sector is pivotal in facilitating access to financial resources and eliminating obstacles to investment, thus contributing significantly to economic development (ED) and economic growth. However, it is important to acknowledge that FD also entails associated costs. The acceleration of economic growth through FD has been determined to be connected to an rise in CO2 emissions, leading to global warming and its far-reaching effects.

Grossman and Krueger (1991) made the first attempt to discover the potential link between economic development and CO2 emissions. They introduced the Environmental Kuznets Curve–EKC hypothesis, which holds that environmental contamination initially rises along the early phases of economic expansion, as identified by Kuznets (1955). However, as higher income levels are attained, the environmental quality improves, indicating an inverted-U relationship between environmental contamination and ED. Similarly, Zilibotti (1994) conducted a study using FD on technology as a proxy for economic development. His research discovered that FD, which fosters the progress of technology, diminishes the concentration of carbon emissions. Studies conducted with countries or country groups with different levels of economic development display that FD has both positive and negative impacts on CO2 emissions (Charfeddine & Khediri,2016; Hao et al., 2016; Anwar et al., 2021). In particular, different FD indicators used in studies may lead to different results on similar subjects. This creates a discord in the literature and necessitates “more detailed studies.”

This study executes a panel autoregressive distributed lag–ARDL model examining the association between FD and CO2 emissions in emerging economies. However, no single indicator of financial institutions and markets can capture all aspects of a financial system. Given the multifaceted nature of financial systems, no single indicator of financial sectors and capital markets can fully encompass all aspects of FD. For this reason, we formed a financial development index, the FDX, which comprises the banking sector and stock market sector components. One of the contributions of this study is the creation of a comprehensive financial development index that will fill the literature gap and emphasise the index's fundamental role in a heterogeneous group of different countries. The second contribution of this paper is about the country group. The second contribution lies in the focus on emerging countries, which face a range of challenges and transitions in their rapidly growing economies, including increasing financial activities. In this context, financial markets play a crucial role in economic activities and, consequently, CO2 emissions. In this context,

financial markets significantly impact economic activities and, thus, CO2 emissions. Thus, this study investigates the nexus between FD and CO2 emissions in fast-growing emerging countries.

The remaining sections of the study are designed as follows: Section 2 explains the theoretical framework, and Section 3 provides information about the data and measures of FD and explains the construction of the composite FDX. The methodological approach is discussed in Section 4. The estimation findings are displayed in Section 5. Finally, the paper is concluded in Section 6.

Theoretical Background

The theoretical background of this study demonstrates a growing interest in understanding the link between FD and environmental quality (EQ), particularly concerning CO2 emissions. The EKC hypothesis offers a possible link between environmental enhancement and ED, and this link can be extended by applying it to FD, one of the indicators of ED. Since the worldwide financial crisis in 2009, FD's critical significance in economic development has got attention, according to scholars and policymakers. Previous empirical studies have provided mixed findings regarding the effect of FD on EQ. Accordingly, Shafik and Bandyopadhyay (1992) claim that the EKC helps explain the relationship between EQ and FD based on its hypothesis. The dynamic link between FD and environmental improvement is a vital concept favoring academic fields and policy networks.

The relationship between FD and CO2 emissions is complex and multifaceted. Although there is no definitive consensus, several studies have explored this relationship and identified various patterns. Many researchers have contended that FD follows an inverted U-shaped pattern with CO2 emissions, similar to the Environmental Kuznets Curve hypothesis. In the initial stages of financial development, CO2 emissions tend to increase as economic activities expand, energy consumption rises, and industrialization occurs. However, as financial development progresses, economies tend to shift towards cleaner and more efficient technologies, leading to a decrease in CO2 emissions (Paramati et al., 2017; Phong, 2019; Jiang & Ma, 2019; Setiawati & Salsabila, 2023; Ofori et al., 2023).

Moreover, another recent study, Yiadom et al. (2023) examined the interaction between finance, ED, and carbon emissions in 97 countries, including 50 with low-income and 47with high-incomes, over the period from 1991 to 2019. Their results revealed that low-income economies need an FD threshold of 0.354, while high-income countries need a higher threshold of 0.662 to reduce carbon emissions, confirming the existence of a finance-led EKC. The authors also highlighted that a per capita GDP of at least US$ 10,067 is needed for ED to reduce emissions, with a subsequent increase in ED leading to a 0.96% reduction in carbon emissions across all income levels.

FD, mainly through increased access to capital and investment, can facilitate technological innovation. This may result in the shift to cleaner energy sources, improved energy efficiency, and the development of eco-friendly technologies, thereby reducing CO2 emissions. Yu et al. (2024) studied the effect of FD and FDI on CO_2 emissions in 57 developed and developing countries over the period of 2000 to 2017, focusing on carbon pricing. The authors found that financial depth in institutions reduces CO_2 intensity in advanced economies but raises it in emerging ones. Access to financial institutions has an adverse effect in both economies. Inward FDI quality raises CO_2 intensity in developing economies but lowers it in advanced ones. They also showed that carbon pricing in advanced countries can lessen the negative impact of FDI on CO2 intensity, boosting climate-friendly investment. Moreover, FD often correlates with improved governance structures and institutions, including environmental regulations. As countries develop financially, they

may introduce stricter regulations and policies to mitigate environmental impacts and enforce emission standards, resulting in reduced CO2 emissions. Moreover, a positive effect of FD through information and communication technology on carbon emission was supported by Tao et al. (2023), who examined the impacts of FD on carbon emission in OECD countries. Their results showed that three FD proxies, namely, deepening, efficiency and size, significantly alleviate carbon emission concentration. They concluded that there is a non-linear nexus between FD and carbon emission intensity. Ahmad et al. (2025) examined the association between FD, EG, and CO2 emissions in 46 Sub-Saharan countries from 2000 to 2020. The authors applied many statistical tests to ensure robustness, including the Pesaran test. Co-integration tests confirmed the long-term relationships. Moreover, they also used four methods (Quantile Methods through the Method of Moments (MMQR), FMOLS, DOLS and Canonical Correlation Regression) to analyse the long-term effect of FD on CO2 emissions. Their results showed that energy use, trade openness, natural resources, and GDP positively impact emissions, while FDI reduces them. These findings provide further evidence that FD can reduce emissions in the long run, particularly through investments that promote cleaner technologies and energy efficiency, complementing the outcomes of other studies such as those by Yu et al. (2024) and Tao et al. (2023).

Additionally, Solaymani and Montes (2024) argued that New Zealand's environmental policies and political situation might influence several factors affecting both EG and CO2 emissions. Their findings indicated that renewable and non-renewable energy consumption, FDI, and effective governance promote EG, while resource wealth income negatively impacts growth because of their high costs. Furthermore, renewable energy use, FD, and effective governance notably lower CO2 emissions. The exchange rate also facilitates the reduction of carbon emissions by negatively affecting EG and trade. Lastly, the burning of fossil fuels remains the major driver of higher CO2 emissions. According to their findings, renewable energy use, FD, and effective governance significantly reduce CO2 emissions.

Financial development can also influence energy consumption patterns. As economies grow financially, there is probably an increase in the energy demand. If fossil fuel-based energy sources primarily meet this demand, it could result in higher CO2 emissions. However, financial development can also encourage the transition to sustainable energy sources and promote energy efficiency by mitigating CO2 emissions.

The development effect in finance has emerged as a disputable question within the domain of natural economics and ED, particularly regarding CO2 emissions. The related literature has different empirical findings for the FD effect on environmental quality with several measures. Some studies report a positive link between FD and EQ, while others have found a negative relationship. The differences in the findings may be attributed to the various measures and proxies used to capture FD and EQ, as well as the level differences for FD in the research.

Prempeh (2024) analysed the role of FD, globalisation, clean energy, EG, and manufacturing expansion in lessening environmental damage in the ECOWAS region, within the framework of the N-shaped EKC between the years 1990 to 2019. The author used second-generation econometric methods, such as the Driscoll-Kraay panel regression and panel quantile estimation. The findings confirmed the N-shaped EKC for the region, revealing that increased FD and green energy usage are linked to lower environmental damage, while globalisation and industrialisation negatively affect environmental quality. The outcomes also showed that the structure of the EKC is determined by the particular characteristics of each country. For countries with low and medium emissions, the N-shaped EKC holds, but this is not the case for high emitters. FD reduces environmental damage in both low and high emitters, with no significant impact on medium emitters.

Some researchers support the EKC hypothesis, while others claim the opposite. For the sake of the study, we just analysed the studies involving country groups. According to some researchers, FD is a negative link between environmental factors (Abbasi & Riaz, 2016; Paramati et al., 2017; Park et al.,2018; Zaidi et al.,2019). For example, Ehigiamusoe and Lean (2019) used FMOLS and DOLS for 122 nations between 1990 and 2014, finding a negative relationship in the whole sample. Moreover, in countries with high income, improvement in finance lowered CO2 emissions, but in others, carbon emissions increased. Khan and Ozturk (2021) used 88 emerging nations between 2000 and 2014. Their findings confirm that FD plays a vital role in reducing pollution. Their outcomes also indicate that FD lessens the negative impacts of income and trade openness|-TO. Al-Mulali et al. (2015c) used ecological footprints with the environmental degradation indicator by using 93 countries that are categorised by income. The authors provided a negative association between FD and environmental degradation. Lee et al. (2015) used 25 OECD countries in their study. According to their findings, there is no EKC for OECD countries. However, they found that the FD coefficient for the eight countries was statistically significant and negative.

According to the study of Lv and Li (2021), 97 countries from 2000 and 2014 were used in the analysis, and their results suggest that FD is crucial to the lessening of CO2 emissions and that a country's environmental performance may be enhanced by its proximity to regions with a high level of FD. Bayar et al. (2020) employed long-term estimation to reveal that primary energy consumption and the growth of the financial sector had a beneficial effect on CO2 emissions in 11 post-transition European economies. Their findings are meant to catch the attention of decision-makers so that they may develop country-specific policies that strike a balance between EG and CO2 emissions.

Kırıkkaleli et al. (2022) studied the effect of FD and green energy consumption on consumption-based CO2 emissions in Chile using ARDL bounds with Kripfganz & Schneider's (2018) estimations, FMOLS, DOLS, and gradual shift causality tests. Their results show that while FD and renewable energy use decrease the consumption-based CO2 emissions in Chile, EG and electricity consumption increase the consumption-based carbon emissions. Rahman et al. (2022) investigated the impact of agricultural and industrial output on carbon emissions by employing the novel FARDL method to obtain quarterly data. They showed that FD and inflation increase carbon emissions, with inflation affecting only the agriculture-CO2 relationship. The authors also demonstrated that agriculture and forestry influence CO2 emissions over the short, medium, and long term. Based on their results, the authors recommended that Pakistan's government focus on sustainable agriculture and introduce a carbon tax on industries to support green energy initiatives and tree planting projects.

On the other hand, in another group of studies, environmental degradation and FD are positively correlated (Hafeez et al., 2018; Phong, 2019; Sheraz et al., 2022; Latif et al., 2023). Dangers arising from financial measures are causing global environmental problems, and improvements in the financial sector and CO2 emissions are positively correlated. (Shahbaz et al., 2020).

Charfeddine and Kahia (2019) analyses were done for 24 MENA countries spanning from 1980 to 2015. Their outcomes imply that FD has a marginal impact and can only marginally account for EG and CO2 emissions. These results show that there has been little progress in the financial sector's ability to promote both economic expansion and the enhancement of environmental conditions. Furthermore, Jamel et al. (2017) used OLS and causality estimation for 40 European countries and showed that energy consumption, FDI, inflation, capital stock, and urban population growth had no impact on CO2 emissions.

Another group of studies found contradictory results about FD on CO2 emissions, and the reason for that is level differences for FD have not existed in their study (Al-Mulali & Sab, 2012; Saidi & Mbarek, 2017; Jiang & Ma, 2019; Cetin & Bakirtas, 2020). Another reason for the contradictory findings is that different intermediaries for the improvement in finance have been used in some research, as Zhang (2011) exhibited that using various intermediaries has several effects on CO2 emissions. Acheampong (2019) used 46 nations of Sub-Saharan Africa between the years 2000 and 2005. The results are somewhat confusing. There are positive and negative associations between FD and environmental quality. Recently, Adebayo et al. (2023) found mixed results. They analysed the impacts of FD of the MINT nations (Indonesia, Mexico, Turkey and Nigeria) on their CO2 emissions by applying historical data covering the years 1969 and 2019. The full-sample bootstrap non-Granger causality results for Turkey and Mexico show that there is a one-way causal relation between FD and CO2 emissions. However, their empirical findings from the rolling-window bootstrap estimation display that the nexus between FD and carbon emissions is date-stamped; these imply important causal feedback links between FD and CO2 emissions in sub-sampled periods in the MINT states.

Most of the above-mentioned research is applied in OECD, European countries, MENA countries, etc. Consequently, more practical proof is required to define the possible link between FD and CO_2 emissions in a heterogeneous group consisting of different countries. In addition, this study proposes a new inclusive financial development index, which incorporates selected variables to offer a more detailed measurement of FD. The contribution of this FD measure to the literature lies in the fact that, while existing studies often rely on limited measures of FD, this study integrates a broader range of FD indicators, empowering a more detailed and comprehensive analysis of the environmental impacts of FD. In this context, the application of this FD index and the use of a broader data set compared to previous studies address the existing gaps in the literature. This study aims to investigate the link between FD and CO2 emissions, with the outcomes suggesting a negative relationship. Moreover, this study analyzes the effect of FD on CO2 emissions using a range of FD indicators. Therefore, these findings have important implications for policymakers, suggesting that emerging countries can alter their CO2 emissions with the aid of FD.

Data and Measurement of FD

This study uses annual data for 21 emerging countries[1] spanning 23 years from 2001 to 2023. The study period ends in 2023 owing to the lack of more recent data, especially energy usage and CO2 emissions indices. Our sample consists of only 21 emerging countries for two reasons. First, by narrowing the focus to a specific country group, it is possible to reduce variability and sample heterogeneity. Second, emerging countries may allow for consistent measurements of financial development since they have less mature financial systems.

CO_2 emission is the dependent variable and is gauged by the metric tons per capita, whereas the indicator of FD constructed by the authors is an independent variable. The control variables are energy consumption and per capita GDP (in 2010 constant US dollars). The energy consumption and CO2 emissions data were acquired from the Statista online database. The remaining data were taken from the World Development Indicators Database (WDI). (Table 1) displays the basic statistics for the indices of FDX and the variables used in the analysis.

[1] Brazil, Chile,China,Colombia, Egypt, Greece, Hungary, India, Indonesia, the Korean Republic, Malaysia, Mexico, Morocco, Pakistan, Peru, the Philippines, Poland, Russia, SouthAfrica, Thailand and Turkey

Table 1
Basic Statistics

Variable	Observation	Mean	Std. Dev.	Min	Max
$lnCO_2$	483	0.51	0.35	−0.20	1.09
lnENG	483	1.77	0.13	1.45	1.94
lnGDP	483	3.77	0.35	2.89	4.51
SMTV	483	65.81	76.57	.84	556.91
SMCAP	483	55.73	46.93	7.47	328.36
SMTR	483	29.85	34.80	.22	249.17
BM	483	69.37	38.90	14.35	211.82
PC	483	58.43	35.38	11.60	182.86
FSD	483	51.68	25.99	12.44	128.84
DMB	483	65.29	34.49	2.02	174.53
BCBD	483	104.49	51.49	35.409	365.99

describing an indication of FD is a difficult task because of the complexity of the financial services that financial systems provide. Although different measures have been used in the empirical literature to determine financial depth, there is no direct extent of financial system development. Given the complexity and diversity of financial systems in emerging economies, this study aims to obtain a more comprehensive picture of FD. Instead of relying solely on the bank-based indicator, we used both bank-based and market-based proxies to evaluate FD in these countries. This approach ensures a fuller understanding of the financial landscape, considering both traditional banking and more advanced market mechanisms. Following Ang and McKibbin(2007), we employ principal component analysis (PCA) to construct a composite FDX. The ratio of stock market turnover (SMTV), stock market capitalisation – SMCAP, and stock market total value traded (SMTR) are used as indices of stock market development. Additionally, we used private credits —PC, broad money—BM, financial system deposits—FSD, deposit money bank assets—DMB, and bank credits to bank deposits – BCBDto measure bank development. All FD indicators are in the form of a percentage of GDP. PCA was used to overcome the multicollinearity problems that may occur due to the standard information present in the financial development indicators. This method converts correlated variables into uncorrelated variables, and the purpose of using PCA was to obtain a composite FDX that captures the most important variations in FD indicators. The outcomes of PCA for FDX are presented below (Table nr. 2).

Table 2
PCA Outcomes

	Comp-1	Comp-2	Comp-3	Comp-4	Comp-5	Comp-6	Comp-7	Comp-8
Eigenvalues	3.981	1.462	1.138	.706	.493	.159	.043	.015
% of the variance	0.497	0.183	0.142	0.088	0.061	0.019	0.005	0.001
Cumulative %	0.497	0.680	0.822	0.911	0.972	0.992	0.998	1.000
Eigenvectors								
VARIABLE	**Vc-1**	**Vc-2**	**Vc-3**	**Vc-4**	**Vc-5**	**Vc-6**	**Vc-7**	**Vc-8**
SMTV	0.220	0.396	0.203	0.865	0.093	0.006	−0.046	0.032
SMCAP	0.264	0.450	0.656	−0.338	−0.085	−0.478	0.048	0.021
SMTR	0.220	0.532	0.334	−0.313	0.650	0.313	−0.039	−0.056

	Comp-1	Comp-2	Comp-3	Comp-4	Comp-5	Comp-6	Comp-7	Comp-8
PC	0.464	0.196	−0.214	0.063	−0.386	−0.422	−0.039	−0.723
BM	0.475	0.310	−0.415	0.157	−0.324	0.160	0.166	−0.078
FSD	0.397	0.465	0.516	0.024	0.327	−0.015	0.258	0.166
DMB	0.488	0.101	0.433	0.079	0.054	−0.347	−0.847	0.484
BCBD	0.218	0.105	−0.578	−0.052	−0.297	−0.154	0.254	0.450

As shown in (Table 2), The first component accounts for 49% of the total variance, while Component 2 and Component 3 explain 18% and 14% of the total variance, respectively. Following Kaiser's rule (Kaiser,1960), we choose the first, second, and third principal components as these components have eigenvalues greater than one.

Methodology

This paper explores the relationship between FD and CO_2 emissions in emerging countries while also addressing potential endogeneity and country-specific effects problems. To accomplish this, following Baltagi (2013), we used panel data analysis, specifically the panel autoregressive distributed lag (ARDL) technique, which can account for variables with different orders of integration and varying lags on each variable (Pesaran et al., 2001) to determine the short-term and long-term dynamics simultaneously.

Expressing our model in the general panel data framework, we get:

$$CO_{2\text{it}} = \alpha_0 + \alpha_1 ENG_{\text{it}} + \alpha_2 GDP_{\text{it}} + \alpha_3 FDX_{\text{it}} + \in_{\text{it}} \quad (1)$$

To reduce the heteroscedasticity problem, we take the logarithm of both sides. As a result, the estimating model can now be written as

$$lnCO_{2\text{it}} = \alpha_0 + \alpha_1 lnENGit + \alpha_2 lnGDPit + \alpha_3 lnFDXit + \in_{\text{it}} \quad (2)$$

The unrestricted specification of the panel ARDL model representation above is given by;

$$Y_{\text{it}} = \sum_{j=1}^{p} \gamma ij Yi, t-j \sum_{j=0}^{q} \delta ij Xi, t-j + \mu i + \varepsilon it \quad (3)$$

Where:

$CO2_{it}$ – Carbon Emission

ENG_{it} – EnergyConsumption

GDP_{it} – per capita GDP

FDX_{it} – Financial Development Index

Xit–set of explanatory variables;

γij – the coefficients ofthe laggedd explanatory variables;

δij – the coefficient ofthe laggedd explained variable in the short run;

i–each cross-section;

t – the estimation period.

To explore the short-term and long-term dynamics simultaneously, we used the mean group estimator MG or the pooled mean group estimator PMG. The MG estimator averages the long-term coefficients of each cross-section to estimate the parameters for the long term, while the PMG approach involves pooling

separate regression coefficients. The PMG approach keeps long-run coefficients constant and homogeneous, while short-run coefficients (such as intercepts, slopes, and adjustment speed coefficients) are permitted to vary across cross-sections.

The validity of the PMG approach relies on the existence of a long-run association between the variables, and the Hausman test can be used to decide the appropriate estimator for the panel ARDL. Overall, this paper utilises a rigorous methodology to observe the link between FD and CO_2 emissions in emerging countries while also addressing potential issues with endogeneity and country-specific effects.

We selected the ARDL method because it is well-suited for examining both short- and long-run relationships in the framework of emerging countries. This model allows us to gauge the effect of FD on CO2 emissions while considering potential endogeneity and controlling for heterogeneity across countries. Given its ability to address these complexities effectively, The ARDL framework itself provides a robust estimation of the relationship, detecting the nuances of the data without the need for supplementary tests.

Estimation Results

According to the panel data literature, the significant cross-sectional dependence – CD is likely shown because of the common shocks and unobserved factors in the panel data models. Thus, the initial stage of the empirical panel time series analysis is detecting the cross-sectional dependence. The null hypothesis of the CD statistic testing assumes zero dependence, while the acceptance of the alternate hypothesis demonstrates cross-sectional dependence between the panel units. We conducted the Friedman, Frees, and Pesaran CD tests on the data to determine whether cross-sectional dependency occurred or not. (Table 3) displays the test outcomes.

Tablo veya Table 3

CD Test Outcomes

CD Tests		
	Test stat.	**Prob.**
Friedman	34.382	0.023
Frees	2.139	0.000
Pesaran CD	4.221	0.000

According to the results, the null hypothesis of zero dependence is strongly rejected, concluding that the variables are not cross-sectionally independent. This result indicates that the rest of the sample could experience a shock that originates in one of the emerging countries.

Panel Unit-Root Tests

Since the co-integration tests require the integration of all the variables into order one, the integration order of the variables must be defined before applying the panel ARDL approach. In the existing panel data literature, Maddala & Wu, Levin-Lin-Chu, and Im-Pesaran-Shin's Unit Root (UR) tests are applied to define the variables' integration order. These tests are mentioned as "first-generation panel *UR* tests." Because these tests assume zero cross-sectional dependence, they cannot be applied in the presence of CD (O'Connell, 1998). In this case, Pesaran (2004) gives the cross-sectional augmented IPS–CIPS unit root testssecond-generation *UR* teststo detect the variables' *UR* properties. (Table 4) shows the CIPS test results both at the level and the 1st difference form. The findings indicate that FDX is stationary at the level whereas the other variables are stationary at 1st difference.

Table 4
CIPS UR Test

Variables	Level (constant&trend)	1st difference (constant)
Emissions	-2.323*	-4.280**
ENG	-2.392**	-4.386**
GDP per capita	-2.386**	-3.782**
FDX	-1.468	-2.982**

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

Results of the Panel ARDL Estimation Method

In this paper, we estimate three regression models using the PMG estimation approach. We first empirically test the effect of the index of the total FD. For the robustness check, we regress the logarithm of the carbon emissions on the PC and SMTV, which are the indicators of the financial market and stock market generally used in the literature. The outcomes of the PMG technique for the panel ARDL estimation are displayed in (Table 5), which presents the long-run effects of the dependent variables on the CO2 emissions.

Table 5
Panel ARDL PMG Estimation Results

Variables	(I)	(II)	(III)
Long-Run PMG Estimation			
FDX_{it}	−0.011*		
PC_{it}		−0.005***	
$SMTV_{it}$			−0.004*
ENG_{it}	0.712	0.643	0.559
$GDPC_{it}$	0.176***	0.138***	0.061**
ECT_{it-1}	−0.436***	−0.428***	−0.523***
Short-Run PMG Estimation			
$\Delta CO2_{it}$	0.302***	−0.218	0.334
FDX_{it}	0.083		
PC_{it}		0.052	
$SMTV_{it}$			0.023
ENG_{it}	0.478***	0.224**	0.152**
$GDPC_{it}$	0.147**	0.095***	0.078***
Hausman Test	0.929	0.994	0.91

Note: *,**,*** show levels of significance at 1%, 5% & %10 respectively.

According to the Hausman test results, we accept the null hypothesis of the homogeneity restriction, providing evidence that the PMG approach is consistent and efficient in all models. As mentioned before, the estimator of the PMG permits the short-run coefficients to vary from country to country while it imposes a homogeneity constraint on the long-run coefficients.

The long-run estimation outcomes show a significantly negative long-run association between CO2 emissions and FD. Specifically, a 1% increase in FD leads to a 0.011% decrease in CO2 emissions in the long term. This finding is consistent with those of Tamazian et al. (2009), Al-Mulali et al. (2015b), and Nasreen et

al. (2017), who have demonstrated that rising financial development results in lower CO2 emissions. It is not surprising that financial markets have helped emerging countries reduce their pollution levels, given the recent developments in their financial systems. (Cole & Elliot, 2005). While the short-run results demonstrate that there is no statistically significant relationship between CO2 emissions and FD, it is vital to note that financial markets in emerging countries may still be in their early phases of development. Therefore, the full impact of FD on emissions may not be immediately observable in the short term.

Furthermore, during FD, countries may adopt new energy technologies, reducing CO2 emissions and environmental pollution (Frankel & Romer, 1999). We further tested the effects of PC and SMTV on CO2 emissions (Column II and Column III). The coefficients of FM and FI also support the identical results (with coefficients of −0.05 and −0.04, respectively). This robustness check confirms the results obtained using the index of FD. However, the effect of both variables on carbon emissions was found to be statistically insignificant in the short term.

We control all models for the logarithm of energy use and real GDPC. The significant positive coefficients of energy usage reveal that a higher level of energy usage will increase CO2 emissions. The coefficients for GPPC are positively significant for all three models in the short and long run, which infers that economies with a higher level of GDPPC experience a higher level of CO2 emissions in emerging countries. This result is consistent with the related literature on the GDP-CO2 emission relationship.

Furthermore, the estimated coefficients for *ECT* in all models are negative and significant, varying between −0.428 and −0.523. In the case of FD, where ECT is −0.436, the CO2 emissions of the preceding year's shocks and deviations from the long-run path are done in the current year.

Conclusion

This paper aimed to examine the association between FD and CO2 emissions in selected emerging economies. For this purpose, first, PCA is applied to conduct the index of FD with three stock market development indices and five banking sector development indices. In the second step, cross-sectional dependence tests were conducted. The estimation results of these tests provided evidence of the cross-sectional dependence between the emerging countries. Under the cross-sectional dependency, we employed the second-generation unit root test to identify the correct integration order. Finally, we used the PMG approach to discover the determinants' long-term cointegration correlations.

The PMG long-run estimation findings demonstrate that FD has a negative impact on CO2 emission. This finding also indicates that FD contributes to improving the EQ in the selected emerging countries. According to the results, a 1% increase in FD will result in a 0.011% reduction in CO2 emission. However, a 1% rise in GDP and ENG will increase CO2 emissions by 0.176% and 0.712%, respectively. The results also demonstrate the validity of the EKC hypothesis in selected emerging countries where the requirement for a high-quality environment increases as economies expand.

Emerging countries account for a noteworthy portion of the global population and contribute significantly to global carbon emissions, GDP, CO2 emissions, and FD. The current trend of rising CO2 emissions is an important issue for emerging countries. To address this issue, several economic and financial policies should be implemented that encourage GDP while protecting the environment. Overall, our findings show that GDP and ENG positively contribute to CO2 emissions in emerging countries. These findings emphasise the importance of enacting clean and environmental policies to minimise the effects of energy usage and economic expansion on CO2 emissions.

To sum up, our findings indicate that policies aimed at improving FD could also improve EQ in these countries. However, GDP and ENG have a positive impact on CO2 emissions, highlighting the importance of implementing clean and environmental policies to mitigate the impacts of economic expansion and energy use. Overall, the findings of this paper provide essential insights for policymakers and researchers interested in understanding the relationship between FD and EQ in emerging economies.

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