Kent Academic Repository

Murshed, Muntasir, Ahmed, Rizwan, Khudoykulov, Khurshid, Kumpamool, Chamaiporn, Nahar Falah Alrwashdeh, Nusiebeh and Mahmood, Haider (2023) *Can enhancing financial inclusivity lower climate risks by inhibiting carbon emissions? Contextual evidence from emerging economies.* Research in International Business and Finance, 65 . ISSN 0275-5319.

The version of record is available from

https://doi.org/10.1016/j.ribaf.2023.101902

This document version

Publisher pdf

DOI for this version

Research in International Business and Finance 65 (2023) 101902

Contents lists available at ScienceDirect

Research in International Business and Finance

journal homepage: www.elsevier.com/locate/ribaf

Can enhancing financial inclusivity lower climate risks by inhibiting carbon emissions? Contextual evidence from emerging economies

Muntasir Murshed[a,b,*], Rizwan Ahmed[c], Khurshid Khudoykulov[d], Chamaiporn Kumpamool[e], Nusiebeh Nahar Falah Alrwashdeh[f], Haider Mahmood[g]

[a] *Department of Economics, School of Business and Economics, North South University, Dhaka 1229, Bangladesh*
[b] *Department of Journalism, Media and Communications, Daffodil International University, Dhaka, Bangladesh*
[c] *Department of Accounting and Finance, Kent Business School, University of Kent, United Kingdom*
[d] *Department of Finance, Tashkent State University of Economics, Uzbekistan*
[e] *Faculty of Business Administration and Accountancy, Khon Kaen University, Khon Kaen, Thailand*
[f] *Department of Accounting, Finance, and Economic, Cardiff Metropoliton University, United Kingdom*
[g] *Department of Finance, College of Business Administration, Prince Sattam Bin Abdulaziz University, Alkharj, Saudi Arabia*

ARTICLE INFO

JEL classifications:
F4
G2
Q4
Q54
Q56

Keywords:
Carbon dioxide emissions
Climate risks
Emerging economies
Energy use efficiency
Financial inclusivity
Renewable energy

ABSTRACT

Climate change is regarded as a global concern whereby lowering climate risks, especially by curbing greenhouse gas emissions, has become a critically important policy agenda worldwide. Hence, this study assesses whether financial inclusion, alongside energy efficiency improvement, renewable energy use, economic growth, international trade, and urbanization, can mitigate carbon dioxide emissions in 22 emerging economies. Considering the period of analysis from 2008 to 2018 and utilizing econometric methods robust to handling cross-sectionally-dependent, heterogeneous, and endogenous panel data, the findings reveal that financial inclusion is directly associated with higher discharges of carbon dioxide. Contrarily, energy efficiency improvement and higher share of renewable energy in the aggregate energy consumption level inhibit carbon dioxide emissions. Moreover, energy efficiency gains moderate the financial inclusion-emissions nexus by jointly reducing carbon emissions with greater financial inclusivity. Finally, the results indicate that economic growth, international trade, and urbanization trigger climate risks by boosting the emission figures. In light of these findings, several carbon dioxide-mitigating policies are recommended for neutralizing climate risks in emerging countries of concern.

1. Introduction

Economic growth is often catalyzed by the combustion of energy resources whereby the rapidly emerging world economies, in particular, often find it relatively more difficult to expedite their economic growth rates without inflicting negative environmental externalities (Yao et al., 2021). Moreover, given the majority of the global emerging nations are severely reliant on fossil fuel supplies

---

* Corresponding author at: Department of Economics, School of Business and Economics, North South University, Dhaka-1229, Bangladesh.

E-mail addresses: muntasir.murshed@northsouth.edu, murshed.northsouth@gmail.com (M. Murshed), r.ahmed@kent.ac.uk (R. Ahmed), kh.khudoyqulov@tsue.uz (K. Khudoykulov), chamaiporn@kku.ac.th (C. Kumpamool), sm23824@cardiffmet.ac.uk (N.N.F. Alrwashdeh), haidermahmood@hotmail.com (H. Mahmood).

https://doi.org/10.1016/j.ribaf.2023.101902
Received 31 December 2021; Received in revised form 2 January 2023; Accepted 7 February 2023

Nomenclature

COP26	26th Conference of Parties
SDG	Sustainable Development Goals
CO2E	Carbon dioxide Emissions
CO2	Carbon dioxide
IEA	International Energy Agency
GDP	Gross Domestic Product
BRICS	Brazil, Russia, India, China, South Africa
OECD	Organization for Economic Cooperation and Development
OIC	Organization of Islamic Cooperation
G7	Group of Seven
BRI	Belt and Road Initiative
EKC	Environmental Kuznets Curve
STIRPAT	Stochastic Impacts by Regression on Population, Affluence, and Technology
IPAT	Impacts on Population, Affluence, and Technology
ATM	Automated Teller Machines
PCA	Principal Component Analysis
CSD	Cross-Sectional Dependency
HSC	Heterogeneous Slope Coefficients
CADF	Cross-sectionally augmented Dickey-Fuller
CIPS	Cross-sectionally Im-Pesaran-Shin
DCCEMG	Dynamic Common Correlated Effects Mean Group
DCCEMG-IV	Dynamic Common Correlated Effects Mean Group-Instrumental Variable
ARDL	Autoregressive Distributed Lag

for meeting their energy demands, tackling energy consumption-related pollution becomes a serious challenge unless the national energy bundles of these nations are diversified with clean energy resources (He et al., 2022). More importantly, considering the goal of simultaneously attaining economic and environmental sustainability, this energy diversification should ideally involve a switch from the use of high carbon-intensive to relatively low carbon-intensive energy resources (Khan, 2021; Murshed et al., 2022a). Nonetheless, due to the predominant monotonic dependency on unclean energy and the associated transition-related constraints, the adoption/utilization of clean energy is often delayed for an indefinite period of time (Hao and Shao, 2021). As a result, the unclean energy use-related greenhouse gas emissions persistently pile up to trigger climate change-related environmental adversities.

The relevance of reducing climate risks has also been extensively discussed at the Paris Climate Conference. Besides, in the recently concluded 26th Conference of Parties (COP26), the signatories of the Paris Agreement have reassured to enhance compliance with the Paris climate goals. Notably, among the emerging economies, India at the COP26 committed to turn carbon neutral by 2070 by significantly scaling clean energy use while Nigeria also announced to achieve carbon neutrality by 2060. Moreover, South Korea promised to reduce its greenhouse gas emissions by 40% compared to the emission level in 2018 (IISD, 2021). On the other hand, the Sustainable Development Goals (SDG) declaration has also stressed the necessity of limiting global climate risks for enhancing environmental welfare alongside socioeconomic development (Fonseca et al., 2020). More importantly, the SDG agenda calls for withdrawing from the utilization of high carbon-intensive energy resources by 2030 by referring to energy as a major contributor to climate risk-related environmental distresses (Onifade et al., 2021). However, given the abject failure of the emerging nations in rapidly greening their respective energy systems, it is critically important for these nations to find factors that can complement the clean energy transition of their traditionally unclean energy-based systems so that the environmental objective of neutralizing climate risks, particularly by reducing greenhouse gas emissions, can be achieved.

Climate risks can be neutralized through diverse modes, especially by restricting the disposal of energy-use-related greenhouse gases into the atmosphere. Among these, the financial sector has been recognized to play a crucial role in tackling climate change hardships, from both the energy production and consumption channels (Anton and Nucu, 2020; Ji and Zhang, 2019). For instance, improving the level of financial inclusivity can enhance access to various financial products like loans, savings, insurance services, payments, and transactions (World Bank, 2018; Amin et al., 2022). However, consumption of these financial products and services may not always guarantee a better environmental condition since the impacts of financial inclusion on the mitigation of carbon emissions can be ambiguous (World Bank, 2018). This is because financial inclusion can lead to more investments in cleaner production and consumption processes whereby it can lower climate risks by inhibiting emissions (Le et al., 2020). Further, low degrees of financial inclusivity have been acknowledged to hamper the deployment and adoption of clean energy technologies and resources (Baulch et al., 2018), which, in turn, can compromise the efficacy of the financial sector in reducing climate risks. On the other hand, financial inclusion can also increase climate risks given that financial products and services are utilized in unclean economic activities. In particular, financial inclusion can boost unclean energy demand by improving the purchasing power of consumers in respect of purchasing more energy-intensive consumer durables (Bayar et al., 2021). Furthermore, the financial inclusion-led rise in private investments can surge unclean energy demand further to impose climate change complications by boosting the carbon emission levels of emerging nations (Sadorsky, 2010; Le et al., 2020). Accordingly, enhancing financial inclusivity can be assumed to influence the climate change risk-mitigation objective.

Apart from the development of the financial sector, the objective of lowering climate risks is also largely dependent on technological advancement, particularly within the energy sector so that more efficient use of modern energy resources can be ensured. Climate risks are primarily driven by Carbon dioxide Emissions (CO2E) generated from the combustion of traditional high carbon-intensive fuels such as coal, natural gas, and petroleum oils. In this regard, energy sector transformation-led management of CO2E-induced climate risks can take two major forms. Firstly, according to a recent report by the International Energy Agency (IEA), attaining carbon neutrality worldwide by 2050 would require a massive transition in the global energy systems so that the dependencies on traditional fossil fuels can be phased out while modern renewable energy resources are substantially deployed in tandem (IEA, 2021). This is because renewable energy resources, such as wind and solar, are not chemically composed of hydrocarbons (Alam et al., 2022); thus, the use of these hydrocarbon-free energy resources is not likely to heighten climate risks by surging emission levels of Carbon dioxide (CO2) and other major greenhouse gases. Secondly, and more importantly, since large-scale deployment of renewable energy is proven to be difficult, especially in emerging economies that have monotonic fossil fuel reliance (Seetharaman et al., 2019), efficient utilization of energy is deemed necessary for relieving the associated climate risk burdens (Khan et al., 2022). Thus, the IEA has also acknowledged the importance of improving energy use efficiency levels for dealing with climate change-related concerns by minimizing energy consumption-based greenhouse gas emissions (IEA, 2019). In contradiction to these views, the energy *rebound effect* associated with an improvement in the level of energy use efficiency suggests that unless proactive measures are implemented the monetary gains from energy use efficiency improvement can stimulate higher use of unclean energy whereby the emissions, rather than declining, can be assumed to surge further (Chen et al., 2021a; Brockway et al., 2021).

Against this background, this study aims to assess whether financial inclusion, along with improvements in energy use efficiency, renewable energy consumption, economic growth, international trade, and urbanization, can lower climate risks by inhibiting CO2E in 22 emerging economies over the 2008–2018 period.[1] These selected nations are leading contributors to the world economy, collectively accounting for more than one-third of the global gross value added (World Bank, 2021). Besides, almost two-thirds of the world's population resides in these selected emerging nations; consequently, in 2018, these nations consumed more than half of the energy resources consumed worldwide (USEIA, 2022). At the same time, the selected economies collectively emitted around 58% of the global volume of CO2E in 2018 (World Bank, 2018). Among these nations, China alone accounted for more than 30% of the world's CO2E figures in 2018 (World Bank, 2021). Furthermore, given that there are tremendous possibilities for these nations to achieve rapid economic growth and also experience a population boom, their collective share in the global CO2E figures is likely to surge with time. Moreover, since these countries are predominantly fossil fuel consumers, a rise in their economic activities in the next couple of decades can be assumed to substantially trigger their energy demand; consequently, it could impose greater risks to the climate by stimulating greater emissions of CO2 and other greenhouse gases. In 2018, the mean share of renewable energy in the total final energy consumption level of these emerging countries was merely around 21% (World Bank, 2021). More alarmingly, apart from Hungary, South Korea, Mexico, and Poland, the renewable energy shares in the respective energy consumption levels of the other 18 selected emerging nations have progressively declined over the last couple of decades (World Bank, 2018). These statistics not only reveal that the fossil fuel dependency within these nations has increased over time, but also indicate that the pathways concerning the deployment and adoption of renewable energy have not been conducive for these selected emerging countries.

The core contributions of this study to the finance-environment nexus are as follows. Firstly, the extant literature is saturated with studies that have attempted to reveal the environmental impacts of the financial sector using financial development, especially in terms of the share of credit given to the private sector in the national output level, as the core indicator of the state of development of the financial sector (Haldar and Sethi, 2022). On the other hand, as pointed out by Le et al. (2020), lack of data availability has kept the effects of financial inclusivity on CO2E largely unexplored in the existing studies. Besides, none of the previous studies have scrutinized the financial inclusion-CO2E relationship specifically for the a moderately large panel of emerging economies. To bridge this gap in the literature, this study constructs a comprehensive financial globalization index, utilizing data regarding various financial inclusivity indicators, for assessing the financial inclusion-CO2E nexus for the emerging nations of concern. Secondly, since the IEA has recognized that energy efficiency gains can both directly and indirectly influence emission levels, this study examines the joint environmental impacts of energy use efficiency and financial inclusivity on the CO2E figures of the selected emerging nations. The preceding studies have largely overlooked these indirect channels through which developing the financial sector and making more productive use of energy can collectively contribute to the reduction of CO2E in the emerging nations' context.

In the next section, the summary of the findings documented in the existing studies is presented in the form of a literature review. Then, the subsequent sections highlight the empirical models and econometric methods, report and discuss the results from the econometric analysis, and conclude by recommending several climate risk mitigation policies.

2. Literature review

The literature on the role of the financial sector in respect of reducing climate risks is mostly saturated with studies that have dissected the effects of financial development on CO2E. In the context of emerging economies, Saidi and Mbarek (2017) employed data

---

[1] The period of the analysis is determined by data availability. The sample of the 22 emerging countries considered in this study includes Bangladesh, Brazil, China, Colombia, Egypt, Hungary, India, Indonesia, Iran, South Korea, Malaysia, Mexico, Morocco, Nigeria, Pakistan, Peru, Philippines, Poland, Russia, South Africa, Turkey, Vietnam.

concerning 19 emerging countries and found that financial development, measured in terms of the share of private sector credit in the Gross Domestic Product (GDP), reduces climate risks by curbing CO2E in the long run. In another study on 15 emerging market economies, Cetin and Bakirtas (2020) also opined that financial development deteriorates the environment based on the findings that as the share of private sector credits provided by banks in the GDP goes up by 1%, the long run CO2E figures of these countries increase by around 0.8%. Accordingly, the authors recommended the imposition of financial regulations to inhibit investments in unclean industries. Faisal et al. (2020) also proxied financial development using private sector credit shares in the GDP of four fast-emerging countries (Brazil, India, China, and South Africa) and alleged financial for enhancing climate risks by surging the long-run CO2E levels of these countries. Recently, in the context of 16 emerging economies, Haldar and Sethi (2022) found evidence of financial development being ineffective in mitigating CO2E; however, the authors mentioned that provided the rate of internet penetration within these economies goes up, financial development can effectively curb the emission figures. Likewise, considering data from the emerging economy of Pakistan, Abbasi and Riaz (2016) asserted that financial development can impose equivocal environmental impacts. Precisely, the authors emphasized that only during periods when the rate of financial development is high, a CO2E-inhibiting effect can be associated with the development of the financial sector of Pakistan. Neog and Yadava (2020), on the other hand, concluded that although positive shocks to the financial development level in the short run help to reduce CO2E in India, financial development does not exert any long-run environmental effect.

A common limitation of these aforementioned studies is that they have only focused on the borrowing component of the financial sector while leaving other types of financial goods and services unaccounted for. However, recently, a couple of studies have looked into the environmental impacts of different financial sector-related products to examine the financial inclusion-CO2E nexus. In the context of the BRICS, comprising Brazil, Russia, India, China, and South Africa, Dou and Li (2022) concluded that financial inclusion enhances climate risks by triggering greater CO2E. In another recent study on the Emerging Seven nations, Qin et al. (2021) remarked that enhancing financial inclusivity is only effective in curbing CO2E in low CO2-emitting emerging nations; precisely, the results from panel quantile regression estimates unearthed that financial inclusion negatively affects CO2E only up to the 50th quantile. Likewise, Liu et al. (2022a) used data from five emerging Asian nations and found that the financial inclusion-CO2E nexus depicts heterogeneity across alternative financial products and services. The authors asserted that as the number of commercial bank branches per 1000 adults and the share of bank credit in bank deposits go up, CO2E tend to decline in the long run. In contrast, a higher share of insurance premium value in the GDP was found to be associated with lower emissions of CO2. Some similar studies have also been conducted for the emerging economy of China. Using data on several financial inclusion-related products, Liu et al. (2022b) concluded that increments in the number of banked adults, the share of bank credits to bank deposits, and life and non-life insurance premium shares in the GDP contribute to reducing the CO2E figures of China both in the short- and long-run. Likewise, using data from 284 Chinese cities, Wang et al. (2022) also advocated in favor of digital financial inclusion impeding CO2E in China.

The financial inclusion-CO2E relationship has also been evaluated using larger samples of global countries comprising both emerging and non-emerging economies. Zaidi et al. (2021) employed data concerning 23 members of the Organization for Economic Cooperation and Development (OECD) and found that the implementation of financial inclusivity-enhancing policies triggers climate adversities by boosting CO2E. On the other hand, Le et al. (2020) considered data from 31 Asian countries and found that positive shocks to financial inclusivity-related variables stimulate higher emissions of CO2 in the long run. Besides, in the context of South Asia, Amin et al. (2022) reported that higher financial inclusivity, although helping to curb CO2E in the short run, goes on to stimulate higher emissions of CO2 in the long run. However, refuting the conclusions of Amin et al. (2022), Chaudhry et al. (2022) utilized data from the Organization of Islamic Cooperation (OIC) nations and found that higher financial inclusivity increases and decreases CO2E in the short- and long-run, respectively. Furthermore, exploring the non-linearity of the financial inclusion-CO2E nexus in the context of 103 global nations, Renzhi and Baek (2020) asserted that the relationship between these variables depicts an inverted U-shape whereby financial inclusion can be considered as a long-term solution for tackling climate risks.

Now, referring to the empirical literature on the energy use-CO2E nexus, it is apparent that the majority of the preceding studies have scrutinized the effects of total, non-renewable, and renewable energy consumption on CO2E. From the perspective of emerging nations, Zafar et al. (2019) used data from 18 emerging economies from 1990 to 2015 and found evidence that non-renewable and renewable energy consumption results in higher and lower emissions of CO2, respectively. Consequently, the authors concluded that clean energy consumption instead of unclean energy can effectively impede climate risks. Besides, the authors remarked that economic growth and international trade openness can complement renewable energy consumption in declining CO2E further. Similarly, using data from seven emerging Asian nations over the 1991–2017 period, Mujtaba et al. (2021) stated that higher energy consumption is responsible for higher CO2E both in the short- and long-run. Paramati et al. (2017) also explored the energy consumption-CO2E nexus for the Next Eleven emerging nations. The results, for the 1990–2012 period, indicated that non-renewable energy consumption enhances climate risks by triggering higher emissions of CO2 while renewable energy consumption does the opposite. Similar studies have been conducted specifically for non-emerging countries. Among these, Doğan et al. (2022) opined that renewable energy consumption is effective in reducing CO2E in the Group of Seven (G7) nations. Besides, in the context of the United States, Pata (2021) found evidence that mitigating CO2E requires scaling up renewable energy consumption and reducing non-renewable energy use, in tandem.

Although plenty of preceding studies commented on the effects of energy consumption (both renewable and non-renewable) on CO2E, the literature on the nexus between energy efficiency and CO2E is relatively limited. Among the few studies focusing on this issue, Nibedita and Irfan (2021) used data from the seven largest emerging economies and stated that energy efficiency gains can reduce CO2E in the long run. Besides, the causality analysis revealed a unidirectional causal association stemming from energy efficiency to CO2E. Lei et al. (2022), in the context of China, found evidence of energy efficiency gains reducing CO2E in the short run while in the long run, more efficient use of energy resulted in higher emissions of CO2. Accordingly, these findings suggested that energy efficiency improvement is likely to exert an energy *rebound effect* to enhance climate risks in the long run. Liu et al. (2021) also verified the presence of the *rebound* effect in China and alleged it as one of the core drivers of CO2E both at the micro and macro levels. Similarly, in studies involving both emerging and non-emerging nations, Shahbaz et al. (2015) documented evidence that higher energy intensity (meaning lower efficiency of energy use) is responsible for higher CO2E in Sub-Saharan African nations. Besides, the causality analysis verified the existence of a unidirectional causal association running from energy intensity to CO2E.

In another relevant study on 66 underdeveloped nations, Akram et al. (2020) asserted that the effects of energy efficiency improvement on CO2E are heterogeneous across nations with different levels of CO2E. The results derived using panel quantile-based estimation techniques showed that although energy efficiency gains reduce emissions of CO2 for all quantiles, the CO2E-impeding impact is higher for relatively more-polluted developing nations. In addition, the authors also concluded that greater use of renewable energy reduces CO2E, but this effect was found to be greater for the comparatively less-polluted developing countries. Likewise, utilizing data from 70 Belt and Road Initiative (BRI) nations, Abban et al. (2020) found statistical evidence that intensification of energy use triggers greater climate risks by boosting CO2E in these countries. Moreover, conducting the analysis separately for the different income groups, the results showed that the positive effects of energy intensity on CO2E also hold for separate samples of high-income, upper-middle-income, lower-middle-income, and low-income BRI countries.

Therefore, the review of the aforementioned studies portrays several of the literature gaps this study aims to address. It is apparent that the financial sector's role in abating CO2E has been extensively explored using the share of private sector credit in the GDP as a proxy for financial development. However, little is known regarding the nexus between financial inclusion and CO2E in the context of emerging nations. Most importantly, it is evident that the joint impacts of energy use efficiency improvement and financial inclusivity on CO2E for tackling climate risks in emerging nations are yet to be comprehensively documented in the literature. As a result, considering these gaps, this current study attempts to explore the possible joint environmental impacts of energy use efficiency with financial inclusivity and renewable energy use in the context of the selected emerging countries.

3. Empirical model, data, and methodology

3.1. Empirical model and data

Many empirical studies related to the determinants of environmental well-being have been documented in the literature. Although several of these studies have tried to examine the macroeconomic determinants of CO2E using the empirical model of the Environmental Kuznets Curve (EKC) hypothesis, this modeling approach has recently been criticized (Hamid et al., 2022; Murshed et al., 2022b). Hence, in this study, we follow Li et al. (2022) and consider the Stochastic Impacts by Regression on Population, Affluence, and Technology (STIRPAT) model proposed by Dietz and Rosa (1997). The STIRPAT model is a stochastic variant of the Impacts on Population, Affluence, and Technology (IPAT) model of Ehrlich and Holdren (1971). Therefore, the baseline STIRPAT model considered in this study for modeling the determinants of CO2E in the selected emerging economies can be shown as follows:

$$\mathbf{Model1}: \mathrm{lnCO2E}_{it} = \beta_o + \beta_1 \mathrm{FI}_{it} + \beta_2 \mathrm{lnEE}_{it} + \beta_3 \mathrm{RE}_{it} + \beta_4 \mathrm{lnY}_{it} + \beta_5 \mathrm{ITO}_{it} + \beta_6 \mathrm{URBR}_{it} + \varepsilon_{it} \quad (1)$$

In Eq. 1 i refers to the cross-sectional units (i.e., the selected emerging countries), t refers to the period of analysis, ε represents the error-term, β_o is the intercept parameter, and $\beta_i (i = 1, 2, \ldots, 6)$ are the elasticity parameters to be estimated. Concerning climate risks, this study considers CO2E as its proxy; thereby, a rise in the level of CO2E can be interpreted as a surge in the degree of climate risks since it has been widely acknowledged in the extant literature that CO2E is the main cause of climate change(Razzaq et al., 2023). Hence, if the predicted elasticity parameters depict a negative (or positive) sign, it would implicate that positive shocks to the corresponding explanatory variable/s reduce (or enhance) climate risks by inhibiting (or promoting) CO2E. Accordingly, the dependent variable lnCO2E represents the natural logarithm of the annual CO2E per capita level of the respective emerging nations. Besides, this variable and also some of the explanatory variables are naturally log-transformed to convert the empirical model into a double-log function so that the elasticities of CO2E in response to a 1% change in the explanatory variables can be easily calculated.

Among the explanatory variables, firstly, FI stands for the financial inclusivity index which is predicted by employing data concerning a couple of financial inclusion-related variables namely (a) the number of Automated Teller Machines (ATM) per 1000,000 adults, (b) the number of commercial bank branches per 100,000 adults, (c) share of bank deposits in the GDP, (d) number of bank accounts per 1000 adults, and the share of loans from non-resident banks in the GDP. This index is calculated using the Principal Component Analysis (PCA) technique and then normalized to assign a range from 0 to 100 in ascending order of financial inclusivity. Similar approaches were adopted for the emerging seven nations by Qin et al. (2021). Due to the preceding studies reporting equivocal environmental effects associated with financial inclusion, it is difficult to hypothesize the sign of the corresponding elasticity parameter (β_1). Secondly, lnEE stands for the natural logarithm of the annual level of energy use efficiency in the selected emerging countries. Since more efficient use of energy is synonymous with greater output per unit of energy utilized, this variable is calculated by dividing the annual GDP value by the corresponding annual energy consumption level. Similar to the dependent variable, this variable is natural log-transformed for easing the prediction of the elasticities of CO2E. Besides, it is noteworthy mentioning that this variable captures the technology aspect of the STIRPAT model in the form of energy innovation since the application of the latest technology can be assumed to facilitate more efficient use of energy (Chen et al., 2021b). Thirdly, the variable RE refers to renewable energy's share in the total final energy consumption level which not only provides an account of the state of the renewable energy sector in the respective emerging nations but also captures the technology aspect within the STIRPAT model (Alam et al., 2022). In this regard, it has been recognized in the literature that technological backwardness hampers the process of replacing renewable energy use with renewable energy (Boulogiorgou and Ktenidis, 2020); consequently, a rise in renewable energy's share in the national energy consumption bundle can be interpretated as technological innovation within the energy sector.

Fourthly, to account for the impacts of affluence within the STIRPAT model, the model (shown in Eqn 1) controls for the natural logarithm of the annual per capita level of real GDP (denoted by lnY). Since the national income level gives an indication of the growth level of an economy, several studies have used the per capita GDP level as a proxy for economic growth/affluence (Aslam et al., 2021). As per the EKC hypothesis, economic growth can both enhance and reduce climate risks by stimulating and inhibiting emissions of CO2, respectively (Alola and Ozturk, 2021). Consequently, the sign of the corresponding elasticity parameter is uncertain. Fifthly, ITO stands for the international trade openness-indicating variable which is given by the percentage share of exports and imports in the GDP of the respective emerging countries. Within the extant literature, this variable is widely used as a proxy for international trade (Das et al., 2022). Lastly, the variable URBR refers to the urbanization rate which is given by the percentage share of urban residents in the total population of the respective emerging country. Within the STIRPAT model, this variable can be assumed to capture the effect of the population from the understanding that as the size of the urban population grows, it exerts environmental pressures to a large extent (Abbasi et al., 2021). The variables ITO and URBR are not naturally log-transformed because these variables are already measured in percentage shares whereby the elasticities of CO2E with respect to 1% changes in the international trade openness index and urbanization rate can be estimated without log-transforming these variables.

Further, apart from exploring the isolated or direct effects of energy use efficiency and financial inclusivity on CO2E, the joint or indirect effect of these variables on the CO2E figures of emerging nations is also scrutinized. Accordingly, we augment our baseline model (shown in Eqn 1) with an interaction term to generate an additional model that is shown below:

$$\textbf{Model2}: \mathrm{lnCO2E}_{it} = \beta_o + \beta_1\mathrm{FI}_{it} + \beta_2\mathrm{lnEE}_{it} + \alpha_1(\mathrm{lnEE}_{it} * \mathrm{FI}_{it}) + \beta_3\mathrm{RE}_{it} + \beta_4\mathrm{lnY}_{it} + \beta_5\mathrm{ITO}_{it} + \beta_6\mathrm{URBR}_{it} + \varepsilon_{it} \tag{2}$$

In Eq. 2, the variable lnEE*FI stands for the interaction term between energy use efficiency and financial inclusion. Therefore, the elasticity parameter $\alpha_1$would portray how these variables jointly impact the CO2E figures of the emerging nations of concern. The analysis involving the interaction term is relevant since the IEA has recognized the importance of improving energy use efficiency for directly and indirectly abating climate risks (IEA, 2019). Based on data availability, the country sample comprises 22 emerging nations and the period of analysis spans from 2008 to 2018. The units of measurement and data sources of the variables are shown in Table 1.

3.2. Econometric methods

Before strategizing the econometric analysis, it is imperative to check for issues of cross-sectional dependence and heterogeneous slope coefficients in the panel data set being utilized. Both these problems compromise the consistency and unbiasedness of the econometric outcomes. Firstly, the Cross-Sectional Dependency (CSD) analysis is conducted utilizing the Pesaran's (2004) technique. In this method, a test statistic is predicted for each variable to verify the alternative hypothesis of cross-sectional dependence. The corresponding results from the Pesaran (2004) CSD analysis, as shown in Table 2, reveal that for all variables the predicted test statistic is statistically significant, whereby the issue of CSD is detected in the panel dataset considered in this study.

Then, the Pesaran and Yamagata (2008) method is employed for testing the presence of Heterogeneous Slope Coefficients (HSC) issue in the data. This approach for HSC testing involves the prediction of two test statistics ($\widehat{\Delta}$and $\widehat{\Delta_{adj.}}$) to verify the alternative hypothesis of slope heterogeneity. The corresponding outcomes, as reported in Table 3, show that for both model specifications (i.e., Models 1 and 2) the calculated test statistics are statistically significant. Hence, the issue of HSC is confirmed by these outcomes. Given that we find evidence of both CSD And HSC problems in our data set, we strategize our subsequent econometric methodology including methods that take these problems into account when estimating the unit root, cointegration, regression, and causality outcomes.

Following the conclusion of the aforementioned set of pre-estimation tests, we proceed to conduct the panel data analysis of unit root using both the Cross-sectionally Augmented Dickey-Fuller (CADF) and Cross-sectionally Im-Pesaran-Shin (CIPS) unit root tests proposed by Pesaran (2007). These second-generation techniques are recognized for efficiently handling cross-sectionally dependent panel data sets and predicting a test statistic for each series to verify the alternative hypothesis that the series in question is stationary (Dogan and Aslan, 2017). After the completion of the unit root analysis, we conduct the Westerlund (2007) panel cointegration analysis which involves the prediction of an error-correction model to distinguish whether long-run relationships between the variables of concern exist or not. In contrast to the first-generation residual-based estimators, this second-generation technique proposed by Westerlund (2007) is efficient in handling CSD issues (Ahmed and Le, 2021). Under this technique, a set of four test statistics (Pa, Pt,

Table 1

The measurement scales and corresponding data sources.

Variable (symbol)	Unit of measurement	Source
Carbon dioxide emissions per capita (lnCO2E)	Metric tons per capita	Global Carbon Atlas (2021)
Financial inclusivity index (FI)	Index (ranges from 0 to 100)	Authors' calculation fromWorld Bank (2021)
Energy use efficiency (lnEE)	Constant 2015 US$ per megajoules of oil equivalent	Authors' calculations fromWorld Bank (2021) and USEIA (2022)
Renewable energy share in total final energy consumption (RE)	Percentage	World Bank (2021)
Real per capita GDP (lnY)	Constant 2015 US$	World Bank (2021)
International trade openness index (ITO)	Percentage	World Bank (2021)
Urbanization rate (URBR)	Percentage	World Bank (2021)

Table 2
The CSD test results.

Variable	Test Statistic	p-value	Decision
lnCO2E	5.450^{a}	0.000	CSD exists
FI	4.995^{a}	0.000	CSD exists
lnEE	2.450^{b}	0.015	CSD exists
RE	6.230^{a}	0.000	CSD exists
lnY	3.909^{c}	0.058	CSD exists
ITO	6.661^{a}	0.000	CSD exists
URBR	4.330^{a}	0.005	CSD exists

Note: Null hypothesis: cross-sectional independence; ^{a}, ^{b}, and ^{c} show statistical significance at 1%, 5%, and 10% levels, respectively

Table 3
The slope homogeneity test results .

Model	Dependent variable	$\hat{\Delta}$ statistic	$\Delta_{adj.}$ Statistic
1	lnCO2E=*f*(FI, lnEE, RE, lnY, ITO, URBR)	32.290^{a}	33.100^{a}
2	lnCO2E=*f*(FI, lnEE, lnEE*FI, RE, lnY, ITO, URBR)	29.950^{a}	30.930^{a}

Note: Null hypothesis: the slope coefficients are homogeneous; ^{a} shows statistical significance at a 1% level

Ga, and Gt) are calculated to verify the alternative hypothesis of cointegrating associations among the variables in the respective model. Once the order of stationarity and cointegrating associations are established, we perform the panel regression and causality analyses.

The past studies have put less emphasis on accounting for CSD and HSC concerns in the panel data set and have utilized traditional methods that arbitrarily assumed cross-sectional independence and homogeneous slope coefficients. However, since we find evidence of our panel data set being heterogeneous and cross-sectionally dependent, recent techniques should be considered for regression purposes. In addition to these two issues, the problem of endogeneity is another serious data concern that can lead to model mis-specification issues and generate misleading inferences concerning the regression outcomes (Abdallah et al., 2015). Conventionally, endogeneity within the model can arise due to interdependency among a pair of dependent and independent variables whereby reverse causation between these variables can label the independent variable as an endogenous covariate. In the context of this study, the issue of endogeneity can be expected since apart from financial inclusivity influencing the CO2E figures of the emerging nations, the aggravation of climate risks in the form of rising emissions of CO2 can trigger the urgency to invest in research and development projects for developing technologies related to carbon sequestration, in particular. Under such circumstances, the causal relationship between financial inclusion and CO2E can be bidirectional which, in turn, can be associated with endogeneity issues in our data. Other than the possibility of reverse causation, the exclusion of relevant explanatory variables from the model is another possible source of endogeneity. Lastly, in the context of a particular explanatory variable being correlated with the error term, the issue of endogeneity can exist within the model as well.

Hence, considering all these three panel data problems (CSD, HSC, and endogeneity), we utilize the recently introduced Dynamic Common Correlated Effects Mean Group-Instrumental Variable (DCCEMG-IV) technique to predict the long-run elasticity parameters concerning CO2E. This method is a contemporary variant of the Dynamic Common Correlated Effects Mean Group (DCCEMG) panel regression estimator introduced by Chudik and Pesaran (2015). Although the DCCEMG technique also can control for CSD, HSC, and endogeneity issues, the DCCEMG-IV method specifically provides an instrumental variable setting to address the endogeneity issue by instrumenting the endogenous covariate/s with the lagged levels of the other independent variables (Churchill et al., 2021). In the context of this study, we instrument the financial inclusivity index variable with first-lagged levels of the other explanatory variables to control for endogeneity concerns that can possibly arise from the interdependency between financial inclusivity and CO2E. In addition, the lagged level of the dependent variable is also included as an additional regressor in the model to tackle the issue of endogeneity.

Moreover, to check whether the long-run findings are robust across the individual emerging nations of concern, we employ Pesaran et al.'s (2001) Autoregressive Distributed lag (ARDL)[2] technique to predict outcomes for each of the 22 emerging countries considered in this study. This method uses time series data that are subject to endogeneity concerns and small time dimensions (Ahmad and Du, 2017; Naseem et al., 2022). Moreover, since the time period considered in this study spans from 2008 to 2018, which is insufficient for conducting the country-specific ARDL analysis, we convert the data into quarterly frequencies by employing the quadratic sum approach to tackle the limited time dimension-related concern. Lastly, to deduce the causal associations between the variables, we perform the Dumitrescu and Hurlin (2012) panel causality analysis. This technique modifies the conventional Granger causality estimation techniques by controlling CSD and HSC concerns in the data. While the issue of CSD is tackled using a bootstrapped approach, the issue of HSC is accounted for by letting the slope coefficients differ across the cross-sectional units. This panel causality

---

[2] Although the ARDL technique provides short-run outcomes as well, since we are checking the robustness of the long-run outcomes from the DCCEMG-IV outcomes, we do not report the short-run outcomes for ensuring brevity.

estimator predicts test statistics to verify the alternative hypothesis of a particular independent variable Granger causing the dependent variable in the concerned model.

4. Results and discussion

This section commences by reporting and analyzing the outcomes derived from the panel unit root analysis. As shown in Table 4, the outcomes from both the unit root tests reveal that at the level the null hypothesis of non-stationarity cannot be rejected for all variables since the corresponding test statistics are statistically insignificant. However, an opposite scenario is evidenced in the case of all variables at the first difference. The statistical significance of the predicted test statistics, at the first difference, from both tests verify the alternative hypothesis of stationarity to affirm a common integration order among the concerned variables. These findings suggest that all variables considered in this study are mean-reverting at their first difference; consequently, regression analysis utilizing these variables is not likely to generate spurious outcomes.

After completing the panel unit root analysis, the cointegration analysis is performed and the related outcomes are presented in Table 5. It can be seen that in the cases of both models, the majority of the predicted test statistics are statistically significant which verifies the alternative hypothesis of the presence of cointegrating equation/s in each model. Hence, these findings suggest that there are long-run relationships among the variables of concern. Once cointegration is affirmed, the next analytical step involves performing the regression analysis using the stationary and cointegrated variables.

The predicted long-run elasticity parameters derived using the DCCEMG-IV panel regression estimator are reported in Table 6. Overall, we find that the results are similar for both models in respect of the estimated effects of financial inclusivity, energy efficiency, renewable energy, economic growth, international trade, and urbanization on the CO2E figures of the selected emerging countries. Firstly, we find that the level of CO2E in the previous period does not influence the current CO2E figure since the predicted elasticity parameters concerning the one-period lagged level of the variable ln CO2E are witnessed to be statistically insignificant. Alternatively, the regression outcomes show that financial inclusivity enhances climate risks by positively influencing CO2E in the long run. Notably, a 1% positive change in the level of financial inclusivity is observed to increase the per capita CO2E figures by 0.94%– 1.03%, on average, ceteris paribus. In contrast, an opposite environmental impact is found to be associated with energy use efficiency improvement. The corresponding estimates of the elasticity parameters reveal that following an improvement in the level of energy use efficiency by 1% the level of per capita CO2E goes down on average by around 0.02%, ceteris paribus.

Moreover, similar to energy use efficiency, renewable energy use is also seen to inhibit climate risks by negatively influencing CO2E. Notably, a 1% increment in the share of renewables in the total final energy consumption level is found to curb CO2E on average by 0.02%– 0.03%, ceteris paribus. Further, it is also found that energy use efficiency gains, apart from directly impeding the emissions of CO2 in the long run, exert moderating effect by jointly reducing CO2E with financial inclusion. The negative signs of the predicted elasticity parameters concerning the interaction term between these explanatory variables (in Model 2) certify this claim. More importantly, the results highlight that energy efficiency improvement indirectly helps in reducing the climate risk-enhancing impacts associated with greater financial inclusivity in the selected emerging nations. Furthermore, the elasticity estimates indicate that economic growth, international trade participation, and urbanization trigger higher climate risks by positively influencing the long-run CO2E figures of these nations. In support, the corresponding elasticity estimates reveal that increments in the levels of real per capita GDP, international trade openness index, and urbanization rate boost CO2E by around 1.38%– 1.52%, 0.06%– 0.08%, 0.17%– 0.19%, respectively, ceteris paribus. All these findings are discussed in detail in the following sub-section.

We also calculate the country-specific outcomes using the ARDL estimator for each of the 22 emerging economies considered in this study. The corresponding findings for Models 1 and 2 are respectively presented in Tables 7 and 8. Overall, in the context of both models, the country-specific results show that in 15 (68.2%) out of the 22 emerging nations financial inclusion results in higher CO2E while in only 5 (22.7%) of the selected emerging countries greater financial inclusivity inhibits CO2E. On the other hand, energy use efficiency gains are observed to reduce CO2E in all 22 (100%) of the selected emerging nations. Similarly, for 20 (90.9%) of the selected emerging nations, higher renewable energy use is seen to lower climate risks by reducing CO2E. Besides, regarding the moderating impacts of energy use efficiency, the country-specific results for Model 2 (as shown in Table 8) indicate that energy use efficiency gains and financial inclusivity jointly reduce CO2E in 19 (86.4%) of the 22 selected emerging countries. Furthermore, the country-specific outcomes for both models show that economic growth homogeneously raises climate risks by positively influencing the CO2E figures of all 22 (100%) selected emerging nations. Besides, concerning international trade, the country-specific outcomes

Table 4
The panel unit root test results.

Variable	CADF test	CIPS test	Variable	CADF test	CIPS test	Order
lnCO2E	2.108	-1.921	ΔlnCO2E	-1.330	-2.961[a]	I(1)
FI	2.125	-1.890	ΔFI	-2.047	-2.894[a]	I(1)
lnEE	1.615	-1.995	ΔlnEE	-1.565	-3.341[a]	I(1)
RE	1.945	-1.627	ΔRE	-1.813	-2.689[a]	I(1)
lnY	2.111	-1.321	ΔlnY	-1.848	-2.347[b]	I(1)
ITO	1.780	-1.600	ΔITO	-0.842	-2.635[a]	I(1)
URBR	1.890	-1.333	ΔURBR	-1.650	-2.405[b]	I(1)

Note: Δ indicates first difference; The Akaike Information Criterion (AIC) was used to determine the optimal lags; Order refers to the integration order; [a] and [b] reveal statistical significance at 1% and 5% levels, respectively

Table 5

The panel cointegration test results.

Model	Dependent variable	Gt	Ga	Pt	Pa
1	lnCO2E=*f*(FI, lnEE, RE, lnY, ITO, URBR)	-3.555^{a}	-11.350	23.250^{a}	15.135^{a}
2	lnCO2E=*f*(FI, lnEE, lnEE*FI, RE, lnY, ITO, URBR)	-3.710^{a}	-12.225	23.790^{a}	16.100^{a}

Note: The AIC was used to determine the optimal lags; the test statistics are estimated using 2000 bootstrapped replication; * ** reveals statistical significance at a 1% significance level

Table 6

The long-run elasticity estimates from the DCCEMG-IV analysis.

Dependent variable: lnCO2		
Model	(1)	(2)
Dep. var.	lnCO2E	lnCO2E
Regressors		
lnCO2(−1)	-1.239	-1.355
	(0.989)	(1.140)
FI	1.027^{a}	0.938^{a}
	(0.007)	(0.008)
lnEE	-0.017^{a}	-0.017^{a}
	(0.002)	(0.001)
(lnEE*FI)		-0.044^{a}
		(0.013)
RE	-0.026^{a}	-0.018^{b}
	(0.008)	(0.009)
lnY	1.375^{a}	1.517^{a}
	(0.210)	(0.220)
ITO	0.063^{a}	0.081^{a}
	(0.013)	(0.022)
URBR	0.170^{a}	0.185^{a}
	(0.024)	(0.037)
Constant	-12.122^{a}	-11.931^{a}
	(2.150)	(2.162)

Note: lnCO2(−1) stands for the first lag of the dependent variable; ^{a} and ^{b} reveal statistical significance at 1% and 5% levels, respectively; the standard errors are reported within the brackets.

Table 7

The country-wise ARDL outcomes for Model 1.

Dependent variable: lnCO2						
Country	FI	lnEE	RE	lnY	ITO	URBR
Bangladesh	2.132^{a}	-0.560^{a}	-0.042^{b}	1.593^{a}	0.078^{a}	0.432^{a}
Brazil	2.564^{a}	-0.314^{b}	-0.120^{a}	1.712^{a}	0.060^{b}	0.204^{b}
China	1.840^{a}	-0.452^{a}	-0.086^{a}	2.223^{b}	0.083^{b}	0.065
Colombia	-1.521^{c}	-0.098^{a}	-0.032^{a}	2.201^{a}	-0.010^{b}	-0.350^{a}
Egypt	1.340^{b}	-0.055^{a}	-0.129^{a}	3.122^{a}	0.006	0.110
Hungary	1.555^{a}	-0.076^{b}	-0.002	1.342^{b}	0.039	0.324^{a}
India	2.623^{a}	-0.120^{a}	-0.044^{a}	0.913^{a}	0.033^{b}	0.423^{a}
Indonesia	1.823^{a}	-0.087^{a}	-0.083^{a}	4.111^{a}	0.012^{c}	0.232^{b}
Iran	-0.342^{b}	-0.120^{a}	-0.119^{a}	1.654^{a}	0.054^{b}	0.020
South Korea	0.850	-0.128^{a}	-0.050^{b}	2.212^{a}	-0.009	0.330^{b}
Malaysia	-0.211^{b}	-0.105^{a}	-0.005	1.764^{a}	0.064^{b}	0.229^{a}
Mexico	1.650^{a}	-0.079^{b}	-0.052^{b}	2.215^{b}	0.081^{a}	-0.054^{b}
Morocco	1.965^{a}	-0.099^{c}	-0.049^{c}	2.212^{b}	0.064^{b}	0.301^{b}
Nigeria	2.235^{a}	-0.121^{a}	-0.065^{a}	1.252^{c}	0.053^{a}	0.441^{a}
Pakistan	1.667^{a}	-0.045^{b}	-0.176^{a}	1.749^{b}	0.121^{a}	0.275^{b}
Peru	-0.227^{a}	-0.101^{c}	-0.392^{a}	2.430^{a}	0.040^{b}	0.290^{b}
Philippines	2.040^{a}	-0.045^{a}	-0.092^{b}	2.222^{b}	0.054^{b}	0.200^{c}
Poland	0.622	-0.088^{a}	-0.044^{b}	3.122^{b}	0.006	0.213^{b}
Russia	1.911^{a}	-0.129^{b}	-0.100^{a}	2.122^{a}	0.102^{a}	0.342^{a}
South Africa	-0.515^{b}	-0.030^{a}	-0.056^{a}	1.265^{b}	0.231^{a}	0.012
Turkey	1.934^{a}	-0.111^{a}	-0.099^{a}	2.548^{a}	0.076^{a}	0.325^{b}
Vietnam	2.150^{a}	-0.328^{a}	-0.037^{a}	2.997^{a}	0.102^{a}	0.553^{a}

Note: Note: ^{a}, ^{b}, and ^{c} reveal statistical significance at 1%, 5%, and 10% levels, respectively; For ensuring brevity, the standard errors are not reported.

Table 8
The country-wise ARDL outcomes for Model 2.

Dependent variable: lnCO2							
Country	FI	lnEE	lnEE*FI	RE	lnY	ITO	URBR
Bangladesh	2.495^{a}	-0.430^{a}	-0.054^{b}	-0.084^{a}	1.834^{a}	0.065^{b}	0.323^{a}
Brazil	2.322^{a}	-0.190^{b}	-0.093^{a}	-0.105^{a}	1.542^{a}	0.098^{b}	0.302^{a}
China	2.912^{a}	-0.234^{a}	-0.110^{b}	-0.094^{a}	1.776^{b}	0.043^{a}	0.066
Colombia	-1.112^{b}	-0.301^{a}	-0.201^{b}	-0.026^{b}	1.546^{a}	-0.034^{b}	-0.231^{b}
Egypt	1.285^{a}	-0.221^{a}	-0.055^{b}	-0.126^{a}	2.931^{a}	0.010	0.155
Hungary	1.222^{a}	-0.095^{b}	0.010	-0.004	2.421^{b}	0.041	0.175^{b}
India	2.432^{a}	-0.103^{a}	-0.075^{b}	-0.075^{a}	1.592^{a}	0.054^{b}	0.249^{a}
Indonesia	2.441^{a}	-0.401^{a}	-0.015^{c}	-0.083^{a}	3.432^{a}	0.019^{b}	0.258^{a}
Iran	-0.329^{b}	-0.129^{b}	-0.111^{b}	-0.102^{a}	1.606^{a}	0.065^{a}	0.014
South Korea	1.001	-0.090^{a}	0.005	-0.082^{a}	2.243^{a}	-0.002	0.230^{b}
Malaysia	-0.225^{a}	-0.101^{a}	-0.142^{a}	-0.006	1.839^{a}	0.099^{a}	0.205^{a}
Mexico	2.432^{a}	-0.320^{a}	-0.088^{b}	-0.063^{c}	3.210^{b}	0.121^{a}	-0.071^{b}
Morocco	2.212^{a}	-0.211^{b}	-0.045^{c}	-0.035^{b}	2.221^{b}	0.134^{a}	0.376^{a}
Nigeria	2.124^{a}	-0.140^{a}	-0.014^{b}	-0.083^{a}	1.225^{a}	0.089^{a}	0.543^{a}
Pakistan	1.554^{a}	-0.093^{b}	-0.050^{b}	-0.205^{a}	1.650^{b}	0.109^{a}	0.666^{a}
Peru	-0.430^{a}	-0.085^{c}	-0.104^{a}	-0.123^{a}	4.221^{a}	0.043^{a}	0.520^{a}
Philippines	2.420^{a}	-0.112^{a}	-0.096^{a}	-0.067^{c}	2.503^{a}	0.076^{a}	0.201^{c}
Poland	0.115	-0.123^{a}	-0.011^{c}	-0.040^{c}	2.190^{a}	0.008	0.302^{b}
Russia	2.212^{a}	-0.105^{c}	-0.054	-0.121^{a}	2.737^{a}	0.122^{a}	0.414^{a}
South Africa	-0.432^{a}	-0.059^{a}	-0.121^{a}	-0.070^{a}	1.555^{a}	0.142^{a}	0.023
Turkey	2.050^{a}	-0.121^{a}	-0.063^{a}	-0.082^{a}	3.022^{a}	0.065^{a}	0.243^{b}
Vietnam	2.230^{a}	-0.249^{a}	-0.075^{a}	-0.072^{a}	3.435^{a}	0.092^{a}	0.656^{a}

Note: Note: ^{a}, ^{b}, and ^{c} reveal statistical significance at 1%, 5%, and 10% levels, respectively; For ensuring brevity, the standard errors are not reported.

for both models reveal that more engagement in international trade boosts CO2E in 17 (77.3%) of the selected emerging nations while impeding CO2E in only 1 (4.5%). Lastly, urbanization is witnessed to respectively enhance and reduce CO2E in 16 (72.7%) and 2 (9.1%) of the selected emerging nations. Therefore, it can be seen that in the majority of the cases the country-specific outcomes (shown in Tables 7 and 8) tend to corroborate the corresponding cross-country findings (shown in Table 6).

Finally, the causality tests are conducted to check the direction of causation among the concerned pairs of variables. The results from the Dumitrescu-Hurlin causality analysis, shown in Table 9, certify a bidirectional causal association between financial inclusivity and CO2E. This is an important finding from two points of view. First, the reverse causation between these variables certifies our assumption of endogeneity issues in our models and, thereby, justifies the decision of using regression estimators that can treat endogenous covariates to generate the elasticity outcomes. Second, this bidirectional causation tends to portray the interdependency between financial inclusion and CO2E whereby simultaneous adoption of policies that are relevant for enhancing financial inclusivity and achieving environmental sustainability in tandem becomes important. Besides, the other causality findings support the corresponding regression outcomes as unidirectional causalities are evidenced to be running from energy use efficiency, renewable energy use, economic growth, international trade, and urbanization to CO2E.

4.1. The discussion of the findings

Climate risk mitigation is a major concern for emerging economies due to these nations having prospects of experiencing rapid economic growth which can simultaneously deteriorate the environment as well. In this regard, our finding of financial inclusion

Table 9
The outcomes from causality analysis.

Null Hypothesis	W-bar statistic	Z-bar statistic	Decision on causality
FI ‡ lnCO2	3.119	6.867^{a}	lnCO2 ↔ FI
lnCO2 ‡ FI	4.546	11.548^{a}	
lnEE ‡ lnCO2	3.984	9.672^{a}	lnEE → lnCO2
lnCO2 ‡ lnEE	2.012	3.279	
RE ‡ lnCO2	4.100	10.050^{a}	RE → lnCO2
lnCO2 ‡ RE	2.063	3.261	
lnY ‡ lnCO2	3.343	7.650^{c}	lnY → lnCO2
lnCO2 ‡ lnY	3.001	6.520	
ITO ‡ lnCO2	3.910	9.410^{c}	ITO → lnCO2
lnCO2 ‡ ITO	2.792	5.809	
URBR ‡ lnCO2	5.303	13.945^{a}	URBR → lnCO2
lnCO2 ‡ URBR	3.068	6.720	

Notes: ‡ stands for does not Granger cause; ↔ stands for bidirectional causality; → stands for unidirectional causality; the probability values are predicted considering 5000 bootstrapped replications; ^{a}, and ^{b} reveal statistical significance at 1% and 5% levels, respectively.

boosting climate risks by triggering higher emissions of CO2 indicates that the traditional financial inclusivity-enhancing policies deployed in these countries are not harnessing their environmental welfare objectives. Besides, the finding of the positive nexus between financial inclusion and CO2E can be explained in terms of the adverse environmental effects associated with the *scale effect of economic growth* (Shahbaz et al., 2016). The '*scale effect*' basically advocates that as the domestic output level increases (i.e., as an economy starts to grow) it tends to put pressure on the energy demand, thus, leading to higher emissions of CO2. Similarly, financial inclusion in emerging countries could be associated with higher energy demand from both the production and consumption side channels. Moreover, since these emerging countries are highly dependent on fossil fuels, the rise in the levels of financial inclusivity-driven energy demand and utilization can be expected to boost the CO2E figures of the concerned emerging nations. Similar CO2E-boosting effects of greater financial inclusivity were reported by Dou and Li (2022) and Liu et al. (2022a) for the BRICS nations and five Asian emerging nations, respectively.

On the other hand, the finding of energy use efficiency gains lowering climate risks by limiting CO2E suggests that the *rebound effect* does not take place in the selected emerging economies. As a result, if energy resources can be used more efficiently, energy resources are likely to be saved for future consumption without compromising the overall energy demand. Consequently, energy efficiency-induced demand-side management of energy requirement can be assumed to be effective in controlling the rise in the CO2E levels of emerging nations. Our findings are in line with the assertions put forward in the study by Liu et al. (2021) in which the authors claimed the *rebound effect* is responsible for driving higher emissions of CO2 in China at both the micro and macro levels. This finding of the negative relationship between energy use efficiency and CO2E is also consistent with the results reported by Nibedita and Irfan (2021) for the cases of the seven largest emerging economies. Furthermore, another key finding from this current study is that higher renewable energy shares in the total final energy consumption levels of emerging nations can mitigate their climate risks by curbing CO2E. This is understandable from the perspective that a rise in renewable energy consumption shares in the total energy consumption level signals a decline in fossil fuel dependency in the emerging countries of concern. Consequently, as fewer volumes of unclean energy resources are combusted, the quantity of energy use-related CO2E can be expected to reduce. Accordingly, the pertinence of transitioning toward a renewable energy-based energy sector for improving environmental conditions globally has been been duly highlighted in many preceding studies (Sun et al., 2022). Our findings are also supported by the studies conducted by Zafar et al. (2019) for 18 emerging economies and Paramati et al. (2017) for the Next Eleven countries.

Apart from the direct effect of energy use efficiency gains on CO2E, we find that efficient use of energy inflicts a moderating impact to lower climate risks by jointly reducing CO2E with financial inclusion. This finding can be considered novel since the moderating impacts of financial inclusivity on the environment, via the financial sector, are some of the unexplored issues in the literature. More importantly, the joint CO2E-inhibiting impact of energy use efficiency gains and greater financial inclusivity portrays that the role of financial inclusion in reducing climate risks is conditional on the improvement in the overall level of energy use efficiency across the emerging countries of concern. This phenomenon can be explained by the understanding that as the financial sector becomes more inclusive, it can be expected to put pressure on energy demand. Under such circumstances, if the use of advanced technology can ensure more efficient utilization of energy then the financial inclusion-driven surge in energy demand can be effectively managed; consequently, the CO2E figures of the emerging nations can be anticipated to decline.

The other key finding regarding economic growth boosting climate risks by triggering higher CO2E verifies the notion that since the emerging nations are on course to attaining higher growth of their respective economy and are managing their energy demands mostly with non-renewables, the economic activities performed in these nations are likely to induce a trade-off between higher economic growth and greater environmental distress. Linking this scenario to the EKC theory, our finding suggests that the selected emerging nations are operating at the upward-sloping portion of the EKC and are yet to reach the threshold growth level after which CO2E-inhibiting policies can be adopted and implemented. Our finding concerning the positive economic growth-CO2E nexus corroborates the findings documented by Wan and Zhang (2021) for 182 global economies and Shahbaz et al. (2021) for the emerging economy of India. On the other hand, regarding the finding of higher international trade openness being linked with greater CO2E-induced climate risks in the concerned emerging countries, it can be said that globalization in the form of international trade has also traded-off economic gains with environmental losses. This scenario can be linked with the trade-related '*pollution haven hypothesis*' which postulates that alongside globalization, pollution-intensive industries are likely to expand rapidly in emerging nations where the environmental regulations are less-stringent and the dependency on fossil fuels is comparatively higher (Banerjee and Murshed, 2020; Wu et al., 2022). As a consequence, opening up these economies for more participation in international trade is likely to trigger greater volumes of CO2E. Similarly, the emerging nations considered in this study are either net oil-importing or net oil-exporting nations. Thus, significant proportions of the trade baskets of these nations are likely to embody high volumes of CO2E which, in turn, can justify the finding of the positive international trade openness-CO2E nexus. This finding is similar to those presented in the existing studies by Kongkuah et al. (2022) and Ali et al. (2021) for China and top-10 CO2–emitting countries, respectively.

Lastly, our finding of urbanization being a catalyst for boosting climate risks by stimulating higher emissions of CO2 indicates the concerning issue of unplanned urbanization in the emerging countries of concern. Once again, the monotonic reliance of these nations on fossil fuels means that the urbanization-driven energy demand is associated with higher consumption of unclean fuels. Consequently, as the emerging nations become more urbanized, their CO2E figures are also likely to surge. Similar findings were reported by Sun et al. (2022) in the context of selected resource-rich countries from the Middle East and North Africa.

5. Conclusion and policy recommendations

Emerging nations are likely to experience significant degrees of economic growth with time; however, alongside the rapid expansion of their economies, emerging nations are also expected to face unprecedented degrees of climate risks. This is because, in the quest of growing economically at a faster rate, emerging nations often agree to couple economic gains with environmental losses. Moreover, the fossil fuel reliance of most of the emerging nations across the globe makes this economic growth-environmental distress trade-off unavoidable. Under such circumstances, it is critically important to identify the means through which the climate risks faced by emerging nations can be mitigated. Against this backdrop, this current study attempted to explore the effects of financial inclusion on CO2E, controlling for energy use efficiency improvement, renewable energy use, economic growth, international trade, and urbanization, in the context of 22 emerging economies. For analytical purposes, the estimation strategy was designed to neutralize issues of CSD, HSC, and endogeneity in the panel data employed in this study.

The overall findings from the econometric analysis revealed that making the financial sectors of the concerned emerging nations more inclusive cannot lower their climate risks by abating CO2E in the long run. In contrast, improving the rate of energy use efficiency and transforming traditional fossil fuel-based energy systems by promoting renewable energy use can help to reduce climate risks by inhibiting emissions of CO2. Moreover, energy use efficiency gains were observed to impose moderating effects on the financial inclusion-CO2E nexus. Notably, higher energy use efficiency was found to jointly inhibit CO2E with greater financial inclusivity within the selected emerging nations. More importantly, the results showed that although financial inclusion enhances climate risks, these adversities can be neutralized given that energy use efficiency levels are enhanced alongside financial inclusion. Furthermore, economic growth, international trade, and urbanization were found to be responsible for triggering higher climate risks by boosting CO2E in the long run. Additionally, in the majority of the cases, the country-specific findings corroborated the corresponding panel data outcomes. Finally, the casualty analysis supported the regression outcomes by revealing causal associations among the variables of concern. Precisely, it was found that financial inclusion and CO2E have bidirectional causal associations while unidirectional causal associations were evidenced to be running from the other explanatory variables toward CO2E.

Therefore, considering these important findings, we recommend a set of relevant climate risk mitigation policies. Firstly, to address the environmental adversities associated with financial inclusivity, it is pertinent for emerging nations to make their financial sectors more inclusive and environmentally-sustainable in tandem. In this regard, it is essential for these nations to identify the sources of financial risks that are linked with climate risks and then take proactive measures to green the corresponding financial services accordingly. Besides, the introduction of green financial schemes should also be considered to further neutralize the negative environmental implications of financial inclusion. Secondly, emphasizing the relevance of improving energy use efficiency to both directly and indirectly impede CO2E, emerging nations should consider boosting financial investments in projects related to energy innovation. Precisely, these nations should scale up research and development investments for advancing the technological stock relevant to enhancing the efficiency at which energy is utilized. In addition, from the consumption side, the replacement of energy-intensive electrical appliances with comparatively less energy-intensive alternatives should be encouraged to ensure more efficient utilization of energy resources. Besides, providing the scope for the energy consumers to trade the energy saved through efficiency improvement can also be thought of as a potential energy use efficiency-improving strategy. Furthermore, financial rewards and tax exemptions in return for using energy more efficiently can also nudge behavioral changes among the end-users of energy so that unnecessary use of energy can be substantially reduced.

Thirdly, the energy systems of emerging countries should immediately be transformed from being predominantly fossil fuels-dependent to being more renewable energy-intensive. This also calls for investments in research and development for advancing renewable electricity generation technologies. In this regard, both the government and the private sectors of emerging nations can consider investing in the respective renewable energy sector so that the traditional fossil fuel-based power generation systems can gradually be replaced by modern renewable energy-based variants. Fourthly, the economic systems should be made more environmentally friendly so that higher economic growth is no longer traded off for poor environmental well-being. Fifthly, regarding international trade, the imported fuel-dependent emerging nations, in particular, should gradually reduce their energy import figures and rather focus on utilizing indigenous low-carbon energy resources to meet domestic energy demand; otherwise, these nations should import relatively cleaner fuels instead of the conventional fossil fuels. On the other hand, the fuel-exporting emerging nations should reduce their fuel export volumes and rather diversify their export baskets by including relatively less-pollution-intensive commodities. Reducing exports of fuels can also be expected to reduce the rates at which primary fossil fuels are extracted which, in turn, can be linked to lower emissions of CO2, as well. Additionally, levying trade barriers on both imports and exports of carbon-intensive tradable commodities can also be considered for significantly reducing the negative environmental implications associated with international trade. Lastly, emerging nations should revisit their traditional urbanization strategies and introduce modern environmentally-sustainable urbanization policies. In this regard, meeting the urban energy demand using clean energy resources can be a credible means of limiting the urbanization-led climate risks in the selected emerging countries.

Taking into consideration the unavailability of relevant data, the sample of emerging countries considered in this study had to be shortened; consequently, several other emerging nations could not be incorporated into the analysis as well. Besides, due to the data regarding various financial products and services being unavailable for all the selected emerging nations, the financial inclusivity index was constructed without considering all aspects of financial inclusion. As far as future studies are concerned, this study can be re-estimated using non-parametric methods so that potential heterogeneous outcomes across emerging countries with different levels of CO2E can be identified. In addition, similar studies can be conducted for a panel of non-emerging economies for comparison purposes.

CRediT authorship contribution statement

Muntasir Murshed: Formal analysis, Validation, Methodology, Software, Conceptualization, Investigation, Supervision, Visualization, Writing – original draft, Writing – review & editing. **Rizwan Ahmed:** Conceptualization, Writing – original draft, Writing – review & editing, Data curation. **Khurshid Khudoykulov:** Writing – review & editing, Investigation. **Chamaiporn Kumpamool:**

Writing – original draft, Formal analysis, Methodology, Investigation. **Nusiebeh Nahar Falah Alrwashdeh:** Writing – original draft, Formal analysis, Methodology, Investigation. **Haider Mahmood:** Writing – review & editing.

Data Availability

Data will be made available on request.

References

Abban, O.J., Wu, J., Mensah, I.A., 2020. Analysis on the nexus amid CO_2 emissions, energy intensity, economic growth, and foreign direct investment in Belt and Road economies: does the level of income matter? Environ. Sci. Pollut. Res. 27 (10), 11387–11402.

Abbasi, F., Riaz, K., 2016. CO_2 emissions and financial development in an emerging economy: an augmented VAR approach. Energy Policy 90, 102–114.

Abdallah, W., Goergen, M., O'Sullivan, N., 2015. Endogeneity: how failure to correct for it can cause wrong inferences and some remedies. Br. J. Manag. 26 (4), 791–804.

Ahmad, N., Du, L., 2017. Effects of energy production and CO_2 emissions on economic growth in Iran: ARDL approach. Energy 123, 521–537.

Ahmed, Z., Le, H.P., 2021. Linking Information Communication Technology, trade globalization index, and CO_2 emissions: evidence from advanced panel techniques. Environ. Sci. Pollut. Res. 28 (7), 8770–8781.

Akram, R., Chen, F., Khalid, F., Ye, Z., Majeed, M.T., 2020. Heterogeneous effects of energy efficiency and renewable energy on carbon emissions: evidence from developing countries. J. Clean. Prod. 247, 119122.

Alam, M.S., Alam, M.N., Murshed, M., Mahmood, H., Alam, R., 2022. Pathways to securing environmentally sustainable economic growth through efficient use of energy: a bootstrapped ARDL analysis. Environ. Sci. Pollut. Res. 29 (33), 50025–50039. https://doi.org/10.1007/s11356-022-19410-9.

Ali, S., Dogan, E., Chen, F., Khan, Z., 2021. International trade and environmental performance in top ten-emitters countries: the role of eco-innovation and renewable energy consumption. Sustain. Dev. 29 (2), 378–387.

Alola, A.A., Ozturk, I., 2021. Mirroring risk to investment within the EKC hypothesis in the United States. J. Environ. Manag. 293, 112890.

Amin, N., Song, H., Khan, Z.A., 2022. Dynamic linkages of financial inclusion, modernization, and environmental sustainability in South Asia: a panel data analysis. Environ. Sci. Pollut. Res. 29 (11), 16588–16596.

Anton, S.G., Nucu, A.E.A., 2020. The effect of financial development on renewable energy consumption. A panel data approach. Renew. Energy 147, 330–338.

Aslam, B., Hu, J., Shahab, S., Ahmad, A., Saleem, M., Shah, S.S.A., Hassan, M., 2021. The nexus of industrialization, GDP per capita and CO_2 emission in China. Environ. Technol. Innov. 23, 101674.

Banerjee, S., Murshed, M., 2020. Do Emissions implied in Net Export validate the Pollution Haven Conjecture? Analysis of G7 and BRICS countries. Int. J. Sust. Econ. 12 (3), 297–319. https://doi.org/10.1504/IJSE.2020.10033008.

Baulch, B., Do, T.D., Le, T.H., 2018. Constraints to the uptake of solar home systems in Ho Chi Minh City and some proposals for improvement. Renew. Energy 118, 245–256.

Bayar, Y., Ozkaya, M.H., Herta, L., Gavriletea, M.D., 2021. Financial development, financial inclusion and primary energy use: evidence from the European Union transition economies. Energies 14 (12), 3638.

Boulogiorgou, D., Ktenidis, P., 2020. TILOS local scale Technology Innovation enabling low carbon energy transition. Renew. Energy 146, 397–403.

Brockway, P.E., Sorrell, S., Semieniuk, G., Heun, M.K., Court, V., 2021. Energy efficiency and economy-wide rebound effects: A review of the evidence and its implications. Renew. Sustain. Energy Rev. 141, 110781.

Cetin, M.A., Bakirtas, I., 2020. The long-run environmental impacts of economic growth, financial development, and energy consumption: evidence from emerging markets. Energy Environ. 31 (4), 634–655.

Chaudhry, I.S., Yusop, Z., Habibullah, M.S., 2022. Financial inclusion-environmental degradation nexus in OIC countries: new evidence from environmental Kuznets curve using DCCE approach. Environ. Sci. Pollut. Res. 29 (4), 5360–5377.

Chen, M., Sinha, A., Hu, K., Shah, M.I., 2021b. Impact of technological innovation on energy efficiency in industry 4.0 era: Moderation of shadow economy in sustainable development. Technol. Forecast. Soc. Change 164, 120521.

Chen, Z., Song, P., Wang, B., 2021a. Carbon emissions trading scheme, energy efficiency and rebound effect–Evidence from China's provincial data. Energy Policy 157, 112507.

Chudik, A., Pesaran, M.H., 2015. Common correlated effects estimation of heterogeneous dynamic panel data models with weakly exogenous regressors. J. Econ. 188 (2), 393–420.

Churchill, S.A., Inekwe, J., Ivanovski, K., Smyth, R., 2021. Transport infrastructure and CO_2 emissions in the OECD over the long run. Transp. Res. Part D: Transp. Environ. 95, 102857.

Das, N., Murshed, M., Rej, S., Bandyopadhyay, A., Mahmood, H., Hossain, M.E., Dagar, V., Bera, P., 2022. 2022. Can clean energy adoption and international trade contribute to the achievement of India's 2070 carbon neutrality agenda? Evidence using quantile ARDL measures. Int. J. Sust. Dev. World Ecol. https://doi.org/10.1080/13504509.2022.2139780.

Dietz, T., Rosa, E.A., 1997. Effects of population and affluence on CO_2 emissions. Proc. Natl. Acad. Sci. 94 (1), 175–179.

Dogan, E., Aslan, A., 2017. Exploring the relationship among CO_2 emissions, real GDP, energy consumption and tourism in the EU and candidate countries: Evidence from panel models robust to heterogeneity and cross-sectional dependence. Renew. Sustain. Energy Rev. 77, 239–245.

Doğan, B., Chu, L.K., Ghosh, S., Truong, H.H.D., Balsalobre-Lorente, D., 2022. How environmental taxes and carbon emissions are related in the G7 economies? Renew. Energy 187, 645–656.

Dou, D., Li, L., 2022. Does sustainable financial inclusion and energy efficiency ensure green environment? Evidence from BRICS countries. Econ. Res. -Ȅkon. Istraživanja. https://doi.org/10.1080/1331677X.2022.2032785.

Dumitrescu, E.I., Hurlin, C., 2012. Testing for Granger non-causality in heterogeneous panels. Econ. Model. 29 (4), 1450–1460.

Ehrlich, P.R., Holdren, J.P., 1971. Impact of Population Growth: Complacency concerning this component of man's predicament is unjustified and counterproductive. Science 171 (3977), 1212–1217.

Faisal, F., Tursoy, T., Pervaiz, R., 2020. Does ICT lessen CO_2 emissions for fast-emerging economies? An application of the heterogeneous panel estimations. Environ. Sci. Pollut. Res. 27 (10), 10778–10789.

Fonseca, L.M., Domingues, J.P., Dima, A.M., 2020. Mapping the sustainable development goals relationships. Sustainability 12 (8), 3359.

Global Carbon Atlas. (2021). Global Carbon Atlas 2021 database. Available at http://www.globalcarbonatlas.org/en/content/welcome-carbon-atlas (Accessed on 10.4.2022).

Haldar, A., Sethi, N., 2022. Environmental effects of Information and communication technology-exploring the roles of renewable energy, innovation, trade and financial development. Renew. Sustain. Energy Rev. 153, 111754.

Hamid, I., Alam, M.S., Kanwal, A., Jena, P.K., Murshed, M., Alam, R., 2022. Decarbonization pathways: the roles of foreign direct investments, governance, democracy, economic growth, and renewable energy transition. Environ. Sci. Pollut. Res. 29 (33), 49816–49831. https://doi.org/10.1007/s11356-022-18935-3.

Hao, F., Shao, W., 2021. What really drives the deployment of renewable energy? A global assessment of 118 countries. Energy Res. Soc. Sci. 72, 101880.

He, X., Khan, S., Ozturk, I., Murshed, M., 2022. The role of renewable energy investment in tackling climate change concerns: environmental policies for achieving SDG-13. Sustain. Dev. https://doi.org/10.1002/sd.2491.

IEA (2019), Multiple Benefits of Energy Efficiency, IEA, Paris https://www.iea.org/reports/multiple-benefits-of-energy-efficiency.

IEA. (2021). Net Zero by 2050. IEA, Paris. Available at https://www.iea.org/reports/net-zero-by-2050.

IISD. (2021). National Pledges and Collective Efforts Highlighted at COP 26 Leaders Summit. Available at https://sdg.iisd.org/news/national-pledges-and-collective-efforts-highlighted-at-cop-26-leaders-summit/.

Ji, Q., Zhang, D., 2019. How much does financial development contribute to renewable energy growth and upgrading of energy structure in China? Energy Policy 128, 114–124.

Khan, S.U.D., 2021. Environmental sustainability: a clean energy aspect versus poverty. Environ. Sci. Pollut. Res. 28 (11), 13097–13104.

Khan, S., Murshed, M., Ozturk, I., Khudoykulov, K., 2022. The roles of energy efficiency improvement, renewable electricity production, and financial inclusion in stimulating environmental sustainability in the Next Eleven countries. Renew. Energy 193, 1164–1176. https://doi.org/10.1016/j.renene.2022.05.065.

Kongkuah, M., Yao, H., Yilanci, V., 2022. The relationship between energy consumption, economic growth, and CO_2 emissions in China: the role of urbanisation and international trade. Environ., Dev. Sustain. 24, 4684–4708.

Le, T.H., Le, H.C., Taghizadeh-Hesary, F., 2020. Does financial inclusion impact CO_2 emissions? Evidence from Asia. Financ. Res. Lett. 34, 101451.

Lei, W., Xie, Y., Hafeez, M., Ullah, S., 2022. Assessing the dynamic linkage between energy efficiency, renewable energy consumption, and CO_2 emissions in China. Environ. Sci. Pollut. Res. 29 (13), 19540–19552.

Li, X., Ozturk, I., Ullah, S., Andlib, Z., Hafeez, M., 2022. Can top-pollutant economies shift some burden through insurance sector development for sustainable development? Econ. Anal. Policy 74, 326–336.

Liu, D., Xie, Y., Hafeez, M., Usman, A., 2022a. The trade-off between economic performance and environmental quality: does financial inclusion matter for emerging Asian economies. Environ. Sci. Pollut. Res. https://doi.org/10.1007/s11356-021-17755-1.

Liu, H., Ren, Y., Wang, N., 2021. Energy efficiency rebound effect research of China's coal industry. Energy Rep. 7, 5475–5482.

Liu, N., Hong, C., Sohail, M.T., 2022b. Does financial inclusion and education limit CO_2 emissions in China? A new perspective. Environ. Sci. Pollut. Res. 29 (13), 18452–18459.

Mujtaba, A., Jena, P.K., Joshi, D.P.P., 2021. Growth and determinants of CO_2 emissions: evidence from selected Asian emerging economies. Environ. Sci. Pollut. Res. 28 (29), 39357–39369.

Murshed, M., Nurmakhanova, M., Al-Tal, R., Mahmood, H., Elheddad, M., Ahmed, R., 2022b. Can intra-regional trade, renewable energy use, foreign direct investments, and economic growth mitigate ecological footprints in South Asia? Energy Sources, Part B: Econ. Plan. Pol. 17 (1), 2038730. https://doi.org/10.1080/15567249.2022.2038730.

Murshed, M., Saboori, B., Madaleno, M., Wang, H., Doğan, B. 2022a., 2022a. Exploring the nexuses between nuclear energy, renewable energy, and carbon dioxide emissions: the role of economic complexity in the G7 countries. Renew. Energy 190, 664–674. https://doi.org/10.1016/j.renene.2022.03.121.

Naseem, S., Mohsin, M., Zia-UR-Rehman, M., Baig, S.A., Sarfraz, M., 2022. The influence of energy consumption and economic growth on environmental degradation in BRICS countries: an application of the ARDL model and decoupling index. Environ. Sci. Pollut. Res. 29 (9), 13042–13055.

Neog, Y., Yadava, A.K., 2020. Nexus among CO_2 emissions, remittances, and financial development: a NARDL approach for India. Environ. Sci. Pollut. Res. 27 (35), 44470–44481.

Nibedita, B., Irfan, M., 2021. The role of energy efficiency and energy diversity in reducing carbon emissions: empirical evidence on the long-run trade-off or synergy in emerging economies. Environ. Sci. Pollut. Res. 28 (40), 56938–56954.

Onifade, S.T., Erdoğan, S., Alagöz, M., Bekun, F.V., 2021. Renewables as a pathway to environmental sustainability targets in the era of trade liberalization: empirical evidence from Turkey and the Caspian countries. Environ. Sci. Pollut. Res. 28 (31), 41663–41674.

Paramati, S.R., Sinha, A., Dogan, E., 2017. The significance of renewable energy use for economic output and environmental protection: evidence from the Next 11 developing economies. Environ. Sci. Pollut. Res. 24 (15), 13546–13560.

Pata, U.K., 2021. Renewable and non-renewable energy consumption, economic complexity, CO_2 emissions, and ecological footprint in the USA: testing the EKC hypothesis with a structural break. Environ. Sci. Pollut. Res. 28 (1), 846–861.

Pesaran, M.H., 2004. General diagnostic tests for cross section dependence in panels. Univ. Camb. -IZA Discuss. Pap. (No. 1240).

Pesaran, M.H., 2007. A simple panel unit root test in the presence of cross-section dependence. J. Appl. Econ. 22 (2), 265–312.

Pesaran, M.H., Yamagata, T., 2008. Testing slope homogeneity in large panels. J. Econ. 142 (1), 50–93.

Pesaran, M.H., Shin, Y., Smith, R.J., 2001. Bounds testing approaches to the analysis of level relationships. J. Appl. Econ. 16 (3), 289–326.

Qin, L., Raheem, S., Murshed, M., Miao, X., Khan, Z., Kirikkaleli, D., 2021. Does financial inclusion limit carbon dioxide emissions? Analyzing the role of globalization and renewable electricity output. Sustain. Dev. 29 (6), 1138–1154.

Razzaq, A., Fatima, T, Murshed, M., 2023. Asymmetric effects of tourism development and green innovation on economic growth and carbon emissions in Top 10 GDP Countries. J. Environ. Plan. Manage. 66 (3), 471–500. https://doi.org/10.1080/09640568.2021.1990029.

Renzhi, N., Baek, Y.J., 2020. Can financial inclusion be an effective mitigation measure? evidence from panel data analysis of the environmental Kuznets curve. Financ. Res. Lett. 37, 101725.

Sadorsky, P., 2010. The impact of financial development on energy consumption in emerging economies. Energy Policy 38 (5), 2528–2535.

Saidi, K., Mbarek, M.B., 2017. The impact of income, trade, urbanization, and financial development on CO_2 emissions in 19 emerging economies. Environ. Sci. Pollut. Res. 24 (14), 12748–12757.

Seetharaman, Moorthy, Patwa, N, K., Gupta, Y., 2019. Breaking barriers in deployment of renewable energy. Heliyon 5 (1), e01166. https://doi.org/10.1016/j.heliyon.2019.e01166.

Shahbaz, M., Solarin, S.A., Sbia, R., Bibi, S., 2015. Does energy intensity contribute to CO_2 emissions? A trivariate analysis in selected African countries. Ecol. Indic. 50, 215–224.

Shahbaz, M., Jam, F.A., Bibi, S., Loganathan, N., 2016. Multivariate Granger causality between CO_2 emissions, energy intensity and economic growth in Portugal: evidence from cointegration and causality analysis. Technol. Econ. Dev. Econ. 22 (1), 47–74.

Shahbaz, M., Sharma, R., Sinha, A., Jiao, Z., 2021. Analyzing nonlinear impact of economic growth drivers on CO_2 emissions: Designing an SDG framework for India. Energy Policy 148, 111965.

Sun, Y., Li, H., Andlib, Z., Genie, M.G., 2022. How do renewable energy and urbanization cause carbon emissions? Evidence from advanced panel estimation techniques. Renew. Energy 185, 996–1005.

2022 USEIA. (2022). United States Energy Information Administration database. Available at https://www.eia.gov/international/data/world/total-energy/total-energy-consumption (Accessed on 22.3.2022).

Wang, Q., Zhang, F., 2021. The effects of trade openness on decoupling carbon emissions from economic growth–evidence from 182 countries. J. Clean. Prod. 279, 123838.

Wang, X., Wang, X., Ren, X., Wen, F., 2022. Can digital financial inclusion affect CO_2 emissions of China at the prefecture level? Evidence from a spatial econometric approach. Energy Econ., 105966

Westerlund, J., 2007. Testing for error correction in panel data. Oxf. Bull. Econ. Stat. 69 (6), 709–748. https://doi.org/10.1111/j.1468-0084.2007.00477.x.

World Bank. (2018). Financial inclusion. Available at: https://www.worldbank.org/en/topic/financialinclusion/overview#1 (Accessed on 2.2.2022).

World Bank. (2021). World Development Indicators. The World Bank. Retrieved on June 20, 2021. Available at: https://databank.worldbank.org/source/world-development-indicators.

Wu, R., Ma, T., Chen, D., Zhang, W., 2022. International trade, CO_2 emissions, and re-examination of "pollution haven hypothesis" in China. Environ. Sci. Pollut. Res. 29 (3), 4375–4389.

Yao, X., Yasmeen, R., Hussain, J., Shah, W.U.H., 2021. The repercussions of financial development and corruption on energy efficiency and ecological footprint: evidence from BRICS and next 11 countries. Energy 223, 120063.

Zafar, M.W., Mirza, F.M., Zaidi, S.A.H., Hou, F., 2019. The nexus of renewable and nonrenewable energy consumption, trade openness, and CO_2 emissions in the framework of EKC: evidence from emerging economies. Environ. Sci. Pollut. Res. 26 (15), 15162–15173.

Zaidi, S.A.H., Hussain, M., Zaman, Q.U., 2021. Dynamic linkages between financial inclusion and carbon emissions: evidence from selected OECD countries. Resour., Environ. Sustain. 4, 100022.