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A Time-Varying Analysis between Financial Development and Carbon Emissions: Evidence from the MINT countries

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Abstract

Since the global economic crisis, researchers and policymakers have paid close attention to the carbon emissions and financial development interrelationship, and some researchers believe that financial development can aid in abating the emissions of carbon. Thus, the objective of this study is to analysis the impacts of financial development of the MINT countries (Mexico, Indonesia, Nigeria and Turkey) on their CO_2 emissions year on year via historical data covering the period 1969–2019. The full-sample bootstrap non-Granger causality test outcomes for Mexico and Turkey reveal that there is a one-way causal association from financial development to CO_2 emissions. Short and long-run instability is shown through a range of parameter constancy tests utilized to investigate the stability of the estimated vector autoregressive models. This implies that the full-sample causality tests are inadequate, necessitating the use of a time-varying (bootstrap) rolling-window technique to address parameter non-constancy and prevent pre-test distortion; therefore, this research uses rolling-window bootstrap estimation. Empirical results from the rolling-window bootstrap estimation show that the nexus between financial development and carbon emissions is date-stamped. These outcomes indicate that significant feedback causal associations exist between financial development

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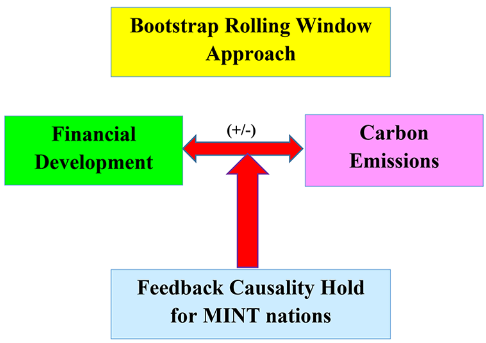
and CO_2 emissions in sub-sampled periods in the MINT nations. In addition, we observe emission-decreasing and emission-increasing effects of financial development in the sampled countries across period. One of the study policy recommendations is that policymakers in these nations through monetary authority should mop-up financial resources from institutions showing emission-increasing tendencies to institutions and/or sectors with emission-reducing tendencies.

Keywords
financial development, carbon emissions, MINT countries, rolling-window bootstrap estimation

Graphical Abstract



1. Introduction

Global warming and climate change are the most serious and divisive global issues that require immediate action from international leaders.[1–4] Economic development has resulted in a rapid expansion of carbon dioxide (CO_2) emissions around the world in recent decades.[5,6] As a result, the worldwide community has attached great importance to ecological issues connected with the rising emissions of CO_2, and several countries across the globe have undertaken policies to combat climate change to stabilize these issues.[7–9] However, since the global economic crisis, researchers and policymakers have paid close attention to the CO_2 emissions and financial development interrelationship, and some researchers believe that financial development can aid in abating the emissions of CO_2.[10–16] Proponents of this viewpoint argue that financial development can not only assist local governments in improving the allocation of resources efficiently and understanding the state of regional pollution and economic expansion,[7,17–19] but can also assist businesses in promoting innovation processes and adopting recent low-carbon technologies in order to improve the efficiency of energy and sophisticated low-carbon technologies.[20–26]

Nevertheless, some researchers disagree with the aforementioned theories (e.g.[27–31]). They contend that financial development will entice foreign direct investment (FDI), which will drive economic expansion and, in turn, boost the emissions of CO_2. They also argue that efficient and prosperous financial intermediation renders it simpler for customers to buy business items and, as a result, more CO_2 is emitted.[32] In summary, the influence of financial development on CO_2 emissions is unknown at this time, and additional research into the financial development–carbon emissions connection will therefore be extremely advantageous, not just for limiting global warming, but also for boosting financial sector expansion.

The MINT nations have experienced remarkable growth in recent years, with similar characteristics underlying this expansion. In other words, these economies have recently been distinguished by huge and growing populations, providing them with outstanding human resource availability and growth possibilities. MINT nations are gathering momentum as a result of their unique economic characteristics, and are anticipated to be global leaders in the next two decades. In this light, Goldman Sachs has anticipated a steady growth trajectory in these nations.[33] Nonetheless, the MINT economies' ecological quality is being eroded by rising economic expansion and population growth. As a result of their status as major and developing nations, the MINT nations must collaborate on global emissions mitigation activities in order to limit the environmental impacts that emerge.[34] Taking this into account, the adoption of financial development initiatives in the MINT economies is critical in order to reduce the level of emissions. As a result, more research on the CO_2 emissions and financial development nexus in MINT nations is required. For a long time, researchers have paid minimal attention to the MINT nations' financial development-carbon emissions connection. Furthermore, few investigations have taken into account the nation-level heterogeneities among the MINT nations, to the best of our understanding. Moreover, while previous researches have conducted extensive and in-depth investigations of the linear interrelationship between CO_2 emissions and financial development, nonlinear interrelationships have not been thoroughly examined.

To address the aforementioned shortcomings in the literature, this research uses historical data covering the period from 1969 to 2019 via a bootstrap rolling window technique to explore the time-varying interrelationship between CO_2 emissions and financial development for the MINT nations. As a result, our research adds to the ongoing studies in three ways: (i) firstly, we utilized the bootstrap subsample rolling-window causality test to uncover the time-varying causality between financial development and CO_2 emissions, whilst past scholars have merely employed the full-sample causality test. It is presumed that a single causality is conserved in all periods, which is the restriction of the full-sample causality test. The present research can offer policies for policymakers in the MINT economies at an appropriate time utilizing the full and subsample rolling-window test; (ii) Secondly, this is the first research to assess the time-varying connection between CO_2 emissions and financial development; and (iii) third, we estimate the common trends as well as nation-specific patterns. In other words, possible nation-level heterogeneities across the MINT nations are taken into account, which can provide fresh evidence for designing policies to reduce CO_2 emissions and boost growth in each MINT country's financial sector. The advantage of such an investigation is that it allows for a more detailed review of the CO_2 emissions and financial development nexus.

The next section presents a synopsis of related studies, which is followed by the methodology in Section 3. The data and methods are depicted in Section 4 and the study concludes in Section 5.

2. Literature and empirical review

Over the last decade, there has been a significant increase in the amount of literature on financial development and CO_2. Prior scholars have reported a diverse range of results, with some showing a positive association between financial development and carbon emissions and others showing a negative association. There are three ways in which financial development has an impact on CO_2. Firstly, the development of the stock market decreases the fixed capital financing costs, which stimulates new investments by listed companies, resulting in new technologies, decreased/increased energy usage, and CO_2. Secondly, when financial development occurs, FDI grows or decreases, resulting in decreased or increased energy use and CO_2 emissions. Lastly, economic growth contributes to more consumer loans and more purchases of energy-intensive durable goods, resulting in a decrease or increase in the consumption of energy and carbon emissions.[35]

The development of a country's financial sector is usually followed by higher energy demand. Studies investigating the impact of financial development on carbon emission have been conducted in various countries using different assumptions and methodologies.[36] Many studies across different countries have demonstrated the long-run relationship between financial development and carbon emissions (see.[37–40]) Unfortunately, in general, the findings regarding the relationship between financial development and carbon emission are not conclusive. Mixed findings are continually being found across different countries despite the use of various financial development indicators. Nevertheless, the investigation of the nexus between financial development and carbon emissions has attracted an ongoing debate at different sample scales.

At global scale, several efforts have been made to reveal the relationship between financial development and carbon emission. In European countries, a positive association between the two measures was found by Al-mulali, Ozturk and Lean[41] covering 23 selected countries for the period 1990–2013. Based on their study, financial development, together with GDP growth and urbanization, are significantly correlated and increases carbon emission in the long run. Coban and Topcu[42] extended the study by arguing that country's status of membership is also matter. In their study, they split a sample of 27 countries during period of 1990–2011, into old members and new members. They found that, in old member countries, greater financial development triggers higher energy consumption, and hence produces greater carbon emission. On the contrary, for the newer member countries, the impact of financial development on carbon emission depends on the metric used. EKC curve hypothesis was confirmed when the banking metric was utilized, while no significant relationship was found when stock market index represents financial development.

Chang[43] also found that banking and stock market seem to deliver different result when comes to approximate the association between financial development and carbon emission. Based on the assessment on 53 countries over the period of 1999–2008, the author revealed that, in the non-high-income countries, financial development and energy consumption are positively associated, particularly when private and domestic credit represent financial development indicators. On the other hand, when the value of traded stocks and stock market turnover are in place, financial development was found to diminish energy consumption, and hence reducing carbon emission. Jiang and Ma[44] implemented the system-GMM approach to investigate the relationship between financial development and carbon emission using a sample of 155 countries. By classifying the sample into two groups, developed countries and emerging countries, the authors revealed that most financial indicators are positive and significant in enhancing carbon emission in emerging economies, but the impact is not evident in advanced economies. Similar to Coban and Topcu[42] banking proxies for financial development have stronger effect on carbon emission than stock market indicators.

However, the inefficacy of stock market indicator to be significantly associated with carbon emission does not happen in Sadorsky.[45] Sadorsky[45] explored the relationship between financial development and energy consumption across 22 emerging economies over the period of 1990–2006. Financial development was presented by stock market variables, including stock market capitalization, stock market value traded, and stock market turnover. The system-GMM panel estimation technique was applied and demonstrated that financial development positively affects energy consumption, and hence increases carbon emission in the sample of emerging economies. Furthermore, due to the crucial role of financial development, the study argues that not incorporating financial development in the projection of energy demand may understate the actual impact.

In contrasts, the study from Saidi and Mbarek[46] contradicts Sadorsky[45] by demonstrating that financial development is helpful and has a long run negative impact on carbon emission. This finding was the result of system-GMM estimation based on 19 emerging economies during period of 1990–2013 with the share of domestic credit to private sector over GDP as the proxy of financial development. However, financial liberalization with weak institutional framework can reduce the efficacy of financial development in reducing carbon emission.[47] Tamazian and Rao[47] also share similar finding with Saidi and Mbarek[46] in that financial development turned out being helpful in reducing carbon emission, based on the implementation of a standard reduced form modeling approach and GMM estimation on 24 transition economies during 1993–2004.

Al-mulali and Sab[48] demonstrated that the relationship between financial development and carbon emission is bidirectional. Based on their assessment on 19 selected countries in the period 1980–2008, the authors revealed that higher energy consumption is one factor that help countries to achieve their development. Based on Pedroni cointegration test, the authors also demonstrated that energy consumption and carbon emission are cointegrated with financial development. However, this finding does not apply in Sub-Saharan African countries.[49] Shahbaz, Tiwari and Nasir[50] contradicts this finding, based on their assessment on South African countries over the period of 1965–2008, by arguing that financial development reduces carbon emission in the region. Also, based on the ARDL bounds testing approach to cointegration, a long-run relationship was also revealed between financial development and carbon emission.

In United Arab Emirates (UAE) region, Charfeddine and Khediri[39] extended the work from Shahbaz et al.[16] investigated the role of financial development on carbon emission in UAE countries over the period of 1975–2011. The author featured the unit root tests with multiple structural breaks and regime-switching cointegration techniques. They argue that financial development and carbon emission is statistically significant, long-run associated, and follows an inverted U-shaped relationship. Charfeddine and Kahia[51] against this finding in case of MENA region where the role of financial development on carbon emission is miniscule. This finding was based on the VAR estimation on MENA countries over period 1980–2015 utilized private credit to real GDP as the proxy of financial development. This finding is consistent with the study from Salahuddin, Gow and Ozturk[52] in case of Gulf Cooperation Countries (GCC), arguing that financial development has no significant link with carbon emission. However, based on the study from Omri, Daly, Rault and Chaivi[53] who also investigated the relationship between financial development and carbon emission across 12 countries in MENA region, higher degree of financial development reduces carbon emission through higher spending on energy innovation to reduce pollution.

The reducing impact of financial development on carbon emission was also found in BRICS countries according to the study from Tamazian, Chousa, and Vadlamannati.[54] The authors assessed the impact of financial development on carbon emission using standard reduced form modeling approach on BRICS panel data over period 1992–2004. Not only being pollutant reducing, but the study also demonstrated that capital market and banking sector development can be more effective in reducing carbon emission when they are equipped by strong level of foreign direct investment. In Asian countries, Saleem and Fatima[55] applied the fully modified ordinary least square (FMOLS) on the region consisting of three countries: Bangladesh, India and Pakistan during 1980–2014. Based on their study, financial development significantly and negatively affected carbon emission in Bangladesh and Pakistan, but not in India.

To sum up, studies investigating the relationship between financial development and carbon emission at regional level remains at the inconclusive results. A contradicting result can even be found from different studies focusing on the same region, which indicates that the association between the two measures is possibly sensitive to countries heterogeneity in the panel data sample. A more consistent result is found at country level studies.

In case of Pakistan, some studies deliver a more consistent result. Siddique[56] applied the ARDL bounds testing cointegration approach on the Pakistan data sample period of 1980–2015, with credit to private sector as the proxy of financial development, in the presence of energy consumption, trade and economic growth. The study found that financial development was found as a catalyst of carbon emission in the country sample and they are long-run associated. The finding is shared by Shahbaz, Shahzad, Ahmad and Alam[57] using the nonlinear ARDL approach on Pakistan data sample over the period of 1985–2014. The authors' proxied financial development using banking and stock market indicators, constructed through principal component analysis and revealed that financial development accelerates carbon emission in the country. Abbasi and Riaz[58] also reveal a positive association between financial development and carbon emission. Using credit and stock market development as the proxies of financial development, the authors revealed that financial development and carbon emission are cointegrated, forming a long-term relationship, and in a positive association. Shahzad, Rehman, Hurr and Zakaria[59] argued that the relationship between the financial development and carbon emission in Pakistan is bidirectional, instead of unidirectional.

In case of China, Ahmad, Khan, Rahman and Khan[27] explored the relationship between financial development and carbon pollution in China during 1980–2014 using the nonlinear autoregressive distributed lag (NARDL) model. The study confirmed a positive and long-term relationship between financial development and carbon emission, conditional on economic growth and energy use. This finding supports the study from Shahbaz, Khan and Tahir[60] on China data sample over the period of 1971–2011 demonstrating that financial development granger causes energy consumption, and hence higher carbon emission. This finding is also consistent with Yuxiang and Chen[61] who investigated the impact of financial development on environmental quality across provincial data level in China over the period 1999–2006, except the pollutant focused in the study was sulfur dioxide rather than carbon dioxide. However, Jalil and Feridun[62] contradicted the findings above by arguing that financial development is carbon-reducing instead of increasing the emission. This finding was based on their assessment in China over the period of 1953–2006 by using deposit liabilities to nominal GDP ratio as the proxy of financial development.

In case of Nigeria, a contradicting result is found. Ali, Yusop and Hook[63] applied the ARDL bound testing technique on Nigeria dataset during the period of 1972–2016. The study revealed a significant negative relationship between financial development and carbon emission, which means that financial development was found to reduce carbon emission in Nigeria. However, this finding contradicts Yahaya, Ado and Datti[64] who employed the ARDL technique on Nigeria data sample during period 1981–2014 which shows a long-run and positive impact of financial development on carbon emission in the country. Abokyi, Appiah-Konadu, Abokyi and Oteng-Abayie[65] in case of Ghana. The study employed the Bayer-Hanck combined cointegration technique and the ARDL bounds test with structural break dummy variables on the data sample of Ghana over the period 1971–2014. Using domestic credit to private sector as the proxy of financial development, the study delivered inconclusive finding. It was shown that financial development has no significant impact on carbon emission based on the ARDL parameters, but it does have based on Granger-causality and variance decomposition.

In case of Malaysia, Islam, Shahbaz, Ahmed and Alam[66] employed ARDL approach and demonstrated that a long run and positive relationship were found between financial development and energy consumption. Furthermore, a causal relationship based on the VECM Granger causality test was also revealed suggesting that carbon emission is influenced by the accelerating financial development in the country, both in short-run and long-run. However, this finding contradicts Shahbaz, Solarin, Mahmood and Arouri[16] who applied the ARDLs bound testing and VECM Granger causality approach to the similar data sample and confirmed that financial development can reduce carbon emission in Malaysia, in addition to their long-run association. In case of Indonesia, despite its close proximity with Malaysia, Shahbaz, Hye, Tiwari and Leitao[40] found that financial development Granger causes carbon emission in Indonesia. This finding was generated based the VECM Granger causality test on the Indonesia data sample over the period of 1975–2011. However, a long run relationship between financial development and carbon emission remains valid.

In the case of Tunisia, Farhani and Ozturk[67] demonstrated that the impact of financial development on carbon emissions was also positive with no sign of EKC curve validity. The finding was based on the ARDL bounds testing approach to cointegration and ECM approach applied on a data sample from Tunisia covering the period of 1971–2012. Financial development was measured by domestic credit to the private sector, together with GDP per capita, trade openness and urbanization. In the case of Turkey, Cetin and Ecevit[68] applied the ARDL bounds test and VECM Granger causality test to examine the role of financial development on carbon emissions in the country over the period of 1960–2011. Using domestic credit to the private sector as a proxy of financial development, the authors found that financial development in Turkey is achieved at the cost of higher carbon emissions. This finding was supported by Ozturk and Avaravci,[69] who applied error-correction based Granger causality models on a dataset from Turkey over the period 1960–2007. They argued that the relationship between financial development and carbon emissions in Turkey follows an inverted U-shape curve.

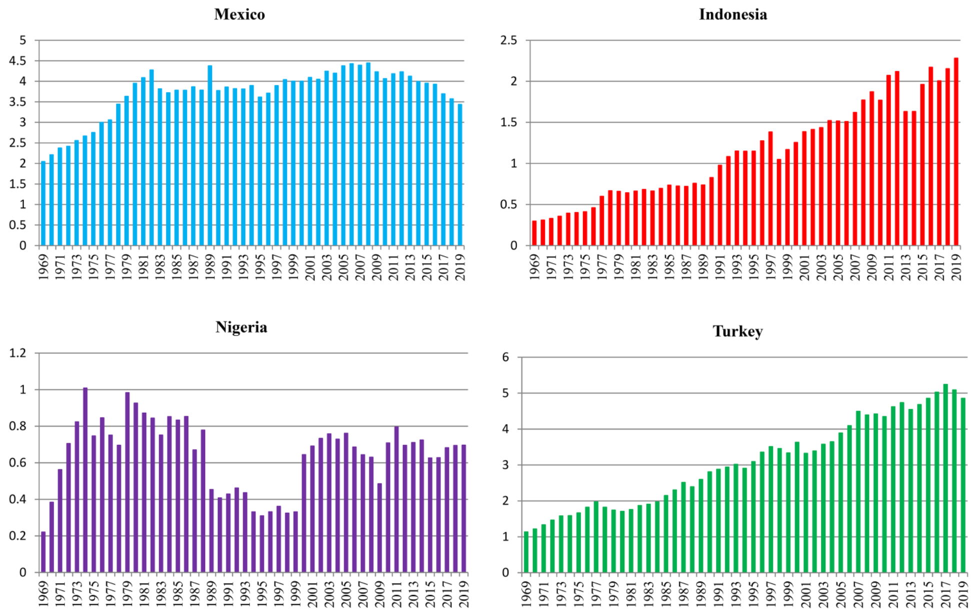
In summary, findings from studies on the nexus between financial development and carbon emissions are still mixed, at both the regional and country level. The contradicting results across different regions and countries indicate the essential role of country heterogeneity in the association between financial development and carbon emissions, which consequently affects the estimation strategy and methodology applied. Furthermore, the proxy of financial development also plays a role in the association, particularly with regard to the choice between banking and stock market indicators. Based on these mixed findings, we applied the novel rolling-window bootstrap estimation developed by Balcilar et al.[70], which has the ability to capture the causality between variables at different sub-sampled periods.

3. Data and methodology

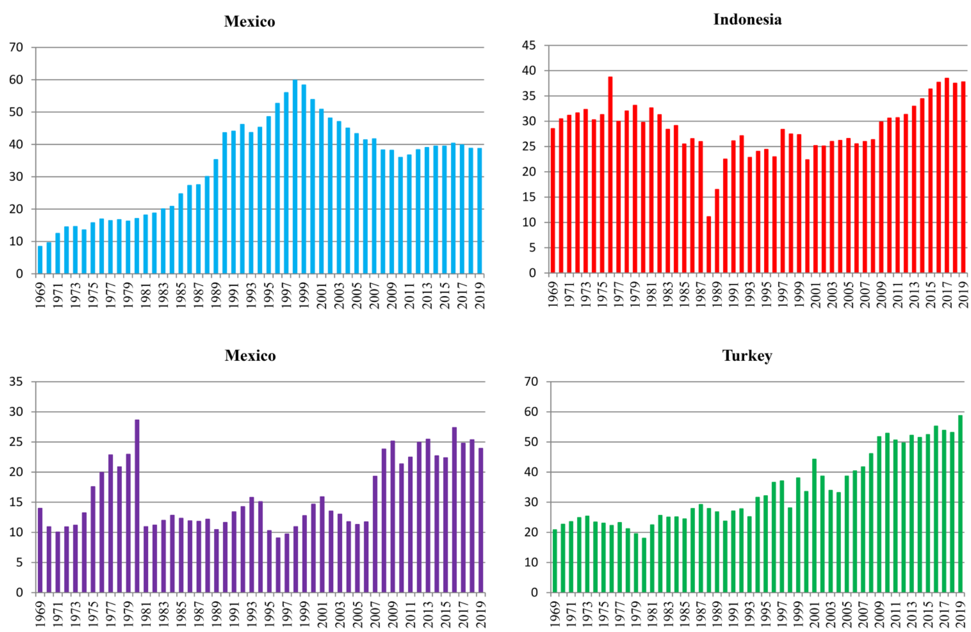
The research assesses the nexus between financial development and CO_2 emissions in the MINT nations. The study uses a dataset covering the period 1969-2019 (50 observations) to assess this nexus. The dataset for CO_2 emissions is utilized as a proxy of environmental degradation, measured as metric tons per capita and sourced from the British Petroleum database, while the ratio of broad money to GDP is utilized as a proxy of financial development, which was gathered from the World Bank database. To decrease skewness, all the series are converted into natural logarithm. The trend of the research variables is illustrated in gcqzs 1 and 2, respectively.

3.1. Methodology

As an initial test, the full sample bootstrap causality test initiated by Hacker & Hatemi-J[71] is utilized to assess the financial development-CO_2 emissions nexus. The full sample bootstrap causality



gcqz 1. Trends of carbon emissions in the MINT nations.



gcqz 2. Trends of financial development in the MINT nations.

technique is an improved version of the[72] causality technique that enables for the investigation of the causal relationship between variables regardless of whether they are cointegrated or not. As a result, the first stage of this approach, consider the vector auto-regression process as follows;

$$y_t = \varphi_0 + \varphi_1 \gamma_{t-1} + \ldots . . \varphi_p \gamma_{t-p} + \varepsilon_t, \; t = 1, \; 2 \ldots . ., \; T \tag{1}$$

Where lag order is depicted by p, $\varepsilon_t = (\varepsilon_{1t}, \; \varepsilon_{2t})^l$ is zero-mean white noise mechanism with covariance matrix Σ. Furthermore, yt is separated into two vectors; CO_2 (y_{1t}) and FD (y_{2t}), and eventually derived as follows;

$$\begin{bmatrix} y_{1t} \\ y_{2t} \end{bmatrix} = \begin{bmatrix} \varphi_{10} \\ \varphi_{20} \end{bmatrix} + \begin{bmatrix} \varphi_{11}(L) & \varphi_{12}(L) \\ \varphi_{21}(L) & \varphi_{22}(L) \end{bmatrix} \begin{bmatrix} y_{1t} \\ y_{2t} \end{bmatrix} + \begin{bmatrix} \varepsilon_{1t} \\ \varepsilon_{2t} \end{bmatrix} \tag{2}$$

Where $\varphi_{ij}(L) = \sum_{k-1}^{p} \varphi_{ij}, k^{L^k}$, i, j = 1, 2, and the operator is depicted by L. The null hypothesis of "FD does not Granger cause CO_2" can be investigated by daunting zero restrictions $\varphi_{12,\, i=0 \text{ for } i=1,\, 2\ldots p}$ and the null of CO_2 does not Granger cause FD is estimated by imposing zero restrictions $\varphi_{21,\, i=0}$ for i = 1, 2, … p. Researchers have utilized a variety of techniques to analyze structural changes in the past (divide the sample into bits, use dummy variables, etc.). As a result, this study employs[73] rolling window causality technique to examine the causative relationship between GDP and energy consumption for sub-sample periods.

The rolling window sub-samples causality for $t = t = \tau - 1 + l, \tau - 1, \ldots, \tau, \tau = l, l + 1, \ldots, T$, was initiated by Balcilar and Ozdemir[74] to identify causality of the rolling window illustrated by Equation 1.

Possible causal alterations between CO_2 emissions and FD are determined by estimating LR-statistical rolling bootstrap values in the form of T-1 sub-samples. In addition, the CO_2 emissions impact of GDP is estimated as $B^{-1} \sum_{k-1}^{p} \hat{\varphi}^*_{21,k}$ with $\hat{\varphi}^*_{21,k}$. The bootstrap replication number is calculated using Equation 2 to calculate the bootstrap (VAR) model. In the same way, the impact of FD on CO_2 emissions is calculated as $B^{-1} \sum_{k-1}^{p} \hat{\varphi}^*_{21,k}$ where $\hat{\varphi}^*_{21,k}$ is estimated bootstrap VAR depicted by Equation 2 relates to the amount of bootstrap repetitions.

4. Results and discussion of findings

Table 1 presents the descriptive statistics of the research data. It shows that the mean values, skewness values, kurtosis values, and the Jarque-Bera (JB) values of most of the series are normally distributed. We proceed by assessing the series stationarity the Augmented Dickey-Fuller (ADF) and Philip-Perron (PP) conventional unit root tests. The PP and ADF outcomes disclosed that all the series are stationary at I(1), i.e., first difference

Table 2 reports the bootstrap Granger causality test results. The empirical results show the existence of a unidirectional causality running from financial development to carbon emissions, specifically in Mexico and Turkey. In other words, changes in financial development predict carbon emissions over the sampled period. Table 3 reports the results of the short-run and long-run parameter stability tests. The results show that at least one or more of the models are stable in both the short and long run at 0.01, 0.05 and 0.10 per cent significant levels, respectively.

Table 1. Descriptive statistics and unit root test outcomes.

	Mean	Median	Std. Dev.	Skewness	Kurtosis	JB	Prob	ADF	PP
CO_2 Emissions									
Mexico	3.7207	3.8660	0.6055	−1.3007	3.8262	15.823	0.0003	−8.718*	−8.718*
Indonesia	1.1426	1.1492	0.5830	0.3059	1.9178	3.2837	0.1936	−8.830*	−8.240*
Nigeria	0.6475	0.6956	0.1922	−0.4557	2.3586	2.6400	0.2671	−7.647*	−7.650*
Turkey	3.0738	3.0185	1.2232	0.1504	1.7429	3.5503	0.1694	−6.645*	−6.862*
Financial Development									
	Mean	Median	Std. Dev.	Skewness	Kurtosis	JB	Prob	ADF	PP
Mexico	33.899	38.389	14.332	−0.1831	1.8403	3.1424	0.2077	−8.679*	−10.743-
Indonesia	28.761	28.527	5.2962	−0.4970	4.4053	6.2968	0.0429	−4.122*	−4.096*
Nigeria	33.899	38.389	14.332	−0.1831	1.8403	3.1424	0.2077	−7.279*	−7.461*
Turkey	16.323	13.527	5.7963	0.6006	1.8433	5.9094	0.0520	−9.595*	−9.843*

Note: 1%, 5% and 10% stands for $P < 0.01$, $P < 0.5$ and $P < 0.10$.

Table 2. Full-sample granger causality tests between financial development and carbon emissions.

	H_0: FD does not cause CO_2		H_0: CO_2 does not cause FD	
Country	*LR*-Statistics	Bootstrap *p*-values	*LR*-Statistics	Bootstrap *p*-values
Mexico	14.807*	0.0000	0.5295	0.7600
Indonesia	1.6597	0.4000	0.1352	0.8800
Nigeria	0.4075	0.8200	1.4513	0.4100
Turkey	5.8240**	0.0100	0.8034	0.5900

Note: The optimal lag order (*k*) of the VAR model is determined by the AIC. The *p*-values are based on 2000 bootstrap replicates. As usual, *, ** and *** indicate rejection of null hypothesis of no causality at the 1%, 5% and 10% significance level, respectively.

4.1. Time-varying outcomes

Next, we estimate the time-varying effect of financial development on CO_2 emissions via the rolling window estimation method. Our findings are presented in Figures 1 to 4. Closely examining the figures, we observe that negative and positive impacts of financial development on CO_2 emissions are evident across periods. This relationship also fluctuates constantly across the observed periods.

Figure 1 reports the results for Mexico. First, we observe that the negative effect in the sub-period of 1978-2000 was due to the crisis that led to the collapse of Mexico's economy in 1982. The major reason for this adverse effect was the ability of the financial sector (system) of Mexico to fund the economy back to recovery at a period when the price of oil dropped significantly, which led to a decrease in carbon emissions. Then, in the sub-period of 2001-2009, carbon emissions-led financial development (direct impact) is broadly noticeable. Although the economy experienced some difficulties (between 2000 and 2003), this gave way to a robust economic recovery in 2004. This was due to the dynamism of exports, followed by the recovery of investment in related sectors. Gross domestic product (GDP) in the first and second quarters

Table 3. Results of short-run and long-run parameter stability tests.

	Financial development Equation		Carbon Emissions Equation		VAR(1) System	
	Statistics	Bootstrap P-Values	Statistics	Bootstrap P-Values	Statistics	Bootstrap P-Values
Mexico						
Sup-LR	32.287*	0.000	39.607*	0.000	52.413*	0.000
Exp-LR	14.369*	0.000	15.737*	0.000	23.956*	0.000
Mean-LR	12.510*	0.000	15.934*	0.000	22.337*	0.000
L_c^b					1.6887*	0.005
Indonesia						
Sup-LR	23.468**	0.050	12.912	0.1201	14.718	0.180
Exp-LR	9.2014*	0.003	4.4221**	0.0318	9.5187***	0.086
Mean-LR	8.6396*	0.006	6.5935***	0.0517	5.7681	0.132
L_c^b					1.7914**	0.005
Nigeria						
Sup-LR	10.818	0.425	19.426**	0.050	15.511	0.610
Exp-LR	3.551	0.873	6.8621**	0.040	6.5671	0.549
Mean-LR	4.1027	0.372	9.0012*	0.050	8.0046	0.653
L_c^b					1.362	0.542
Turkey						
Sup-LR	32.014*	0.000	35.381*	0.0000	17.204*	0.000
Exp-LR	12.014*	0.000	14.877*	0.0000	18.534*	0.000
Mean-LR	16.096*	0.000	11.723*	0.0139	43.135*	0.000
L_c^b					2.6200*	0.000

Note: The null hypothesis for all tests is that the estimated parameters are constant. As usual, *, ** and *** indicate rejection of null hypothesis of no causality at the 1%, 5% and 10% significance level, respectively.

grew by 3.7 and 3.9 per cent, respectively, which was due to the United States intervention programs. During this period, economic performance and financial system development led to a rise in household consumption and industrial production, thus leading to a rise in carbon emissions between the sub-periods.

The global economic crisis of 2008-2009 significantly affected the nation's financial system, which affected industrial production, hence causing a decrease in the emissions level. During this period, the percentage of Mexicans living in poverty increased from 18 per cent to 46 per cent.[75] Furthermore, the adverse effect of financial development is obvious in the sub-period of 2010-2016. This is possibly attributed to the fact that Mexico is the third largest nation in terms of investment in solar energy (renewable energy source). In 2005, 1 million square meters (msm) of solar energy panels was installed in Mexico, and by 2012, this had increased to around 1.8 million (msm). Thus, investment in renewable energy (i.e. solar panels) via the involvement of the financial system decreased the nation's carbon emissions level. Lastly, the results show that financial development had a positive effect on emissions in the sub-period of 2016-2018. In 2017, Mexico was the sixth most visited country with the thirteenth highest income, which

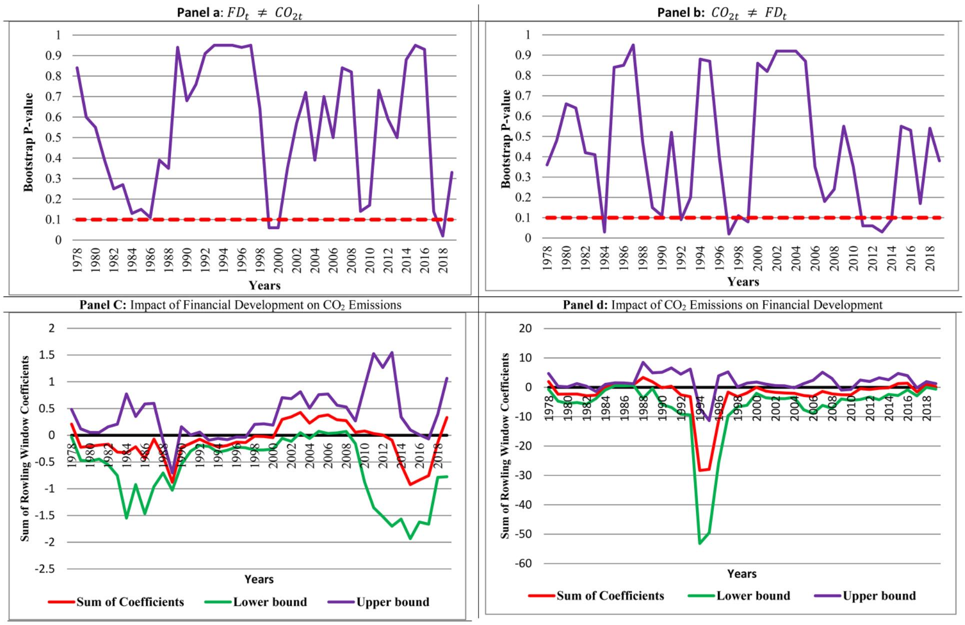


Figure 3. Rolling window estimates for Mexico.

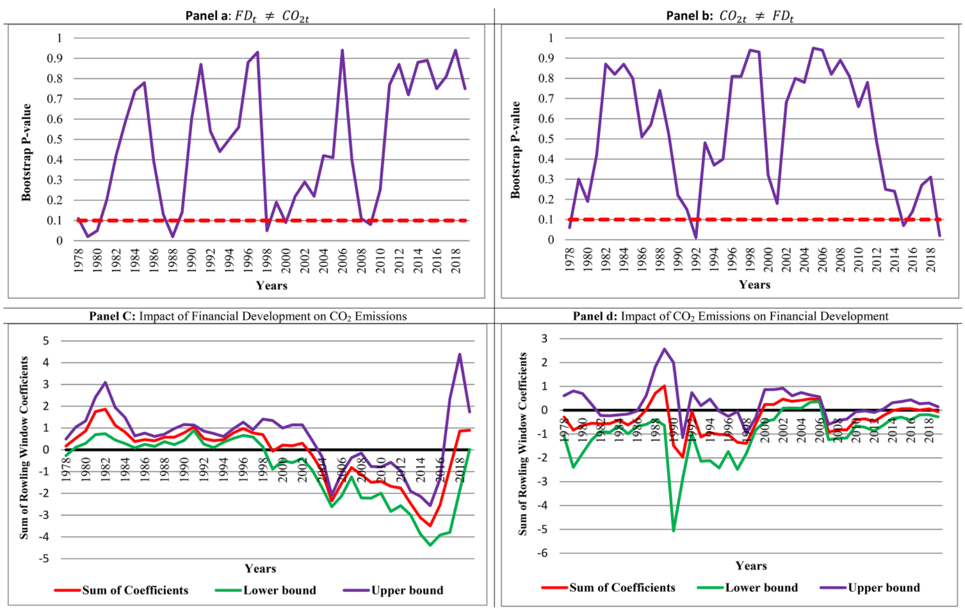


Figure 4. Rolling window estimates for Indonesia.

contributed to the emissions-led financial development experienced during this period. The economic performance as a result of the increase in tourism and financial system development led to a rise in household consumption and industrial production, thus leading to a rise in carbon emissions in this sub-period. This outcome resonates with the study of Arouri et al.[76] on the nexus among business activity, CO_2 emissions, and energy consumption in Mexico, while controlling for industrialization and financial development. The study found that environmental pollution in Mexico is driven by financial development and energy consumption. Thus, any energy savings policy may result in a decrease in national income or employment.

Figure 4 reports the results for Indonesia. In Indonesia, unlike in Mexico, we observe that positive and negative impacts of financial development on CO_2 emissions are evident across the periods, as reported in Figure 2. This relationship is observed across two periods. The sub-period of 1978-1999 (which corresponds with the period of oil crises) shows a positive relationship between financial development and carbon emissions, while the sub-period of 2000-2018 exhibits a negative nexus between financial development and carbon emissions in Indonesia. Due to the improvement in the financial system that increased indigenous credit to the private sector, the carbon emissions in Indonesia rose from 0.67 metric tons per capita in 1978 to 1.33 metric tons per capita in 1999. This justifies the positive movement observed from financial development led-emissions across the period. In recent years (2000s), the Indonesian government and policymakers have embarked on the enforcement of green economy initiatives.

The growth of green policies that started in the sub-period of 2000-2018 significantly influenced Indonesia's financial system, which improved industrial production, hence decreasing the emissions level. Over this period, the Indonesian ex-president Susilo Bambang Yudhoyono officially agreed to reduce carbon emissions by 26 per cent as opposed to the "Business as usual" 2020 CO_2 emissions trajectory. This represents the largest carbon emission reduction effort made by

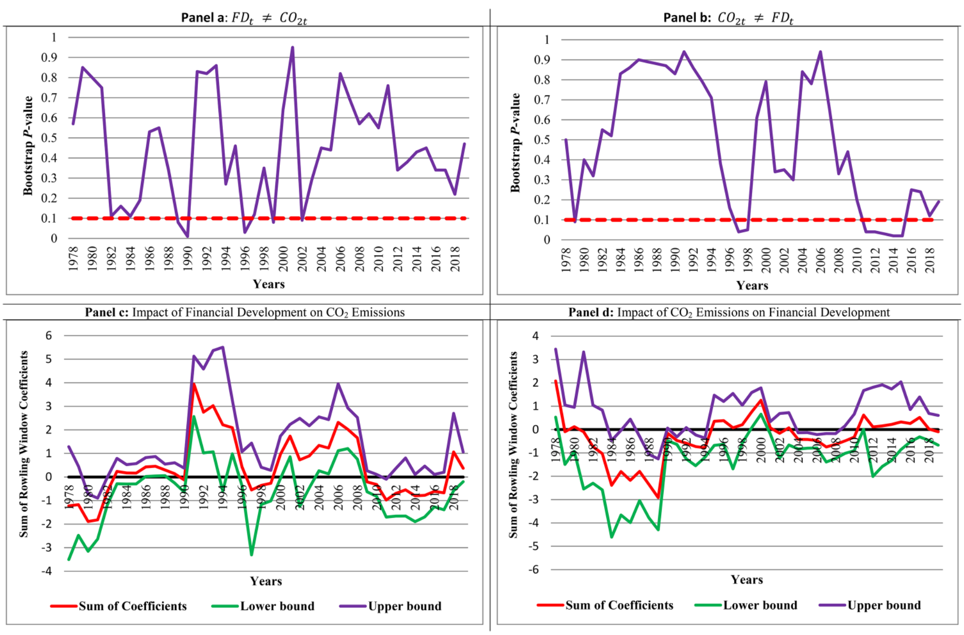


Figure 5. Rolling window estimates for Nigeria.

any developing nation. Fueled by the improvement in financial development and the commitment of the financial system, the government was able to reduce greenhouse gas emissions by 41 per cent in Indonesia. However, in terms of emissions-led financial development, we observe that negative and positive impacts of CO_2 emissions on the financial system are evident across periods. This positive-negative relationship fluctuates constantly across the observed periods. This finding resonates with the study of Fitriyah[77] on the impact of financial development on environmental degradation, which used the ARDL method in the case of Indonesia. The study emphasized the negative impact of financial development on environmental quality. He argued that the financial sector can have a negative impact on power consumption by advancing energy efficient technologies through technological advancements in the power industry to decrease toxic carbon emissions.

Figure 5 reports the results for Nigeria. In Nigeria, in the sub-period of 1978-1990, the carbon emissions-decreasing effect of financial development is observed, as shown in Figure 3. This is due to the deregulation policy introduced in 1978 under the Structural Adjustment Programme (SPA). The SPA provided incentives for the growth of both financial and non-financial institutions. The number of banks increased from 41 to 115 between 1986 and 1996, while the number of bank branches increased from 1367 to 2551 in the same period.[78] The carbon emissions-decreasing effect of financial development was due to the development of the financial system as the transfer of financial resources to emissions-decreasing activities increased. In fact, the emission-rising impact of financial development was obvious in the sub-periods of 1991-1997 and 2000-2009, while the emission-decreasing impact of financial development stands out in the sub-periods of 1997-1999 and 2010-2017, respectively. The increase in the performance of the financial system as a result of the extension of loans to individual and private investors and the global economic/financial crisis contributed immensely to the decreasing/increasing emissions level of the nation.

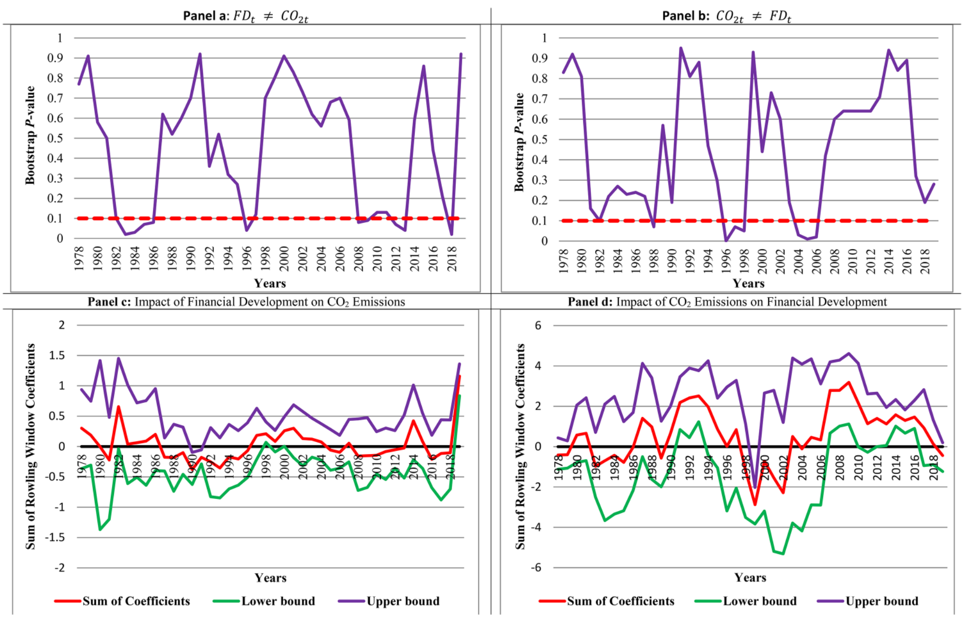


Figure 6. Rolling window estimates for Turkey.

On the one hand, the higher level of non-performing loans recorded by the commercial banks in Nigeria during the sub-period of 1993-1994 where about 42 financial institutions recorded about 45 per cent of loans as non-performing[79] might have contributed adversely to carbon emissions, as firms produced little or no output. On the other hand, the improvements in the financial system due to bank consolidation during the sub-period of 2004-2005 when banks were fully merged and become more efficient and reliable entities might have contributed to the emission-increasing effect (as industrial production increased using more non-renewable energy sources) recorded over these sub-periods. This finding resonates with the study of Ali et al.,[80] who argued that financial development contributes positively to environmental degradation in Nigeria**.** To support this finding, Iorember, Goshit and Dabwor[81] found that renewable energy consumption improves environmental quality, while financial development damages the environment. They suggested that renewable energy and financial development will play important toles in reforming energy policies to achieve environmental sustainability in Nigeria.

Finally, in Turkey, a closer examination of Figure 6 reveals that negative and positive impacts of financial development on CO_2 emissions are evident across the periods. This relationship also fluctuates constantly across the observed periods. The results reported in Figure 4 show the emission-decreasing effect of financial development in the sub-periods of 1978-1982, 1988-1996, 2005-2012, 2016-2018, and the emission-increasing effect of financial development in the sub-periods 1983-1987, 1997-2005, 2013-2015 and 2018 respectively. It is paramount to state here that, during the 1980s, the Turkish economy experienced structural reforms that revamped the nation's financial system. Emphasis was placed on financial liberation as well as industrialization in the economy. This period made a significant contribution to financial development-led emissions in the region. It may not be possible to pinpoint each of these dates to specific emission-increasing or decreasing periods, even though they play a significant role. For example, in the sub-period of 1982-1986, the legal and institutional reform of the securities markets was established, which gave the public authorities the right to regulate the primary markets.

In addition, a legal framework for the regulation of secondary markets was enacted in 1983. This framework empowers the authorities to initiate the establishment and regulate all operations in these markets. In 1985, the Istanbul Stock Exchange (ISE) reopened and became operational in 1986. This in one way or another led to the emission-increasing effect of financial development as the development of the Turkish financial system impacted positively on the economy as a whole. On the other hand, the global economic and financial crisis of 2009-2009 contributed immensely to the emission-decreasing effect of financial development in Turkey. This finding is in line with the studies of Gokmenoglu et al.[82] and Cetin and Ecevit[68] for Turkey. Both studies agreed that financial development is linked with Turkey's industrialization and carbon emissions. However, Rjoub et al.[21] stated that financial development played a significant moderating role in the relationships between economic growth and carbon emissions, capital formation and carbon emissions, and urbanization and carbon emissions. They advocated for environmental–financial related policies in order to aid the reduction of carbon emissions with of the aim of improving environmental quality in Turkey.

5. Conclusion and policy recommendations

5.1. Conclusion

This paper examines the relationship between financial development and CO_2 emissions in the MINT nations. The objective of this study was to analyze the impacts of financial development in the MINT countries on their CO2 emissions year on year via historical data. Thus, we examined a panel series of countries covering the period 1969-2019 (50 observations) to assess this relationship via the time-varying method. The dataset for CO_2 emissions was utilized as a proxy of environmental degradation, measured as metric tons per capita and sourced from the British Petroleum database, while the ratio of broad money to GDP was utilized as a proxy of financial development and was gathered from the World Bank database.

Based on our empirical results, we infer that the impacts of financial development on the immediate environment vary from period to period due to distinct political, social or economic shocks for the individual country. According to the results for specific sub-periods, such as the oil crises periods of the 1970s, we observe that financial system development enhances environmental degradation. Our results show that in some periods, financial development and carbon emissions are negatively correlated, while in other periods the relationships are positive or mixed. These findings are in line with existing literature for individual country sampled. First, we observed that the negative effect in the sub-period of 1978-2000 was due to the crisis that led to the collapse of Mexico's economy in 1982. The major reason for this adverse effect was the ability of the financial sector (system) of Mexico to fund the economy back to recovery in a period when the price of oil dropped significantly, which led to a decrease in carbon emissions. Then, in the sub-period of 2001-2009, carbon emissions-led financial development (direct impact) is broadly noticeable. Although the economy experienced some difficulties (between 2000 and 2003), this gave way to a robust economic recovery in 2004. This was due to the dynamism of exports, followed by the recovery of investment in related sectors. Gross domestic product (GDP) in the first and second quarters grew by 3.7 and 3.9 per cent, respectively, due to the United States intervention programs. During this period, economic performance and financial system development led to a rise in household consumption and industrial production, thus leading to a rise in carbon emissions between the sub-periods and vice versa.

In Indonesia, the sub-period of 1978-1999 (which corresponded to the period of oil crises) showed a positive relationship between financial development and carbon emissions, while 2000-2018 exhibited a negative nexus between financial development and carbon emissions in Indonesia. Due to the improvement in the financial system that increased indigenous credit to the private sector, the carbon emissions in Indonesia rose from 0.67 metric tons per capita in 1978 to 1.33 metric tons per capita in 1999. In Nigeria, in the sub-period of 1978-1990, the carbon emissions-decreasing effect of financial development was observed, as shown in Figure 3. This was due to the deregulation policy introduced in 1978 under the Structural Adjustment Programme (SPA). The SPA provided incentives for the growth of both financial and non-financial institutions. The number of banks increased from 41 to 115 between 1986 and 1996, while the number of bank branches increased from 1367 to 2551 in the same period.[78] In the case of Turkey, the results reported in Figure 4 show the emission-decreasing effect of financial development in the sub-periods of 1978-1982, 1988-1996, 2005-2012, 2016-2018, and the emission-increasing effect of financial development in the sub-periods 1983–1987, 1997–2005, 2013–2015 and 2018, respectively. It is paramount to state here that during the 1980s, the Turkish economy experienced structural reforms that would revamp the nation financial system. Emphasis was placed on financial liberation as well as industrialization of the economy.

5.2. Policy recommendations

From the policy standpoint, we urge the governments and policymakers in these regions to take precautions against political, financial and economic shocks that could reverse the carbon emissions-declining impact pattern, particularly in nations where the nexus among carbon emissions and development of the financial system is inverse. We observed that negative shocks from financial development to carbon emissions were mostly experienced when oil crises (discovery of oil), political instability and financial crises occurred. Thus, we are of the opinion that first, shocks emanating from the development of the financial system to carbon emissions in periods of political instability, particularly during election periods as was the case in Mexico, should be well-managed by sound fiscal and monetary policies that would mop-up excess liquidity from circulation that might create an imbalance in the economy, hence causing the emission-increasing effect. Second, shocks from financial development to carbon emissions when new cheap non-renewable energy resources are discovered should be well-managed by preventing such discoveries from finding their ways into the sectors or households that have been consuming and/or producing using clean energy sources. Policymakers can discourage this by introducing subsidies, incentives, and tax facilities to encourage the continuous use of clean (renewable energy), while investment in renewable energy sources should be encouraged and sustained.[83] Finally, to discourage the emission-increasing effect of financial development among nations, monetary authorities have a role to play. Monetary authorities in these nations should mop-up financial resources from institutions exhibiting emission-increasing tendencies to institutions or sectors with emission-reducing tendencies. This would lead to the creation of reserves. On the one hand, these reserves can be used to enhance the investment in energy-saving and energy efficient technologies across all sectors and households, while on the other hand, such reserves can be used to finance investment in the green economy to ensure the sustainability of the economy and the environment for both current and future generations.

Availability of data and material

Corresponding authors can provide data used in the study on appropriate request

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