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RESEARCH ARTICLE

Analysis of the dynamics of environmental degradation for 18 upper middle-income countries: the role of financial development

Murat Çetin[1] · Alper Aslan[2] · Sevgi Sümerli Sarıgül[3]

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Abstract
This study aims at investigating the dynamics of environmental degradation by focusing on the financial development-CO_2 emissions link. In this purpose, economic growth, renewable energy consumption, trade openness and urbanization are integrated into the CO_2 emissions model as other explanatory variables. In this study, 18 upper-middle-income countries with the highest growth rate in the world are examined for the period 1990–2018 by AMG method, which considers the cross-sectional dependence and slope heterogeneity. In addition, the causal linkages between variables are explored by Dumitrescu-Hurlin panel bootstrap causality technique. As a result of the study, it is found that financial development and renewable energy consumption reduce CO_2 emissions. In addition, it is determined that economic growth, urbanization, and trade openness deteriorate the environmental quality. As a result of causality analysis, while one-way is found from renewable energy consumption to CO_2 emissions, a bidirectional causality is observed between financial development and CO_2 emissions. Empirical findings provide several policy suggestions that decrease CO_2 emissions in these countries.

Keywords Financial development · CO_2 emissions · AMG · Bootstrap causality

JEL Classification K32 · O13 · P18 · Q43

Introduction

Since sustainable development is a priority issue for policy makers both globally and locally, countries have started to take very serious steps in terms of socio-economic sustainability through a healthy environment. However, an important problem arises here. Because the world economy depends on fossil fuels to a very important ratio in meeting the energy demand, unfortunately, fossil fuels are the most important cause of greenhouse gas emissions (Yu et al. 2022). CO_2 emissions are inevitably directly related to the consumption of fossil energy fuels. For this reason, other macroeconomic variables that cause economic progress and economic growth of countries appear as a factor that also increases CO_2 emissions. Environmental pollution and CO_2 emissions (127%) emerge as a cost of high-income levels (516%, as seen Table 1), especially in upper middle-income countries (UMICs). Better environmental quality and sustainable development have become the main focus of these country groups in the current decade. As it can be seen from Table 1, when we examine the GDP and energy data in 5-year periods, we observe that the per capita income grew by 516% in the 1990–2015 period; it is observed that CO_2 emissions have also increased by 127%. It is observed that renewable energy consumption (% of total final energy consumption) decreased by 30%.

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✉ Alper Aslan
alperaslan@erciyes.edu.tr

Murat Çetin
mcetin@nku.edu.tr

Sevgi Sümerli Sarıgül
ssumerli@kayseri.edu.tr

1 Faculty of Economics and Administrative Sciences, Department of Economics, Tekirdağ Namik Kemal University, Tekirdağ, Turkey

2 Faculty of Aeronautics and Astronautics, Department of Aviation Management, Erciyes University, Kayseri, Turkey

3 Technical Sciences Vocational School, Marketing and Foreign Trade Department, Kayseri University, Kayseri, Turkey

Table 1 Upper-middle income countries

Year	GDP per capita (current US$)	CO_2 emissions (kt)	Fossil fuel energy consumption (% of total)	Renewable energy consumption (% of total final energy consumption)
1990	1323.913	6,587,670	83.31673	19.57759
1995	1730.832	6,900,174	82.47417	20.67885
2000	1975.329	7,270,665	82.55349	20.86649
2005	3115.857	10,210,300	85.09062	16.28103
2010	6324.496	13,327,777	86.29326	13.97575
2015	8155.882	14,971,353	88.96048	13.77263

Source: prepared by authors

As can be seen from Table 1, increased macroeconomic activities in UMICs cause serious damage to human health, ecological disaster, and environmental deficits. The extent of these damages is analyzed by Sarkodie (2018), Shahbaz and Sinha (2019), Akadiri et al. (2019), and Usman et al. (2020) studies. Especially, the European Union countries have set themselves the primary goal of achieving sustainable development goals with effective policies. For this reason, it is essential to know the factors behind this environmental problem and to produce a policy by taking into account the effects of these factors.

There is a consensus in the literature that financial development directly or indirectly helps and positively affects economic growth through different macroeconomic channels, especially through export growth. If a country has a well-functioning financial sector, it can have a positive effect on exports in addition to its effect on output growth. Therefore, it is very important to have a well-developed large financial system in order to have higher export shares in world trade competition. (Shahbaz and Rahman 2014; Hur and Riyanto, 2006; Gokmenoglu et al. 2015). In addition to these effects of financial development, its relationship with environmental pollution is an important research topic. From a theoretical point of view, it is stated that an advanced financial structure can reduce financial costs, which can lead companies to benefit from economies of scale by investing in new production areas and heavy machinery display. However, this situation can lead to environmental pollution. On the other hand, the financial sector has a function that can improve environmental quality due to its promotion of investments in environmentally sensitive and clean technologies. Although the relationship between financial development and CO2 emissions has been discussed for a long time in empirical literature, it is seen that there is no consensus on empirical findings (Shahbaz et al. 2016; Ahmad et al. 2018; Zhao and Yang 2020). As a matter of fact, these findings are quite complex and inconsistent due to different periods, different methodologies, and country groups.

In light of the above assessments, the following research questions are raised: (1) What are the underlying factors of environmental degradation in UMIC countries? (2) What kind of policies can be developed in UMIC countries that can reduce environmental pollution? (3) Can measures to be taken in the context of the development of the financial sector be used as a policy tool in reducing environmental pollution? (4) What kind of energy resources can improve environmental pollution in these countries? (5) Can the economic growth of these countries have an impact on increasing environmental pollution? (6) Can other variables (such as urbanization and commercial openness) be used in the determination of environmental pollution reduction policies in accordance with the environmental pollution literature?

With these research questions, this article, which examines the factors affecting environmental degradation in upper middle income country group by using the variables used that there is no consensus about the results, contributes to the literature through 4 different channels. This article focuses on the link between financial development and CO_2 emissions. In general, in the literature, either G7 countries within the scope of developed country groups, EU countries or less developed countries regionally are discussed. The first contribution is to address the upper middle-income countries, which both shape the world economy and are an important source of environmental degradation. The second contribution is related to an important econometric problem in panel studies. The econometrics literature is now moving towards a consensus that it can lead to unreliable results, especially when cross-sectional dependence, which is an important problem in panel data methodology, is not taken into account. Third, since the augmented mean group (AMG) estimator based on the approach suggested by Eberhardt and Bond (2009) and Eberhardt and Teal (2010) is robust to parameter heterogeneity and cross-sectional dependence, AMG approach is employed. Fourth, by including individual results for each country instead of just panel results, we also avoided the problem aggregation bias. Fifth, Dumitrescu-Hurlin panel bootstrap causality approach is used for causal links between variables. Finally, the study presents robust empirical findings that alleviate CO_2 emissions. The main finding is that financial development decreases CO_2 emissions.

In the light of the contributions mentioned above, the following sections of the study are organized as follows: The second section includes the literature review, while the third section includes econometric methods, model and data. The fourth section dwells on empirical results and discussion. Our last section covers the conclusions and policy recommendations.

A critical review of the literature

Financial development and CO_2 emissions

Financial development can positively or negatively affect CO_2 emissions. Shahbaz et al. (2013b) examines the impact of economic growth and energy consumption and financial development on CO_2 emissions for Malaysia in the 1971–2011 period with the ARDL bounds testing approach and shows that economic growth, energy consumption, and foreign direct investments retards environmental quality. The findings also show that financial development decreases CO_2 emissions. This result means that financial development has an important role in tackling environmental pollution in the country, because more financial sector development can be interpreted as facilitating more financing at lower costs and indirectly impacting environmental degradation. For India, Boutabba (2014) investigates the determinants of CO_2 emissions with ARDL model. According to ARDL results, it is found that financial development is positively linked with CO_2 emissions in the long run. In addition, it is found that there is a one-way causal linkage from financial development to CO_2 emissions and energy use in the long run. Focusing on the Chinese economy, Ahmad et al. (2018) examine the causes of CO_2 emissions for the period 1980–2014, taking into account the effects of economic growth and financial development. They conclude that there is a long-term and positive relationship between financial development, economic growth, energy use, and CO_2 emissions. Charfeddine and Kahia (2019) examine the effect of renewable energy consumption and financial development on CO_2 emissions and economic growth using the PVAR technique for MENA countries in the period 1980–2015. The results show that both renewable energy consumption and financial development have a slight effect on CO_2 emissions. Zhao and Yang (2020) examine the effect of financial development on CO_2 emissions in China's provinces by using the between-dimension, group-mean FMOLS and DOLS estimators, PECM Granger causality test, and PVAR model based on the data during 2001–2015. The two-way causal relationship between financial development and CO_2 emissions in the long term is determined. Financial development delays the inhibitory effect on provincial CO_2 emissions. Gok (2020) examines the role of financial development on CO_2 emissions with the meta-regression method based on 72 primary studies and 275 estimations, and it is determined that financial development causes environmental degradation.

Acheampong et al. (2020) investigate the impact of financial market development on CO_2 emissions intensity for 83 countries, covering the period 1980–2015, taking into account the various stages of financial development between countries. In the study, it is found that general financial market development and its sub-measures such as financial market depth and efficiency reduce CO_2 emissions. Moreover, the nonlinear and regulatory effects of financial market development on CO_2 emissions intensity are found to differ between countries at different stages of financial development. Khan and Ozturk (2021) examine the relationship between financial development and air quality for a large sample of 88 developing countries over the period 2000–2014. Estimated results based on five different financial development indicators confirm the pollution prevention role of financial development for selected countries. In addition, the results of indirect channels show that financial development also reduces the negative effects of income, trade openness and foreign direct investment on pollution emissions. They conclude that the direct effects of financial development on CO_2 emissions are negative, indicating the fact that more financial development will lead to better environmental quality.

Renewable energy consumption and CO_2 emissions

One of the main determinants of CO_2 emissions is renewable energy consumption. In a study for the USA as a developed country, Menyah and Wolde-Rufael (2010) find a unidirectional causality running from CO_2 emissions to renewable energy consumption from 1960 to 2007. Shafiei and Salim (2014) examine the determinants of CO_2 emissions for OECD countries covering the period 1980–2011. The results of the study show that non-renewable energy consumption increases CO_2 emissions, while renewable energy consumption reduces CO_2 emissions. In another study for OECD countries, Bilgili et al. (2016) examine the 1977–2010 period for 17 OECD countries and investigate the validity of the environmental Kuznets curve (EKC) hypothesis for CO_2 emissions within the framework of renewable energy consumption and emphasize the necessity of renewable consumption to improve environmental quality. Taking a large group of countries, Dong et al. (2020) analyze based on four different income groups to examine the link between renewable energy consumption and CO_2 emissions. The findings reveal that renewable energy consumption is negatively correlated with CO_2 emissions. But this is not statistically significant. For the BRIICTS countries, Wolde-Rufael and Weldemeskel (2020) indicate that there is a negative link between renewable energy consumption and CO_2 emissions by using the PMG-ARDL models over the period 1993–2014. Adebayo et al. (2022) investigate the link between trade openness, renewable energy use, GDP, and CO_2 emissions in Sweden for the period 1965–2019. With the new quantitative-over-quantile regression (QQ) approach used in the study, the combination of renewable energy consumption and CO_2 emissions in lower and higher quantities (0.1–0.90) shows that the effect of renewable energy consumption on CO_2 emissions is negative and most of the quantities are economic. The effect of growth on CO_2 emissions is also found to be negative. Usman et al. (2022a, b) analyze financially rich countries for the period 1990–2018. As a result of the study, bidirectional causality is determined between financial development, non-renewable energy, renewable energy, and ecological footprint. Inspired by energy consumption and CO_2 studies, many studies have been carried out recently to test the impact of renewable energy consumption on CO_2 emissions. Most of the scientists investigating this interaction between variables with different models have pointed out that there is a negative correlation between the variables.

Trade and CO_2emissions

The different dynamics of the relationship between trade and CO_2 emissions (technological, scale, and compositional effect) are explained in the literature as follows: The increase in trade volume with the technological effect includes not only the transfer of goods but also the transfer of information, reducing environmental damage with technological progress. On the other hand, the scale effect is the negative effect of more production on environmental quality, as more production is produced in the producing country for the purpose of more income, with the increasing trade relationship between countries. Lastly, the composition effect suggests that most underdeveloped countries attract pollution-intensive productions, which then aids in environmental degradation. In other words, while the negative effect of trade on CO_2 may occur with scale and composition effect from three possible effects, it simply means that the technological-technical impact has a direct positive effect on CO_2 emissions (Jahanger et al. 2021; Usman et al. 2022a, 2022b).

Sánchez-Chóliz and Duarte (2004) examine the Spanish economy's exports and imports in terms of direct and indirect CO_2 emissions (CO2 embodied) produced in Spain and abroad. The results show some export behavior in the Spanish economy, which nevertheless hides significant pollution changes. In addition, they find that the shipping materials, mining and energy, non-metallic industries, chemicals, and metals sectors are the most relevant exporters of CO_2 emissions, and other services, construction, shipping materials, and food are the largest importers of CO_2 emissions. Yunfeng and Laike (2010) find that 10.03–26.54% of the CO_2 emissions of China, which is called a world factory, is produced during export production. However, CO_2 emissions from China's imports account for only 4.40–9.05% of that. According to the results of the study, the rate of CO_2 emissions from China's net exports is large and significant. Jayanthakumaran et al. (2012) compare the world's two largest transition countries and growing economies, China and India, using the ARDL methodology to test the long- and short-term relationships between growth, trade, energy use, and CO_2 emissions. It is concluded that international trade will tend to reduce CO_2 emissions (in China in the short term). For Indonesia, Shahbaz et al. (2013a) examine the impact of economic growth, energy consumption, financial development, and trade openness on CO_2 emissions by taking the period 1975Q1–2011Q4. They find that trade openness is inversely related to CO_2 emissions in Indonesia. Hasanov et al. (2018) explore the effects of exports and imports on CO_2 emissions in a panel of nine oil exporting countries. They find that exports and imports play important roles in the formation of consumption-based CO_2 emissions in both the long and short run. The magnitudes of the effects of both trade variables on consumption-based CO_2 emissions are greater in the long run than in the short run. Muhammad et al. (2020) examine the effects of urbanization and foreign trade on CO_2 emissions in 65 BRI countries by using panel quantile regression method, taking the period 2000–2016. As a result of the study, the findings confirm that exports reduce CO_2 emissions in low- and high-income countries, while increasing them in lower middle countries. Imports increase CO_2 emissions in low-income countries and decrease them in middle- and high-income countries. Zeng et al. (2021), using spatial econometric techniques, examine the relationship between energy trade and CO_2 emissions in the period 2000–2014, taking into account a sample of 98 countries. As a result of the study, the magnitude of the contribution of the spatial interaction between developed and developing countries or developed and developing countries through fossil fuel energy trade to global CO_2 emissions has fluctuated over time. Dauda et al. (2021) examines the nonlinear link between innovation, CO_2 emissions, and trade in 9 African countries from 1990 to 2016, at both the panel and individual country level. They find that trade openness increases CO_2 emissions across the panel and reduces CO_2 emissions in some countries at the country level. The study confirms the pollution haven hypothesis (PHH) and the pollution halo effect.

Urbanization andCO_2emissions

The development of the economy and the emergence of environmental problems are a major challenge facing the world. The environmental Kuznets curve (EKC) examines the dynamic relationship between environmental quality and economic development. The EKC hypothesis proposes that environmental quality first declines, then gradually increases with economic growth, showing an inverted U-shape. There is a broad consensus in the literature that social factors should be added to support this hypothesis. At the beginning of these social factors, urbanization comes as a good proxy variable (Yao et al. 2021; Wang et al. 2022).

Both "ecological modernization" and "urban environmental transition" theories argue that urbanization can have positive and negative effects on the natural environment, and the net effect is difficult to predict in advance. If urbanization is found to have a statistically insignificant effect on CO_2 emissions, urbanization will not have a significant effect on CO_2 emissions. It is about the positive and negative effects of urbanization on CO_2 emissions canceling out (Sadorsky 2014).

Zarzoso and Maruotti (2011) examine the urbanization-CO_2 emissions link in developing countries, covering the period 1975–2003, taking into account the dynamics and the presence of heterogeneity in the country sample. As a result of the study, an inverted U-shaped relationship is found between urbanization and CO_2 emissions. Zhu et al. (2012) explores the urbanization-CO_2 emissions linkage within the framework of STIRPAT using a semi-parametric panel data model with fixed effects in a sample of 20 developing countries over the period 1992–2008. They show a nonlinear relationship between urbanization and CO_2 emissions. On the other hand, they confirm an inverted U relationship between urbanization and CO_2 emissions which means that the Kuznets hypothesis is not confirmed. Ali et al. (2019) examine the effect of urbanization on CO_2 emissions in Pakistan for the period 1972–2014 using the ARDL bounds test. As a result of the study, urbanization increases CO_2 emissions and it is concluded that one percent increase in urbanization is associated with a 0.84% increase in CO_2 emissions. Also, there is unidirectional short-term causality from urbanization to CO_2 emissions. Zhang et al. (2021) use panel data from 25 provinces in China for the years 2008–2017 to empirically estimate the effects of urbanization on CO_2 emissions from the construction industry with the STIRPAT model. It is concluded that there is an inverted U-shaped relationship between CO_2 emissions and urban economic growth, and the rate of urbanization is negatively related to CO_2 emissions. Cheng and Hu (2022) focus on the STIRPAT model to analyze the effects of China's urbanization and urban sprawl on CO2 emissions from 1997 to 2018. They conclude that both urbanization and urban sprawl increase CO_2 emissions.

Econometric methods, model, and data

Econometric methods

Cross-sectional dependency (CSD) is estimated. Failure to take CSD into account may result in spurious and bias regression results (Chudik et al. 2011). For this purpose, CD test developed by Pesaran (2004) is applied in the study. Here, null hypothesis of no CSD is tested against the alternative hypothesis that there is dependence between cross-section units. This test can be expressed as follows:

$$CD = \sqrt{\frac{2T}{N(N-1)}}\left(\sum_{i=1}^{N-1}\sum_{j=i+1}^{N}\hat{\rho}_{ij}\right) \tag{1}$$

Next step, the slope-homogeneity/heterogeneity is investigated with the help of Pesaran and Yamagata (2007) test. In this test procedure, the null hypothesis is constructed as slope parameters are homogeneous, while the alternative hypothesis assumes that the slope parameters are heterogeneous. This approach uses the following tests:

$$\tilde{\Delta} = (N)^{\frac{1}{2}}(2k)^{-\frac{1}{2}}\left(\frac{1}{N}\tilde{S} - k\right) \tag{3}$$

$$\tilde{\Delta}_{Adj.} = (N)^{\frac{1}{2}}\left(\frac{2k(t-K-1)}{T+1}\right)^{-\frac{1}{2}}\left(\frac{1}{N}\tilde{S} - 2k\right) \tag{4}$$

CIPS test of Pesaran (2007) is applied for unit root analysis. This test considers the cross-sectionally augmented ADF (CADF) test as a second generation unit root approach developed by Pesaran (2007). The CADF procedure is based on the following equation:

$$\Delta y_{it} = \alpha_i + \beta_i y_{it-1} + \gamma_i \hat{\bar{y}}_{t-1} + \theta_i \Delta\hat{\bar{y}}_t + \varepsilon_{it} \tag{4}$$

The Pesaran (2007) calculates CIPS statistics based on CADF statistics as follows:

$$CIPS = \frac{1}{N}\sum_{i=1}^{N} CADF_i \tag{5}$$

In both tests, the null hypothesis is that $H_0 : \beta_i = 0$ for all i, whereas the alternative hypothesis is that $H_1 : \beta_i < 0$ for some i.

The study analyzes the long-term relationship between variables using the techniques Kao (1999) and Pedroni (2004). These approaches are well-known as residual-based cointegration methods. In these tests, the null hypothesis, in which there is no cointegration, is tested against the alternative hypothesis that accepts the existence of cointegration.

The AMG forecaster is a technique developed for long-term forecasting and cannot provide a finding of causality relationships between variables. Therefore, in order to guide policy proposals, the study includes the causality test developed by Dumitrescu and Hurlin (2012) in the study of causality relationships between variables. The most important feature of this approach is that it is a panel bootstrap causality test that takes into account CSD. This procedure first focuses on a model such as follows:

$$y_{it} = \delta_i + \sum_{i=1}^{K} \gamma_i^k y_{i,t-k} + \sum_{i=1}^{K} \theta_i^k x_{i,t-k} + \varepsilon_{i,t} \tag{6}$$

where δ_i is the cross-sectional units; K is the lag length; t is the time period and θ_i^k is the slope coefficients.

This procedure uses bootstrapped critical values as CSD is taken into account in causality analysis. The null hypothesis of no causality in the panel is tested against the alternative hypothesis of the existence of a causal linkage in at least one cross-section unit. The Zbar ($\overline{Z}$) and the Wbar ($\overline{W}$) statistics developed by Dumitrescu and Hurlin (2012) are used to test the null hypothesis. The authors calculate test statistics as follows:

$$\overline{W} = \frac{1}{N} \sum_{i=1}^{N} W_i \tag{7}$$

$$\overline{Z} = \sqrt{\frac{N}{2K}} \left(\overline{W} - K \right) \tag{8}$$

Model specification and data

One of the most important variables of the literature investigating the main determinants of CO2 emissions is economic growth. It emits theoretical foundations underneath. It is like, "Oh, my God." When the environmental Kuznets curve hypothesis is taken into account, the most important variable affecting environmental pollution is per capita income. In addition, when economic growth is considered as an increase in economic activities and production, it also encourages energy use and can affect the environment. Thus, the "economic growth increases CO2 emissions" hypothesis can be determined as the first hypothesis of the study.

The relationship between energy consumption and environmental pollution is frequently seen in the literature of energy and environmental economics. However, some studies appear to be focusing on renewable energy sources to improve environmental quality rather than non-renewable energy sources such as fossil fuels. Renewable energy sources are the focus of research by policymakers and many international institutions focused on climate change as an alternative to environmentally insensitive fossil fuels. Renewable energy sources such as solar energy, water and wind energy are among the energy sources that are not exhausted due to their structure, are environmentally sensitive with renewable properties, and reduce environmental crisis. In this context, the second hypothesis of the study can be established as "renewable energy consumption negatively affects CO2 emissions."

One of the channels that address the impact of financial development on CO2 emissions is the technology channel. The implementation of new technologies that create energy efficiency here can improve environmental quality. The development of the financial sector can take a role in reducing environmental criterion by financing investments in such technologies. In this case, the third hypothesis of the study can be expressed as "financial development reduces CO2 emissions."

Urbanization, which can be expressed as the increase of the urban population, can affect CO2 emissions by supporting industrial structure and human capital accumulation on the one hand and economic growth and technological progress on the other. On the other hand, increased economic activities and energy use together with urbanization are considered among the causes of environmental pollution. Thus, the hypothesis "urbanization positively affects CO2 emissions" can be developed as another hypothesis.

Another variable that can affect CO2 emissions is trade openness. Environmental pollution can be caused by the production of products and their consumption by other countries. Therefore, the increase of foreign trade can determine the level of environmental pollution. When the increase in the level of trade openness is considered as the development of foreign trade, the final hypothesis of the study can be constructed as "trade openness supports CO2 emissions."

It is possible to model the relationship between financial development and CO2 emissions in line with the theoretical evaluations and hypotheses. In this modeling, economic growth, renewable energy consumption, financial development, urbanization, and trade openness can be taken as control variables. Thus, a linear regression equation can be created to describe the relationship between the related variables, such as the following:

$$lnCO_2 = f(lnGDP, REN, lnFIN, URB, TR) \tag{9}$$

We can write the above equation as follows:

$$\begin{aligned} lnCO_{2it} = \alpha + \beta_1 lnGDP_{it} + \beta_2 REN_{it} + \beta_3 lnFIN_{it} \\ + \beta_4 URB_{it} + \beta_5 TR_{it} + \varepsilon_{it} \end{aligned} \tag{10}$$

Here, CO_2 indicates CO_2 emissions, which is measured as kilotons of oil equivalent. GDP shows economic growth measured in real GDP per capita. REN refers to renewable energy consumption, which is measured as a percentage of total final energy consumption. FIN indicates financial development as measured by the financial development index. URB is urbanization measured as urban population growth. Finally, we are going to have to TR symbolizes the trade openness measured as the share of total trade in GDP.

α, t, i, and ε refer to the constant term, the time, the countries and the error terms, respectively. β_1, β_2, β_3, β_4, and β_5 are parameters that predict the impact of economic growth, renewable energy consumption, financial development, urbanization and trade openness on CO_2 emissions. The CO_2, GDP, REN, URB, and TR series are available from the World Bank-World Development Indicators (2021) database and the FIN series is available from the IMF (2021) data site.

In the study, only the logarithm of CO_2, GDP, and FIN variables is taken. Table 2 defines the variables used in the study and describes the expected effect of explanatory variables on CO_2 emissions. Table 3 presents a list of countries included in the analysis. The main reason for focusing on these countries is that they are all included in the upper-middle income country classification and are developing countries. The reason for the 1990–2018 period in the study is the availability of data. In addition, with the help of Fig. 1, it is possible to see the course that each series follows in the period 1990–2018.

Only the logarithm of CO_2, GDP, and FIN variables is taken in the study. Table 2 describes the expected effect of arguments on CO_2 emissions in defining the variables used in the study. Table 3 presents a list of countries included in the analysis. The main reason for focusing on these countries is that they are all included in the upper-middle income country class and have developing country process.

Results and discussion

Table 4 provides information about the descriptive statistics of variables for the period 1990–2018 used in the study. The average values of lnCO2, lnGDP, REN, lnFIN, URB, and TR are 10,369, 25,094, 30,166, – 1,334, 2,714, and 77,784, respectively. On the other hand, the standard error values vary between 0.596 and 39.995. The lowest average variable is lnFIN among all variables while REN has the highest value. The variable with the lowest standard deviation is URB, while the lowest skewness value belongs to lnFIN.

The variable with the lowest standard deviation is URB, while the lowest skewness value belongs to lnFIN. REN stands out with its highest maximum value, while lnGDP emerges with the highest minimum value. When we take into account all the descriptive statistics of $lnCO_2$, it shows the highest value with its maximum value and the lowest value with the value of kurtosis.

The correlation matrix, which we can evaluate about the correlation between variables, is presented in Table 5. The correlation matrix shows a positive correlation between lnGDP and $lnCO_2$, while a similar result occurs between lnFIN and lnCO2. While REN is negatively correlated with $lnCO_2$, negative correlation between URB and $lnCO_2$ is also noted. It can be stated that the negative correlation between URB and lnCO2 does not match theoretical expectations. Finally, TR is positively correlated with $lnCO_2$.

Whether there is CSD between the countries on the panel is investigated with the test of Pesaran (2004) CD test. The results mentioned in Table 6 reveal a rejection of the null hypothesis that there is cross-sectional independence at 1% level of significance. This proves that there is CSD for each variable. Thus, it means that a shock in one of the 18 countries can spread to other countries. In the study, Pesaran (2007) unit root test is used, which is the ability to cope with CSD in order to determine the unit root characteristics of

Table 3 Country list

Brazil	Gabon	Panama
Botswana	Guatemala	Peru
Colombia	Jamaica	Paraguay
Costa Rica	Jordan	Thailand
Dominican Republic	Mexico	Turkey
Ecuador	Malaysia	South Africa

Table 2 Variables and their expected signs

Variables	Definition	Source	Expected sing
$lnCO_2$	Carbon dioxide emissions (kilotons of oil equivalent) (ktoe) (Bekun et al. 2019)	World Bank	-
lnGDP	Real gross domestic product (constant 2010 US $) (Sharma et al. 2021)	World Bank	(+) (Ahmad et al. 2021)
REN	Renewable energy consumption (% of total final energy consumption) (Salman et al. 2022)	World Bank	(–) (Zafar et al. 2020)
lnFIN	Financial development index (Aluko and Opoku, 2022)	IMF	(+) (–) (Shahbaz et al. 2013a, b, c, d) (Qin et al. 2021)
URB	Urban population growth (annual %) (Islam et al. 2022)	World Bank	(+) (Xue et al. 2022)
TR	Trade (% of GDP) (Yilanci and Ozgur 2019)	World Bank	(+) (–) (Sinha and Shahbaz 2018)

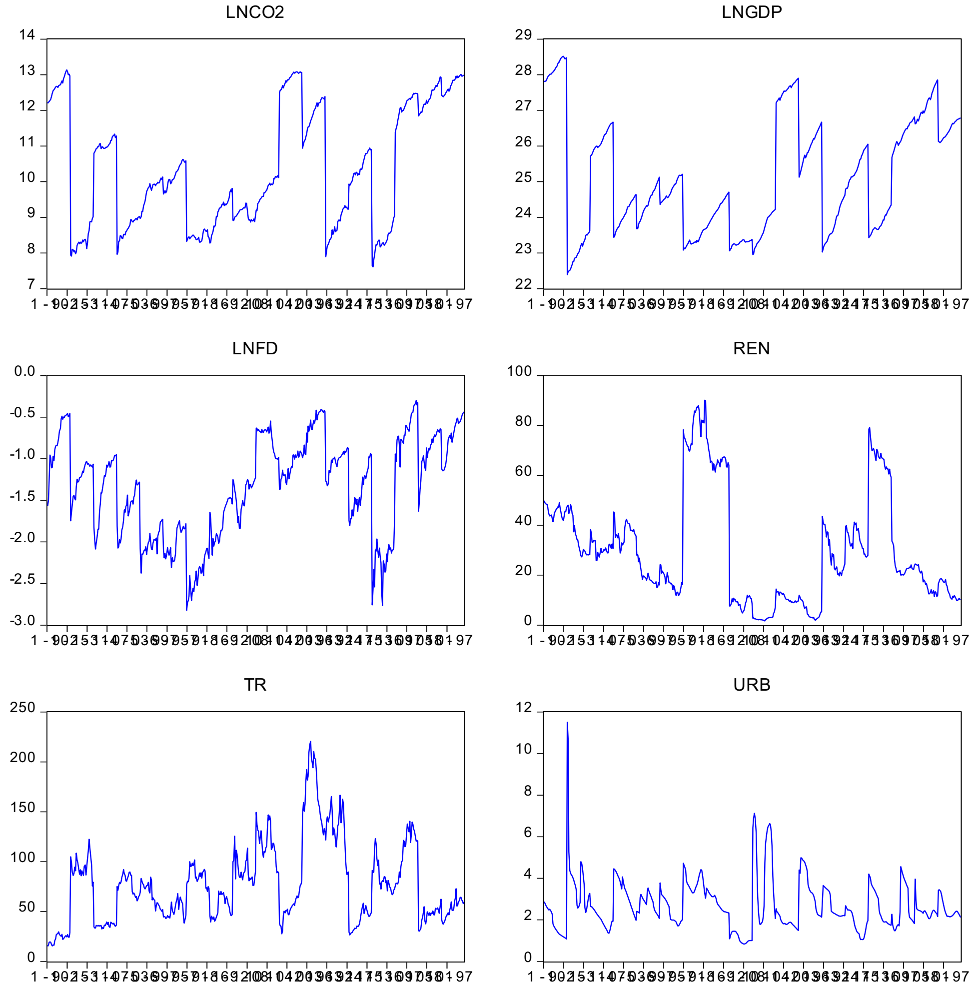

Fig. 1 The trends of the series (1990–2018)

Table 4 Summary statistics

	$lnCO_2$	lnGDP	REN	lnFIN	URB	TR
Mean	10.369	25.094	30.166	− 1.334	2.714	77.784
Median	9.979	24.640	24.173	− 1.239	2.416	71.460
Std. dev	1.670	1.594	22.045	0.596	1.229	39.995
Min	7.610	22.394	1.689	− 2.821	0.842	15.161
Max	13.135	28.516	90.115	− 0.302	11.498	220.406
Skewness	0.254	0.414	0.873	− 0.342	2.003	0.991
Kurtosis	1.606	1.971	2.849	2.130	11.649	3.854
Obs	522	522	522	522	522	522

Table 5 Correlation matrix

	$lnCO_2$	lnGDP	REN	lnFIN	URB	TR
$lnCO_2$	1.000					
lnGDP	0.947	1.000				
REN	-0.485	-0.288	1.000			
lnFIN	0.656	0.552	-0.606	1.000		
URB	-0.321	-0.386	0.133	-0.131	1.000	
TR	-0.239	-0.383	-0.230	0.246	0.402	1.000

Table 6 CSD and CIPS tests results

Variables	CD-test	*P*-value	Corr	Abs (corr.)	CIPS	
					Level	First difference
$lnCO_2$	49.48***	0.000	0.743	0.782	1.167	−5.985***
lnGDP	64.07***	0.000	0.962	0.962	−0.003	−5.179***
REN	21.48***	0.000	0.322	0.500	2.810	−5.515***
lnFIN	38.27***	0.000	0.574	0.719	−1.128	−8.877***
URB	30.50***	0.000	0.458	0.559	−0.122	−2.236**
TR	7.77***	0.000	0.117	0.394	0.163	−6.356***

*** and ** indicate significance at %1 and %5 level, respectively

Table 7 Slope homogeneity test results

Test statistics	*t*-statistics	*P*-value
$\tilde{\Delta}$	18.130***	0.000
$\tilde{\Delta}_{adjusted}$	20.816***	0.000

*** denotes significance at %1 level

Table 8 Cointegration tests

	Statistic	*P*-value
Panel A. Pedroni tests		
Modified Phillips-Perron *t*	3.462***	0.000
Phillips-Perron *t*	−0.978	0.164
Augmented Dickey-Fuller *t*	−1.507*	0.065
Panel B. Kao test		
Modified Dickey-Fuller *t*	−1.195	0.116
Dickey-Fuller *t*	−1.220	0.111
Augmented Dickey-Fuller *t*	−1.588*	0.056
Unadjusted modified Dickey-Fuller *t*	−1.484*	0.068
Unadjusted Dickey-Fuller *t*	−1.383*	0.083

*** and * indicate significance at %1 and %10 level, respectively. The option demean is used to alleviate the effect of cross-sectional dependent structure

variables. Table 6 also reports CIPS test results. The results reveal that each series is not stable at the level, but becomes stationary when the first differences are taken. Thus, the degree of integration of the series is 1.

After unit root analysis of the variables, the determination of slope-homogeneity is made. Table 7 presents the results of Pesaran and Yamagata (2007) slope-homogeneity test. The findings support the hetoregenity of the slope parameters, as the null hypothesis that the slope parameters are homogeneous is rejected at 1% level of significance. The study uses residual-based cointegration tests of Pedroni (2004) and Kao (1999), as in the Hussain et al. (2021) and Vo et al. (2021) studies to test the existence of a long-term equilibrium relationship between variables. The null hypothesis that there is no cointegration according to the findings of the tests presented in Table 7 is rejected at different levels of significance, thus revealing that there is a cointegration between economic growth, renewable energy consumption, financial development, urbanization, trade openness, and CO_2 emissions. This proves the existence of a long-term relationship between variables. This empirical finding allows us to analyze in detail the impact of economic growth, renewable energy consumption, financial development, urbanization, and trade openness on CO_2 emissions (Table 8).

Cointegration tests detect the existence of a long-term relationship between variables but do not provide any evidence for estimating the coefficients of variables. In this context, as in the works Yang et al. (2021) and Sun et al. (2020), the AMG estimator suggested by Eberhardt and Teal (2010) is used. The findings presented in Table 9 show coefficient estimates in detail, taking into account four different empirical models. First of all, the fact that Wald χ^2 values, which are diagnostic tests, are statistically significant at 1% level indicates that the relevant models are suitable. According to these results; all the models show that economic growth positively affects CO_2 emissions, while renewable energy consumption and financial development negatively affect CO_2 emissions. The results also explain that urbanization and trade openness are positively related to financial development.

Since the model 4 represents the largest empirical model discussed in the study, the estimation results for this model can be evaluated in detail. Accordingly, the coefficient of renewable energy consumption (−0.021) is negative and statistically significant at 1% level. This result indicates that a 1% increase in renewable energy consumption will result in a 0.021% decrease in CO_2 emissions. Therefore, in the long-term, renewable energy consumption can be seen as a factor that reduces CO_2 emissions. Increased demand for traditional energy sources, especially fossil fuels, is pushing policymakers to alternative energy sources (Doğan and Seker, 2016). Energy policies today tend to reduce dependence on fossil fuels and therefore reduce CO_2 emissions (Dogan and Ozturk 2017). In this context, renewable energy sources stand out because they are clean and environmentally

Table 9 AMG estimation results

Regressors	Model (1) Coefficient	z-value	Model (2) Coefficient	z-value	Model (3) Coefficient	z-value	Model (4)	
lnGDP	0.714*** (0.075)	9.40	0.719*** (0.067)	10.61	0.739*** (0.072)	10.24	0.697*** (0.043)	16.20
lnFIN	−0.092** (0.046)	−2.00	−0.093** (0.037)	−2.49			−0.095** (0.039)	−2.43
REN	−0.018*** (0.003)	−4.99	−0.022*** (0.004)	−5.20	−0.019*** (0.004)	−4.17	−0.021*** (0.004)	−5.18
URB			0.049** (0.022)	2.18	0.060** (0.025)	2.39	0.050** (0.025)	2.02
TR					0.0007* (0.0004)	1.86	0.0009** (0.0004)	2.30
Constant	−7.247*** (2.031)	−3.57	−7.048*** (1.633)	−4.31	−7.218*** (1.643)	−4.39	−6.807*** (1.071)	−6.35
Wald χ^2	117.36		150.65		131.52		304.41	
Prob	0.000		0.000		0.000		0.000	
RMSE	0.053		0.046		0.049		0.044	
Number of countries	18		18		18		18	

***, **, and * indicate rejection of null hypothesis at 1%, 5%, and 10% significance level, respectively. The values in parantheses indicate standard deviation

sensitive and are preferred as a key explanatory variable in reducing CO_2 emissions in many empirical studies (Destek and Aslan 2020; Danish et al. 2017; Bulut 2017). In addition, structural changes in developing countries, especially the transition from agricultural sector to industrial sector and from there to services sector, require effective use and diversity of energy resources. Therefore, they attach more importance to clean energy sources that have a positive effect on environmental quality (Munasinghe 1999).

This negative finding between renewable energy consumption and CO_2 emissions is in line with the finding of Dong et al. (2018), which analyzes the relationship between economic growth, CO_2 emissions, and environmental Kuznets curve (EKC) in the Chinese economy. The Bayer-Hanck test results show a cointegration between the variables, while the ARDL findings suggest that renewable energy consumption negatively affects CO_2 emissions. Our findings are consistent with Bekhet and Othman's (2018) findings for Malaysia and Sinha and Shahbaz (2018) for India, while they differ from Pata's (2018) findings for Turkey. The first two studies find a negative relationship between the two variables, while the last study finds no statistically significant relationship between the variables. Some panel data studies such as Al-Mulali and Ozturk (2016) for 27 developed countries, Paramati et al. (2018) for G20 countries, Hanif (2018) for SSA countries, Bekun et al. (2019) for 16-EU country conclude that renewable energy consumption is negatively correlated with CO_2 emissions. Danish et al. (2019), another panel data study, does not achieve a statistically significant relationship for BRICS countries. Ben Jebli et al. (2015) for 22 SSA countries and Adams and Nsiah (2019) for 28 countries provide evidence that renewable energy consumption increases CO_2 emissions.

The financial development coefficient (−0.095), just like the renewable energy consumption coefficient, has a negative and statistically significant value at 5% level. This result means that a 1% increase in financial development will reduce CO_2 emissions by 0.021% and can be interpreted as negatively affecting CO_2 emissions in the long-term. Relations between financial development and foreign direct investment (FDI) can be effective in improving environmental quality (Doytch and Narayan 2016). An advanced financial sector creates a gravitational pull for FDI by reducing the loan costs of grizzlies (Pazienza 2019). Increased FDI inflows increase energy efficiency and accelerate investment in environmentally friendly technologies. This development acts as a improver of environmental quality by reducing CO_2 emissions (Essandoh et al. 2020). On the other hand, development in the financial sector supports the implementation of new technologies in developing countries and accelerates its development by providing necessary financial services to environmentally conscious industries. Thus, CO_2 emissions decrease, making an improvement in environmental quality feel itself (Ma and Stern 2008).

This negative finding between financial development and CO_2 emissions is similar to that of E and Bekwa (2022), which tests the relationship between energy consumption, financial development, and environmental pollution for 18 African countries by applying the PMG approach. The study concludes that long-term financial development reduces CO_2

Table 10 Robustness check

Dependent variable: FD	DOLS Coefficients	*P*-value	FMOLS Coefficients	*P*-value
lnGDP	0.788***	0.000	0.796***	0.000
lnFIN	– 0.208***	0.008	– 0.148***	0.000
REN	– 0.023***	0.000	– 0.028***	0.000
URB	– 0.017	0.499	0.041***	0.002
TR	0.0018**	0.030	0.0004	0.163

*** and ** indicate significance at %1 and %5 level, respectively. Optimal lag length is selected using SIC

emissions. Some panel data studies (Tamazian et al. 2009; Al-Mulali et al. 2015; Salahuddin et al. 2015) draw attention to the negative relationship between the two variables. Similar findings are found in some of the time-series studies (Shahbaz et al. 2013a, b, c, d; Shahbaz et al. 2015; Atsu et al. 2021). However, these findings do not match the finding of Ebokyi et al. (2018), which investigates the impact of industrial growth, energy consumption and financial development on CO_2 emissions for Ghana. ARDL model prediction results reveal a statistically insignificant finding between the two variables. Shahbaz et al. (2018) focus on the relationship between financial development, FDI, energy innovation, and CO_2 emissions and prove that financial development for the French economy increases CO_2 emissions in the context of the ARDL model.

Table 11 Summary of the long-term results

Variables	AMG	DOLS	FMOLS
lnGDP	(+) ✓	(+) ✓	(+) ✓
lnFIN	(–) ✓	(–) ✓	(–) ✓
REN	(–) ✓	(–) ✓	(–) ✓
URB	(+) ✓	(–)	(+) ✓
TR	(+) ✓	(+) ✓	(+)

Note: ✓ indicates statistical significance. (–)/(+) indicate the sign (negative or positive) of the impact of explanatory variables on the financial sector development

The coefficient of economic growth (0.697) is positive and statistically significant at 1% level. This means that a 1% increase in economic growth will enhance CO_2 emissions by 0.697%. Therefore, economic growth has an effect on increasing CO_2 emissions. This finding will be better understood when considering the mechanisms by which economic growth can have an impact on environmental quality. As Aye and Edoja (2017) point out, it concludes that economic growth due to production activities increases CO_2 emissions and impairs environmental quality by causing overuse of natural resources, decreased natural habitats, climate change, and excessive energy consumption. In this context, most countries have started to adapt their environmentally conscious growth models to their economies (Smulders et al. 2014). As a matter of fact, Withagen and Smulders (2012) explore the dynamic relationships between environmental issues and economic growth models and develop the Ramsey model by adding natural resource inputs and environmental pollution variables. Thus, an environmentally conscious augmented growth model has been proposed.

This positive finding between economic growth and CO_2 emissions coincides with the finding of Espoir et al. (2022), which examines the relationship between economic growth and CO_2 emissions in African countries. A group of literature reaches the same conclusion (Kais and Sami 2016; Apergis et al. 2018; Yusuf et al. 2020). Uddin et al. (2017) prove a negative relationship between economic growth and ecological footprint using DOLS and FMOLS. Magazzino (2016) tests the relationship between CO_2 emissions, economic growth, and energy consumption with the panel VAR technique for GCC countries. The estimation results reveal the negative relationship between the two variables. The findings of these two studies are not in the line with our findings. Our finding is not in line with the finding of Acheampong (2018), which analyzes the relationship between economic growth, CO_2 emissions, and energy consumption using panel VAR and system GMM approaches. The study finds that economic growth on a global scale negatively affects CO_2 emissions.

Table 9 reveals that the coefficient of urbanization (0.050) is positive and statistically significant at 5% level. According to this result, a 1% increase in urbanization will increase CO_2 emissions by 0.050%. This indicates a positive relationship between urbanization and CO_2 emissions. As Ahmad et al. (2019) demonstrates, rapid urbanization accelerates demand for infrastructure and buildings, and thus CO_2 emissions can increase. In another view, the increase in the urban population and the growth of the industrial scale stimulate the economies of accumulation and scale, causing more energy use, thus increasing CO_2 emissions (Zhang et al. 2018).

Our finding that "urbanization increases CO_2 emissions" is in the line with the findings of Sheng and Guo (2016) and Yao et al. (2021). The first study demonstrates that rapid urbanization increases CO_2 emissions by applying MG, PMG, and DFE forecasting techniques within the framework of the STIRPAT model. The second study focuses on the relationship between different types of urbanization and CO_2 emissions by performing a spatial and threshold analysis on Chinese cities. Empirical findings suggest that all three types of urbanization positively affect CO_2 emissions. These findings do not match the findings of Zhang et al. (2021), which analyzes the impact of urbanization on CO_2 emissions in the Chinese economy with a regional approach. Indeed,

Table 12 Results of AMG heterogeneous country-specific analysis

Countries	lnGDP	lnFIN	REN	URB	TR	Constant
Brazil	1.287*** (0.113)	−0.089** (0.044)	−0.019*** (0.002)	0.073 (0.051)	0.003 (0.002)	−23.042*** (3.389)
Bostwana	1.262*** (0.161)	−1.439*** (0.446)	−0.002 (0.011)	−0.031* (0.017)	−0.002 (0.002)	−22.079*** (3.977)
Colombia	0.821*** (0.066)	−0.327*** (0.064)	−0.006** (0.003)	0.013 (0.052)	−0.005 (0.005)	−10.604*** (1.767)
Costa Rica	1.485*** (0.131)	−0.438*** (0.095)	−0.003 (0.002)	0.217*** (0.059)	0.001 (0.001)	−28.555*** (3.385)
Dominican Rebuplic	0.502*** (0.092)	0.041 (0.156)	−0.043*** (0.008)	0.060 (0.038)	0.005** (0.002)	−2.161 (2.544)
Ecuador	0.943*** (0.099)	0.005 (0.088)	−0.027*** (0.005)	0.084* (0.045)	0.0004 (0.001)	−13.011*** (2.708)
Gabon	0.605*** (0.094)	0.021 (0.084)	−0.009*** (0.001)	0.119*** (0.017)	0.0002 (0.001)	−5.384** (2.485)
Guatemala	1.588*** (0.169)	−0.091 (0.093)	−0.018*** (0.004)	0.262** (0.111)	0.003*** (0.000)	−29.263*** (4.678)
Jamaica	0.709*** (0.222)	−0.308*** (0.111)	−0.066*** (0.009)	0.216 (0.131)	−0.0005 (0.001)	−7.521 (4.954)
Jordan	0.659*** (0.022)	−0.286*** (0.095)	−0.022*** (0.008)	−0.015*** (0.004)	0.001** (0.000)	−6.111*** (0.499)
Mexico	0.234 (0.192)	0.048 (0.119)	−0.064*** (0.012)	−0.004 (0.072)	0.001 (0.001)	7.087 (5.453)
Malaysia	0.642*** (0.070)	0.054 (0.143)	−0.033*** (0.006)	−0.068*** (0.024)	0.0002 (0.000)	−4.477** (1.939)
Panama	0.628*** (0.044)	0.004 (0.165)	−0.023*** (0.003)	0.099*** (0.037)	0.001** (0.000)	−6.021*** (1.192)
Peru	0.754*** (0.126)	−0.152 (0.160)	−0.016*** (0.003)	−0.043 (0.042)	−0.0009 (0.002)	−8.343** (3.494)
Paraguay	0.750*** (0.123)	0.056 (0.068)	−0.044*** (0.006)	0.123*** (0.033)	0.0003 (0.001)	−6.837** (3.282)
Thailand	0.791*** (0.062)	−0.108 (0.072)	−0.016*** (0.002)	−0.012 (0.008)	0.001** (0.000)	−8.590*** (1.655)
Turkey	0.681*** (0.057)	−0.050 (0.109)	−0.015*** (0.005)	−0.012 (0.037)	0.0008 (0.001)	−5.987 (1.621)
South Africa	0.657*** (0.197)	−0.136 (0.183)	−0.018** (0.007)	−0.037 (0.045)	0.001 (0.001)	−4.559 (5.323)

***, **, and * indicate rejection of null hypothesis at 1%, 5%, and 10% significance level, respectively. The values in parantheses indicate standard deviation

this study indicates the existence of a negative relationship between urbanization and CO_2 emissions. Dimnwobi et al. (2021), which analyzes the impact of population dynamics on environmental quality in Africa, cannot find a statistically significant relationship between urbanization and CO_2 emissions by applying the CS-ARDL model.

Finally, the coefficient of trade openness (0.0009) is positive and statistically significant at 5% level. This result implies that a 1% increase in trade openness will enhance a 0.0009% increase in CO_2 emissions. Therefore, it can be noted that trade openness has a positive effect on CO_2 emissions. Ahmed et al. (2017) specify that trade accelerates the production of goods and services as well as energy consumption. So, CO_2 emissions can increase and environmental quality can deteriorate. This is actually known in the literature as the effect of scale (Antweiler et al. 2001).

Our finding that there is a positive correlation between trade openness and CO_2 emissions is in line with the findings of Dou et al. (2021), which focuses on the relationship between trade openness and CO_2 emissions for China-Japan-ROK FTA countries. The authors note that trade openness promotes CO_2 emissions. Zhang et al. (2017) for 10 NIC countries and Balsalobre-Lorente et al. (2018) for 5 EU countries obtain similar findings. On the contrary, Koc and Bulus (2020) for the Korean economy, Managi et al. (2009) for OECD countries and Gozgor (2017) for 5 OECD countries provide evidence of a negative relationship between the variables.

DOLS and FMOLS forecasting techniques are also utilized to provide healthier long-term estimation in the study. In this context, the AMG forecast results presented in Table 9 are comparable to the DOLS and FMOLS results in Table 10. DOLS estimation results, just like the AMG forecast results, provide evidence that renewable energy consumption and financial development reduce CO_2 emissions, while economic growth and trade openness increase. FMOLS forecast results, just like the AMG forecast results, show that renewable energy consumption and financial development negatively affect CO_2 emissions, while economic growth and urbanization have a positive effect. Table 11 is an overview of the results from AMG, DOLS, and FMOLS forecasting techniques. In summary, renewable energy consumption and financial development serve as a function that reduces environmental pollution and therefore improves environmental quality, while economic growth, urbanization, and trade openness perform a function that impairs environmental quality because it supports environmental pollution.

Tables 9 and 10 reveal the effect of each explanatory variable on CO_2 emissions but do not provide any information on the results of country-specific analysis. In this context, the estimation results in Table 12 can be analyzed. The findings suggest a negative relationship between renewable energy consumption and CO_2 emissions in all countries except Costa Rica and Bostwana.

While the financial development in Brazil, Bostwana, Colombia, Costa Rica, Jamaica, and Jordan negatively affects CO_2 emissions, there is no statistically significant relationship in other countries. The findings reveal a positive relationship between economic growth and CO_2 emissions in all countries except the Mexican economy. On the other hand, urbanization in Bostwana, Jordan, and Malaysia reduces CO_2 emissions, while urbanization in Costa Rica, Ecuador, Gabon, Guatemala, Panama, and Paraguay has a positive effect on CO_2 emissions. In other countries, there is no statistically significant relationship. Finally, we are going to have to trade openness positively affects CO_2 emissions in the Dominican Republic, Guatemala, Jordan, Panama, and Thailand, while no statistically significant relationship can be detected in other economies.

After estimating the long-term coefficients of the variables with AMG, DOLS, and FMOLS forecasters, the causality relationships between the variables used in the study are investigated. In this context, Dumitrescu and Hurlin (2012) bootstrap causality test is used for causality analysis. The causality findings reported in Table 13 point to a one-way causality that operates from economic growth to CO_2 emissions due to the rejection of the null hypothesis at 5% level of significance. Kim et al. (2010) for Korea and Shahbaz et al. (2013a, b, c, d) for Indonesia detect two-way causality, while Saboori et al. (2012) show a one-way causality for Malaysia that runs from economic growth to CO_2 emissions. For causality findings, financial development is not the cause of CO_2 emissions and CO_2 emissions are not the cause of financial development, and null hypotheses are rejected, pointing to a two-way causality between financial development and CO_2 emissions. This finding is in line with the finding of Zafar et al. (2019), which finds a two-way causality for G-7 countries. Abbasi and Riaz (2016) point to a causality for Pakistan from financial development to CO_2 emissions, while Ibrahim and Vo (2021) do not see any causality for the 27 industrialized countries. In this study, there is a one-way causality that works from renewable energy consumption to CO_2 emissions, since the null hypothesis is rejected at 1% significance level. Apergis et al. (2010) for 19 countries and Paramatia et al. (2017) for G-20 countries make a similar finding, while Danish et al. (2017) for Pakistan and Danish et al. (2019) BRICS economies point to the existence of a two-way causality. In addition, there is a one-way causality from CO_2 emissions to urbanization due to the rejection of the null hypothesis at 1% significance level. This finding does not coincide with the finding of Dou

Table 13 Dumitrescu-Hurlin bootstrap causality test results

Null hypothesis	Zbar-stat	Boot-strapped *p*-value	Zbar tilde-stat	Bootstrapped *p*-value	Causality
lnGDP does not cause $lnCO_2$	9.070**	0.026	7.109**	0.026	$lnGDP \rightarrow lnCO_2$
$lnCO_2$ does not cause lnGDP	3.836	0.310	1.660	0.310	
lnFIN does not cause $lnCO_2$	6.091*	0.058	3.093*	0.058	$lnFIN \leftrightarrow lnCO_2$
$lnCO_2$ does not cause lnFIN	7.469**	0.030	3.966**	0.030	
REN does not cause $lnCO_2$	4.886*	0.070	3.312*	0.002	$REN \rightarrow lnCO_2$
$lnCO_2$ does not cause REN	2.922	0.444	1.080	0.444	
URB does not cause $lnCO_2$	2.460	0.626	1.892	0.626	$lnCO^2 \rightarrow URB$
$lnCO_2$ does not cause URB	22.141***	0.000	13.277***	0.000	
TR does not cause $lnCO_2$	1.190	0.566	0.800	0.608	No
$lnCO_2$ does not cause TR	1.617	0.778	0.252	0.870	

***, **, and * indicate rejection of null hypothesis at 1%, 5%, and 10% significance level, respectively. Bootstrapped *p*-values are computed by using 500 bootstrap replications et al. (2021), which points to a two-way causality for China-Japan-ROK FTA countries. Finally, there exists no causality between trade openness and CO_2 emissions. This conclusion is not in line with Javid and Sharif (2016)'s finding of a two-way causality for Pakistan and Ertugrul et al. (2016)'s result of one-way causality that operates from trade openness to CO_2 emissions for all countries participating in the analysis. Cetin et al. (2018) also indicate a one-way causality for the Turkish economy from trade openness to CO_2 emissions.

Conclusion and policy implications

In recent years, issues such as environmental pollution, economic sustainability, and global warming have become important focuses of interest by both researchers and policymakers. Undoubtedly, the basis of this interest is the global increase in CO2 emissions, which is responsible for approximately 80% of greenhouse gas emissions. The fact that CO2 emissions have also increased significantly in the context of UMIC countries requires researching the underlying factors of this development and developing policies to reduce environmental pollution. In the context of the hypotheses developed in these countries, the question of financial development, renewable energy sources, economic growth, urbanization, and commercial openness can be exploited in reducing environmental pollution? In this context this study investigates the effect of financial development on CO2 emissions by integrating economic growth, renewable energy consumption, urbanization, and trade openness into the CO2 emissions model as control variables. For this purpose, panel time series for 18 upper-middle income countries are used in the period 1990–2018.

The study tests the hypotheses that "financial development and renewable energy consumption reduce CO2 emissions" and "economic growth, urbanization and trade openness increase CO2 emissions." In this purpose, we have applied the AMG, DOLS and FMOLS estimators, and Dumitrescu-Hurlin bootstrap causality test. Empirical findings reveal that financial development and renewable energy consumption decrease CO2 emissions while economic growth, urbanization, and trade openness increase CO2 emissions in the long run. We detect a one-way causality that operates from economic growth and renewable energy consumption to CO2 emissions, and a two-way causality between financial development and CO2 emissions.

Depending on the results of the analysis, the study may also develop some policy recommendations that can reduce CO2 emissions. Firstly, the finding that renewable energy consumption reduces CO2 emissions can be interpreted as these economies should benefit more from renewable energy sources in reducing environmental pollution. Because, in these developing economies, energy demand is mainly met from non-renewable energy sources that are not environmentally friendly. In addition, since obtaining economic benefits from renewable energy resources and investments in these resources require very high costs, it is obligatory for governments to offer important incentives, especially reasonable incentives, tax exemptions, and reductions, for entrepreneurs in the renewable energy sector. Otherwise, it does not seem possible for the sector entrepreneurs to get the desired results from these investments.

Second, the finding that financial development can improve environmental quality by reducing CO2 emissions suggests that applications for financial sector development in these countries should be accelerated and the need for financial sector loans should be met. The shift of financial sector loans to environmentally sensitive projects/investments that can produce technological and innovative products will be able to serve to weaken environmental degradation by enabling the technology channel of the financial sector to function. Another empirical finding, the finding that economic growth supports CO2 emissions highlights the fact that the countries subject to the research face the danger of environmental pollution due to economic growth. Although investment, employment, and growth are priority targets in such developing economies, it seems possible to achieve these goals with a growth/development strategy based on environmentally conscious and clean energy sources. The finding that trade openness increases CO2 emissions requires these economies to reorganize their commercial structures in weakening this effect. More specifically, governments should implement tax incentives to support the trade of low-carbon products and to prevent the trade of high-carbon products. In addition, the trade in environmentally sensitive high-tech products should also be considered. In addition to these measures, the need to control the population of the city arises as it is an important factor that increases CO2 emissions. In addition, measures should be introduced to reduce the emissions of vehicles in urban areas. Residents should be informed and aware of environmental pollution.

The consideration of future research groups of countries with different income and development levels can be effective in better understanding the impact of financial development and renewable energy consumption on environmental pollution. In addition, such studies are likely to serve to develop different policies by presenting comparative empirical findings.

Author contribution AA: writing–original draft, conceptualization. SSS and MÇ: writing–original draft. MÇ and SSS: data curation. AA and MÇ: supervision, project administration.

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References

Abbasi F, Raiz K (2016) CO_2 emissions and financial development in an emerging economy: an augmented VAR approach. Energy Policy 90:102–114. https://doi.org/10.1016/j.enpol.2015.12.017

Acheampong AO (2018) Economic growth, CO_2 emissions and energy consumption: what causes what and where? Energy Econ 74:677–692. https://doi.org/10.1016/j.eneco.2018.07.022

Acheampong AO, Amponsah M, Boateng E (2020) Does financial development mitigate carbon emissions? Evidence from heterogeneous financial economies. Energy Econ 88:104768. https://doi.org/10.1016/j.eneco.2020.104768

Adams S, Nsiah C (2019) Reducing carbon dioxide emissions; does renewable energy matter? Sci Total Environ 693:133288. https://doi.org/10.1016/j.scitotenv.2019.07.094

Adebayo S, Rjoub H, Akinsola GD (2022) The asymmetric effects of renewable energy consumption and trade openness on carbon emissions in Sweden: new evidence from quantile-on-quantile regression approach. Environ Sci Pollut Res 29:1875–1886. https://doi.org/10.1007/s11356-021-15706-4

Ahmad M, Khan Z, Ur Rahman Z, Khan S (2018) Does financial development asymmetrically affect CO_2 emissions in China? An application of the nonlinear autoregressive distributed lag (NARDL) model. Carbon Manag 9(6):631–644. https://doi.org/10.1080/17583004.2018.1529998

Ahmad M, Zhao Z-Y, Li H (2019) Revealing stylized empirical interactions among construction sector, urbanization, energy consumption, economic growth and CO_2 emissions in China. Sci Total Environ 657:1085–1098. https://doi.org/10.1016/j.scitotenv.2018.12.112

Ahmad M, Jiang P, Murshed M, Shehzad K, Akram R, Cui L, Khan Z (2021) Modelling the dynamic linkages between eco-innovation, urbanization, economic growth and ecological footprints for G7 countries: does financial globalization matter? Sustain Cities Soc 70:102881. https://doi.org/10.1016/j.scs.2021.102881

Ahmed K, Rehman MU, Ozturk I (2017) What drives carbon dioxide emissions in the long-run? Evidence from selected south Asian countries. Renew Sustain Energy Rev 70:1142–1153. https://doi.org/10.1016/j.rser.2016.12.018

Akadiri AC, Saint AS, Gungor H (2019) The role of natural gas consumption in Saudi Arabia's output and its implication for trade and environmental quality. Energy Policy 129:230–238. https://doi.org/10.1016/j.enpol.2019.02.001

Alcalá F, Ciccone A (2004) Trade and productivity. The Q J Econ 119(2):613–646. https://www.jstor.org/stable/25098695

Ali R, Khuda B, Yasin MA (2019) Impact of urbanization on CO_2 emissions in emerging economy: evidence from Pakistan. Sustain Cities Soc 48:101553. https://doi.org/10.1016/j.scs.2019.101553

Al-Mulali U, Ozturk I (2016) The investigation of environmental Kuznets curve hypothesis in the advanced economies: the role of energy prices. Renew Sust Energ Rev 54:1622–1631

Al-mulali U, Tang CF, Ozturk I (2015) Estimating the environment Kuznets curve hypothesis: evidence from Latin America and the Caribbean countries. Renew Sustain Energy Rev 50:918–924. https://doi.org/10.1016/j.rser.2015.05.017

Antweiler W, Copeland BR, Taylor MS (2001) Is free trade good for the environment? Am Econ Rev 91:877–908. https://doi.org/10.3386/w6707

Apergis N, Ben Jebli M, Ben Youssef S (2018) Does renewable energy consumption and health expenditures decrease carbon dioxide emissions? Evidence for sub-Saharan Africa countries. Renew Energy 127:1011–1016. https://doi.org/10.1016/j.renene.2018.05.043

Apergis N, Payne JE, Menyah K, Wolde-Rufael Y (2010) On the causal dynamics between emissions, nuclear energy, renewable energy, and economic growth. Ecol Econ 69:2255e2260. https://doi.org/10.1016/j.ecolecon.2010.06.014

Atsu F, Adams S, Adjei J (2021) ICT, energy consumption, financial development, and environmental degradation in South Africa. Heliyon 7(7):e07328. https://doi.org/10.1016/j.heliyon.2021.e07328

Aye GC, Edoja PE (2017) Effect of economic growth on CO_2 emission in developing countries: evidence from a dynamic panel threshold model. Cogent Econ Financ 5(1):1379239. https://doi.org/10.1080/23322039.2017.1379239

Balsalobre-Lorente D, Shahbaz M, Roubaud D, Farhani S (2018) How economic growth, renewable electricity and natural resources contribute to CO_2 emissions? Energy Policy 113:356–367. https://doi.org/10.1016/j.enpol.2017.10.050

Bekhet HA, Othman NS (2018) The role of renewable energy to validate dynamic interaction between CO2 emissions and GDP toward sustainable development in Malaysia. Energy Economics 72:47–61. https://doi.org/10.1016/j.eneco.2018.03.028

Bekun FV, Alola AA, Sarkodie SA (2019) Toward a sustainable environment: Nexus between CO2 emissions, resource rent, renewable and nonrenewable energy in 16-EU countries. Sci Total Environ 657:1023–1029. https://doi.org/10.1016/j.scitotenv.2018.12.104

Ben Jebli M, Ben Youssef S, Ozturk I (2015) The role of renewable energy consumption and trade: environmental Kuznets curve analysis for sub-Saharan Africa countries. Afr Dev Rev 27:288–300. https://doi.org/10.1111/1467-8268.12147

Bilgili F, Koçak E, Bulut Ü (2016) The dynamic impact of renewable energy consumption on CO_2 emissions: a revisited environmental Kuznets curve approach. Renew Sustain Energy Rev 54:838–845. https://doi.org/10.1016/j.rser.2015.10.080

Boutabba MA (2014) The impact of financial development, income, energy and trade on carbon emissions: evidence from the Indian economy. Econ Model 40:33–41. https://doi.org/10.1016/j.econmod.2014.03.005

Bulut U (2017) The impacts of non-renewable and renewable energy on CO2 emissions in Turkey. Environ Sci Pollut Res 24:15416–15426. https://doi.org/10.1007/s11356-017-9175-2

Cetin M, Ecevit E, Yucel AG (2018) The impact of economic growth, energy consumption, trade openness, and financial development on carbon emissions: empirical evidence from Turkey. Environ Sci Pollut Res 25:36589–36603. https://doi.org/10.1007/s11356-018-3526-5

Charfeddine L, Kahia M (2019) Impact of renewable energy consumption and financial development on CO2 emissions and economic growth in the MENA region: a panel vector autoregressive (PVAR) analysis. Renew Energy 139:198–213. https://doi.org/10.1016/j.renene.2019.01.010

Cheng Z, Hu X (2022) The effects of urbanization and urban sprawl on CO_2 emissions in China. Environ Dev Sustain. https://doi.org/10.1007/s10668-022-02123-x

Chudik M, Pesaran H, Tosetti E (2011) Weak and strong cross-section dependence and estimation of large panels. Econ J 14(1):C45-C90. https://www.jstor.org/stable/23127216

Danish, Zhang B, Wang B, Wang Z (2017) Role of renewable energy and non-renewable energy consumption on EKC: evidence from Pakistan. J Clean Prod 156:855–864. https://doi.org/10.1016/j.jclepro.2017.03.203

Danish, Baloch MA, Mahmood N, Zhang JW (2019) Effect of natural resources, renewable energy and economic development on CO_2 emissions in BRICS countries. Sci Total Environ 678:632–638. https://doi.org/10.1016/j.scitotenv.2019.05.028

Dauda L, Long X, Nyarko CMM, Salman M, Boamah KB, Ampon-Wireko S, Dogbe CSK (2021) Innovation, trade openness and CO_2 emissions in selected countries in Africa. J Clean Prod 281:125143. https://doi.org/10.1016/j.jclepro.2020.125143

Destek MA, Aslan A (2020) Disaggregated renewable energy consumption and environmental pollution nexus in G-7 countries. Renew Energy 151:1298–1306. https://doi.org/10.1016/j.renene.2019.11.138

Dimnwobi SK, Ekesiobi C, Madichie CV, Asongu SA (2021) Population dynamics and environmental quality in Africa. Sci Total Environ 797:149172. https://doi.org/10.1016/j.scitotenv.2021.149172

Dogan E, Ozturk I (2017) The influence of renewable and non-renewable energy consumption and real income on CO_2 emissions in the USA: Evidence from structural break tests. Environ Sci Pollut Res 24:10846–10854. https://doi.org/10.1007/s11356-017-8786-y

Dogan E, Seker F (2016) Determinants of CO_2 emissions in the European Union: the role of renewable and non-renewable energy. Renew Energy 94:429–439. https://doi.org/10.1016/j.renene.2016.03.078

Dong K, Sun R, Jiang H, Zeng X (2018) CO_2 emissions, economic growth, and the environmental Kuznets curve in China: what roles can nuclear energy and renewable energy play? J Clean Prod 196:51–63. https://doi.org/10.1016/j.jclepro.2018.05.271

Dong K, Dong X, Jiang Q (2020) How renewable energy consumption lower global CO2 emissions? Evidence from countries with different income levels. World Econ 43:1665–1698. https://doi.org/10.1111/twec.12898

Dou Y, Zhao Y, Malik MN, Dong K (2021) Assessing the impact of trade openness on CO_2 emissions: evidence from China-Japan-ROK FTA countries. J Environ Manage 296:113241. https://doi.org/10.1016/j.jenvman.2021.113241

Doytch N, Narayan S (2016) Does FDI influence renewable energy consumption? An analysis of sectoral FDI impact on renewable and non-renewable industrial energy consumption. Energy Econ 54:291–301. https://doi.org/10.1016/j.eneco.2015.12.010

Dumitrescu EI, Hurlin C (2012) Testing for Granger non-causality in heterogeneous panels. Econ Model 29(4):1450–1460. https://doi.org/10.1016/j.econmod.2012.02.014

Eberhardt M, Bond S (2009) Cross-sectional dependence in nonstationary panel models: a novel estimator. MPRA Paper 17692, University Library of Munich

Eberhardt M, Teal F (2010) Productivity analysis in global manufacturing production. Discussion Paper 515, Department of Economics

Ertugrul HM, Cetin M, Seker F, Dogan E (2016) The impact of trade openness on global carbon dioxide emissions: evidence from the top ten emitters among developing countries. Ecol Ind 67:543–555. https://doi.org/10.1016/j.ecolind.2016.03.027

Essandoh OK, Islam M, Kakinaka M (2020) Linking international trade and foreign direct investment to CO_2 emissions: any differences between developed and developing countries? Sci Total Environ 712:136437. https://doi.org/10.1016/j.scitotenv.2019.136437

Gok A (2020) The role of financial development on carbon emissions: a meta regression analysis. Environ Sci Pollut Res 27:11618–11636. https://doi.org/10.1007/s11356-020-07641-7

Gokmenoglu KK, Amin MY, Taspinar N (2015) The relationship among international trade, financial development and economic growth: the case of Pakistan. Proc Econ Financ 25:489–496. https://doi.org/10.1016/S2212-5671(15)00761-3

Gozgor G (2017) Does trade matter for carbon emissions in OECD countries? Evidence from a new trade openness measure. Environ Sci Pollut Res 24:27813–27821. https://doi.org/10.1007/s11356-017-0361-z

Hanif I (2018) Impact of economic growth, nonrenewable and renewable energy consumption, and urbanization on carbon emissions in sub-Saharan Africa. Environ Sci Pollut Res 25(15):15057–15067. https://doi.org/10.1007/s11356-018-1753-4

Hasanov FJ, Liddle B, Mikayilov JI (2018) The impact of international trade on CO_2 emissions in oil exporting countries: territory vs consumption emissions accounting. Energy Econ 74:343–350. https://doi.org/10.1016/j.eneco.2018.06.004

Hussain M, Ye Z, Bashir A, Chaudhry NI, Zhao Y (2021) A nexus of natural resource rents, institutional quality, human capital, and financial development in resource-rich high-income economies. Resour Policy 74:102259. https://doi.org/10.1016/j.resourpol.2021.102259

Ibrahim M, Vo WV (2021) Exploring the relationships among innovation, financial sector development and environmental pollution in selected industrialized countries. J Environ Manage 284:112057. https://doi.org/10.1016/j.jenvman.2021.112057

Islam M, Irfan M, Shahbaz M, Vo XV (2022) Renewable and non-renewable energy consumption in Bangladesh: the relative influencing profiles of economic factors, urbanization, physical infrastructure and institutional quality. Renew Energy 184:1130–1149. https://doi.org/10.1016/j.renene.2021.12.020

Jahanger A, Usman M, Ahmad P (2021) A step towards sustainable path: the effect of globalization on China's carbon productivity from panel threshold approach. Environ Sci Pollut Res 29:8353–8368. https://doi.org/10.1007/s11356-021-16317-9

Javid M, Sharif F (2016) Environmental Kuznets curve and financial development in Pakistan. Renew Sustain Energy Rev 54:406–414. https://doi.org/10.1016/j.rser.2015.10.019

Jayanthakumaran K, Verma R, Liu Y (2012) CO_2 emissions, energy consumption, trade and income: a comparative analysis of China and India. Energy Policy 42:450–460. https://doi.org/10.1016/j.enpol.2011.12.010

Kais S, Sami H (2016) An econometric study of the impact of economic growth and energy use on carbon emissions: panel data evidence from fifty eight countries. Renew Sustain Energy Review 59:1101–1110. https://doi.org/10.1016/j.rser.2016.01.054

Kao C (1999) Spurious regression and residual-based tests for cointegration in panel data. J Econ 90(1):1–44. https://doi.org/10.1016/S0304-4076(98)00023-2

Khan M, Ozturk I (2021) Examining the direct and indirect effects of financial development on CO_2 emissions for 88 developing countries. J Environ Manage 293:112812. https://doi.org/10.1016/j.jenvman.2021.112812

Kim SW, Lee K, Nam K (2010) The relationship between CO_2 emissions and economic growth: the case of Korea with nonlinear evidence. Energy Policy 38:5938–5946. https://doi.org/10.1016/j.enpol.2010.05.047

Koc S, Bulus GC (2020) Testing validity of the EKC hypothesis in South Korea: role of renewable energy and trade openness. Environ Sci Pollut Res 27:29043–29054. https://doi.org/10.1007/s11356-020-09172-7

Ma C, Stern DI (2008) China's changing energy intensity trend: a decomposition analysis. Energy Economics 30(3):1037–1053. https://doi.org/10.1016/j.eneco.2007.05.005

Magazzino C (2016) The relationship between CO2 emissions, energy consumption and economic growth in Italy. Int J Sustain Energy 35(9):844–857

Managi S, Hibiki A, Tsurumi T (2009) Does trade openness improve environmental quality? J Environ Econ Manag 58:346–363. https://doi.org/10.1016/j.jeem.2009.04.008

Zhu HM, You W-H, Zeng Z-F (2012) Urbanization and CO_2 emissions: a semi-parametric panel data analysis. Econ Lett 117(3):848–850. https://doi.org/10.1016/j.econlet.2012.09.001

Muhammad S, Long X, Salman M, Dauda L (2020) Effect of urbanization and international trade on CO2 emissions across 65 belt and road initiative countries. Energy 196:117102. https://doi.org/10.1016/j.energy.2020.117102

Menyah K, Wolde-Rufael Y (2010) Energy consumption, pollutant emissions and economic growth in South Africa. Energy Econ 32(6):1374–1382

Paramati SR, Alam MS, Lau CKM (2018) The effect of tourism investment on tourism development and CO2 emissions: empirical evidence from the EU nations. J Sustain Tour 26(9):1587–1607

Munasinghe M (1999) Is environmental degradation an inevitable consequence of economic growth: tunneling through the environmental Kuznets curve. Ecol Econ 29:89–109. https://doi.org/10.1016/S0921-8009(98)00062-7

Paramatia SR, Mo D, Gupta R (2017) The effects of stock market growth and renewable energy use on CO_2 emissions: evidence from G20 countries. Energy Econ 66:360–371. https://doi.org/10.1016/j.eneco.2017.06.025

Pata UK (2018) Renewable energy consumption, urbanization, financial development, income and CO_2 emissions in Turkey: testing EKC hypothesis with structural breaks. J Clean Prod 187:770–779. https://doi.org/10.1016/j.jclepro.2018.03.236

Pazienza P (2019) The impact of FDI in the OECD manufacturing sector on CO2 emission: evidence and policy issues. Environ Impact Assess Rev 77:60–68. https://doi.org/10.1016/j.eiar.2019.04.002

Pesaran MH (2004) General diagnostic tests for cross section dependence in panels, Cambridge: Cambridge working papers in economics no. 0435, Faculty of Economics, University of Cambridge

Pesaran MH (2007) A simple panel unit root test in the presence of cross-section dependence. J Appl Econom 22(2):265–312. https://doi.org/10.1002/jae.951

Pesaran MH, Yamagata T (2007) Testing slope homogeneity in large panels. J Econ 142(1):50–93. https://doi.org/10.1016/j.jeconom.2007.05.010

Pedroni (2004) Panel cointegration: asymptotic and finite sample properties of pooled time series tests with an applicaton to the PPP hypothesis. Economet Theor 20:597–625. https://doi.org/10.1017/S0266466604203073

Qin L, Hou Y, Miao X, Zhang X, Rahim S, Kirikkaleli D (2021) Revisiting financial development and renewable energy electricity role in attaining China's carbon neutrality target. J Environ Manage 297:113335. https://doi.org/10.1016/j.jenvman.2021.113335

Saboori B, Sulaiman J, Mohd S (2012) Economic growth and CO_2 emissions in Malaysia: a cointegration analysis of the environmental Kuznets curve. Energy Policy 51:184–191. https://doi.org/10.1016/j.enpol.2012.08.065

Sadorsky P (2014) The effect of urbanization on CO_2 emissions in emerging economies. Energy Econ 41:147–153. https://doi.org/10.1016/j.eneco.2013.11.007

Salahuddin M, Gow J, Ozturk I (2015) Is the long-run relationship between economic growth, electricity consumption, carbon dioxide emissions and financial development in Gulf Cooperation Council Countries robust? Renew Sustain Energy Rev 51:317–326. https://doi.org/10.1016/j.rser.2015.06.005

Salman M, Zha D, Wang G (2022) Interplay between urbanization and ecological footprints: differential roles of indigenous and foreign innovations in ASEAN-4. Environ Sci Policy 127:161–180. https://doi.org/10.1016/j.envsci.2021.10.016

Sánchez-Chóliz J, Duarte R (2004) CO_2 emissions embodied in international trade: evidence for Spain. Energy Policy 32(18):1999–2005. https://doi.org/10.1016/S0301-4215(03)00199-X

Sarkodie SA (2018) The invisible hand and EKC hypothesis: what are the drivers of environmental degradation and pollution in Africa? Environ Sci Pollut Res 25(22):21993–22022. https://doi.org/10.1007/s11356-018-2347-x

Shafiei S, Salim RH (2014) Non-renewable and renewable energy consumption and CO_2 emissions in OECD countries: a comparative analysis. Energy Policy 66:547–556. https://doi.org/10.1016/j.enpol.2013.10.064

Shahbaz M, Sinha A (2019) Environmental Kuznets curve for CO_2 emissions: a literature survey. Journal of Economic Studies 46(1):106–168. https://doi.org/10.1108/JES-09-2017-0249

Shahbaz M, Hye QMA, Tiwari AK, Leitão NC (2013a) Economic growth, energy consumption, financial development, international trade and CO2 emissions in Indonesia. Renew Sustain Energy Rev 25:109–121. https://doi.org/10.1016/j.rser.2013.04.009

Shahbaz M, Solarin SA, Mahmood H, Arouri M (2013b) Does financial development reduce CO2 emissions in Malaysian economy? A time series analysis. Econ Model 35:145–152. https://doi.org/10.1016/j.econmod.2013.06.037

Shahbaz M, Tiwari AK, Nasir M (2013c) The effects of financial development, economic growth, coal consumption and trade openness on CO_2 emissions in South Africa. Energy Policy 61:1452–1459. https://doi.org/10.1016/j.enpol.2013.07.006

Shahbaz M, Hye QMA, Tiwari AK, Leitao NC (2013d) Economic growth, energy consumption, financial development, international trade and CO_2 emissions in Indonesia. Renew Sustain Energy Rev 25:109–121. https://doi.org/10.1016/j.rser.2013.04.009

Shahbaz M, Nasir MA, Roubaud D (2018) Environmental degradation in France: the effects of FDI, financial development, and energy innovations. Energ Econ 74:843–857

Shahbaz M, Mallick H, Mahalik MK, Loganathan N (2015) Does globalization impede environmental quality in India? Ecol Ind 52:379–393. https://doi.org/10.1016/j.ecolind.2014.12.025

Shahbaz M, Shahzad SJH, Ahmad N, Alam S (2016) Financial development and environmental quality: the way forward. Energy Policy 98:353–364. https://doi.org/10.1016/j.enpol.2016.09.002

Sharma R, Shahbaz M, Kautish P, Vo XV (2021) Does energy consumption reinforce environmental pollution? Evidence from emerging Asian economies. J Environ Manage 297:113272. https://doi.org/10.1016/j.jenvman.2021.113272

Sheng P, Guo X (2016) The long-run and short-run impacts of urbanization on carbon dioxide emissions. Econ Model 53:208–215. https://doi.org/10.1016/j.econmod.2015.12.006

Sinha A, Shahbaz M (2018) Estimation of environmental Kuznets curve for CO_2 emission: role of renewable energy generation in India. Renew Energy 119:703–711. https://doi.org/10.1016/j.renene.2017.12.058

Smulders S, Toman M, Withagen C (2014) Growth theory and 'green growth'. Oxford Rev Econ Policy 30(3):423–446. http://oxrep.oxfordjournals.org

Sun Y, Ak A, Serener B, Xiong D (2020) Natural resource abundance and financial development: a case study of emerging seven (E-7) economies. Resour Policy 67:101660. https://doi.org/10.1016/j.resourpol.2020.101660

Tamazian A, Chousa JP, Vadlamannati KC (2009) Does higher economic and financial development lead to environmental degradation: evidence from BRIC countries. Energy Policy 37(1):246–253. https://doi.org/10.1016/j.enpol.2008.08.025
Uddin GA, Salahuddin M, Alam K, Gow J (2017) Ecological footprint and real income: panel data evidence from the 27 highest emitting countries. Ecol Ind 77:166–175. https://doi.org/10.1016/j.ecolind.2017.01.003
Usman M, Kousar R, Yaseen MR (2020) An empirical nexus between economic growth, energy utilization, trade policy, and ecological footprint: a continent-wise comparison in upper-middle-income countries. Environ Sci Pollut Res 27:38995–39018. https://doi.org/10.1007/s11356-020-09772-3
Usman M, Balsalobre-Lorente D, Jahanger A, Ahmad P (2022b) Pollution concern during globalization mode in financially resource-rich countries: do financial development, natural resources, and renewable energy consumption matter? Renew Energy 183:90–102. https://doi.org/10.1016/j.renene.2021.10.067
Usman M, Kousar R, Makhdum MSA (2022a) Do financial development, economic growth, energy consumption, and trade openness contribute to increase carbon emission in Pakistan? An insight based on ARDL bound testing approach. Environ Dev Sustain https://doi.org/10.1007/s10668-021-02062-z
Vo DH, Nguyen NT, Vo AT, Ho CM, Nguyen TC (2021) Does the Kuznets curve apply for financial development and environmental degradation in the Asia-Pacific region? Heliyon 7(4):e06708. https://doi.org/10.1016/j.heliyon.2021.e06708
Wang Q, Wang X, Li R (2022) Does urbanization redefine the environmental Kuznets curve? An empirical analysis of 134 Countries. Sustain Cities Soc 76:103382. https://doi.org/10.1016/j.scs.2021.103382
Withagen C, Smulders S (2012) Green growth: lessons from growth theory. The World Bank Policy Research Working Paper No. 6230. https://www.greengrowthknowledge.org
World Bank (2021) World development indicators. Washington, D.C
Wolde-Rufael Y, Weldemeskel EM (2020) Environmental policy stringency, renewable energy consumption and CO_2 emissions: panel cointegration analysis for BRIICTS countries. Int J Green Energy 17(10):568 582. https://doi.org/10.1080/15435075.2020.1779073
Xue C, Shahbaz M, Ahmed Z, Ahmad M (2022) Clean energy consumption, economic growth, and environmental sustainability: what is the role of economic policy uncertainty? Renew Energy 184:899–907. https://doi.org/10.1016/j.renene.2021.12.006
Yang QC, Chen X, Chang CP, Chen D, Hao Y (2021) What is the relationship between government response and COVID-19 pandemics? Global evidence of 118 countries. Struct Chang Econ Dyn 59:98–107. https://doi.org/10.1016/j.strueco.2021.08.007
Yao F, Zhu H, Wang M (2021) The impact of multiple dimensions of urbanization on CO_2 emissions: a spatial and threshold analysis of panel data on China's prefecture-level cities. Sustain Cities Soc 73:103113. https://doi.org/10.1016/j.scs.2021.103113
Yilanci V, Ozgur O (2019) The asymmetric effects of foreign direct investment on clean energy consumption in BRICS countries: a recently introduced hidden cointegration test. J Clean Prod 237:117786. https://doi.org/10.1016/j.jclepro.2019.117786
Yu J, Tang YM, Chau KY, Nazar R, Ali S, Iqbal W (2022) Role of solar-based renewable energy in mitigating CO_2 emissions: evidence from quantile-on-quantile estimation. Renew Energy 182:216–226. https://doi.org/10.1016/j.renene.2021.10.002
Yunfeng Y, Laike Y (2010) China's foreign trade and climate change: a case study of CO_2 emissions. Energy Policy 38(1):350–356. https://doi.org/10.1016/j.enpol.2009.09.025
Yusuf AM, Abubakar AB, Mamman SO (2020) Relationship between greenhouse gas emission, energy consumption, and economic growth: evidence from some selected oil-producing African countries. Environ Sci Pollut Res 27:15815–15823. https://doi.org/10.1007/s11356-020-08065-z
Zafar MW, Zaidi SAH, Sinha A, Gedikli A, Hou F (2019) The role of stock market and banking sector development, and renewable energy consumption in carbon emissions: insights from G-7 and N-11 countries. Resour Policy 62:427–436. https://doi.org/10.1016/j.resourpol.2019.05.003
Zafar MW, Shahbaz M, Sinha A, Sengupta T, Qin Q (2020) How renewable energy consumption contribute to environmental quality? The role of education in OECD countries. J Clean Prod 268:122149. https://doi.org/10.1016/j.jclepro.2020.122149
Zarzoso IM, Maruotti A (2011) The impact of urbanization on CO_2 emissions: evidence from developing countries. Ecol Econ 70(7):1344–1353. https://doi.org/10.1016/j.ecolecon.2011.02.009
Zeng C, Lindsay C, Stringer TL (2021) The spatial spillover effect of fossil fuel energy trade on CO_2 emissions. Energy 223:120038. https://doi.org/10.1016/j.energy.2021.120038
Zhang S, Liu X, Bae J (2017) Does trade openness affect CO_2 emissions: evidence from ten newly industrialized countries? Environ Sci Pollut Res 24:17616–17625. https://doi.org/10.1007/s11356-017-9392-8
Zhang GL, Zhang N, Liao WM (2018) How do population and land urbanization affect CO_2 emissions under gravity center change? A spatial econometric analysis. J Clean Prod 202(510–523):510–523. https://doi.org/10.1016/j.jclepro.2018.08.146
Zhang S, Li Z, Ning X, Li L (2021) Gauging the impacts of urbanization on CO_2 emissions from the construction industry: evidence from China. J Environ Manage 288:112440. https://doi.org/10.1016/j.jenvman.2021.112440
Zhao B, Yang W (2020) Does financial development influence CO_2 emissions? A Chinese Province-Level Study. Energy 200:117523. https://doi.org/10.1016/j.energy.2020.117523