



RETRACTED: Testing Environmental Kuznets Curve in the USA: What Role Institutional Quality, Globalization, Energy Consumption, Financial Development, and Remittances can Play? New Evidence From Dynamic ARDL Simulations Approach

OPEN ACCESS

Edited by:

Umer Shahzad,
Anhui University of Finance and
Economics, China

Reviewed by:

Tomiwa Sunday Adebayo,
Cyprus International University,
Cyprus
Diogo Ferraz,
Universidade Federal de Ouro Preto,
Brazil

*Correspondence:

Bahareh Oryani
bahare.oryani@snu.ac.kr
Sultan Salem
s.salem@bham.ac.uk

Specialty section:

This article was submitted to
Environmental Economics and
Management,
a section of the journal
Frontiers in Environmental Science

Received: 05 October 2021

Accepted: 11 November 2021

Published: 13 December 2021

Retracted: 07 August 2025

Citation:

Khan MI, Kamran Khan M, Dagar V,
Oryani B, Akbar SS, Salem S and
Dildar SM (2021) Testing
Environmental Kuznets Curve in the
USA: What Role Institutional Quality,
Globalization, Energy Consumption,
Financial Development, and
Remittances can Play? New Evidence
From Dynamic ARDL Simulations
Approach.
Front. Environ. Sci. 9:789715.
doi: 10.3389/fenvs.2021.789715

**Muhammad Imran Khan¹, Muhammad Kamran Khan², Vishal Dagar³, Bahareh Oryani^{4*},
Syeda Saba Akbar⁵, Sultan Salem^{6*} and Sayyad Mahejabin Dildar⁷**

¹School of Economics and Management, Northeast Normal University, Changchun, China, ²Management Studies Department, Bahria Business School, Bahria University, Islamabad, Pakistan, ³Amity School of Economics, Amity University Uttar Pradesh, Noida, India, ⁴Technology Management, Economics, and Policy Program, College of Engineering, Seoul National University, Seoul, South Korea, ⁵Ghulam Ishaq Khan Institute of Engineering Sciences and Technology (GIKI), Swabi, Pakistan, ⁶Department of Economics, Birmingham Business School, College of Social Sciences, University of Birmingham, Birmingham, United Kingdom, ⁷Department of Commerce, Agasthi Arts, Commerce and Dadasaheb Rupwate Science College, Savitribai Phule Pune University, Pune, India

This study intends to examine the validity of the Environmental Kuznets Curve (EKC) in the United States of America (USA), considering the vital role of macroeconomic variables, such as economic growth, institutional quality, globalization, energy consumption, financial development, urbanization, and remittance from 1985 to 2020. The impact of positive/negative shock in a regressor on CO₂ emissions keeps other regressors unchanged and has been investigated using the novel dynamic stimulated autoregressive distributed lag (ARDL) model. The empirical findings revealed the positive impact of economic growth and negative impact of the square economic growth on environmental degradation in the short- and long term. It indicates the validity of the EKC hypothesis in the case of the USA. Moreover, financial development, energy consumption, globalization, remittances inflow, and urbanization reduce the environmental quality. On the contrary, institutional quality improves the environmental quality by reducing CO₂ emissions. The appropriate recommendations to design the inclusive economic-environment national energy policy were proposed.

Keywords: financial development, remittances inflow, economic growth, institutional quality, globalization

INTRODUCTION

During the previous decades, especially since the 90s, cases of worsening situations start to arise, such as the circumstances of global warming for environmental quality due to uncontrolled greenhouse gas emissions, have been at their all-time high. The rise in the Earth's temperature and unexpected climate variations result from burning fossil fuels in excess, which produce

TABLE 1 | Summary of related studies.

| Ref | Region | Variables | Methodology | Impact of explanatory variables on environmental quality |
|-------------------------------|---|---|---|--|
| Zhang et al. (2021b) | Malaysia | CO ₂ , GDP, FD, GCF, URB | Maki cointegration, FMOLS, DOLS, wavelet coherence, gradual shift causality test | GDP (+), GCF (+), URB (+) |
| Adebayo and Rjoub (2021) | Argentina | CO ₂ , GDP, REC, TO | Wavelet statistical tools | REC (–) in the medium and long term. TO (–) in the medium term. EC (–), GDP (–) in the short and long term |
| Kirikaleli and Adebayo (2021) | Worldwide | CO ₂ , GDP, TI, REC, FD | FMOLS, DOLS, CCR, Bayer and Hanck cointegration, frequency-domain causality tests | GDP (–), TI (–), REC (+) |
| Akadir and Adebayo (2021) | India | CO ₂ , GDP, EC, REC, FGLOB | NARDL | Desired change in FGLOB (+) The positive shock in EC (–) The negative shock in EC (+) Desired shock in FD (–) The positive shock in GDP (–) REC (+) |
| Adebayo and Kirikaleli (2021) | Japan | CO ₂ , GDP, TI, REC, GLOB | Wavelet statistical tools | GDP (–), FD (+), REC (+) in the short and medium-term |
| Shan et al. (2021) | Top seven decentralized fiscally OECD members | CO ₂ , GDP, FID, IQ, CPIE | CS-ARDL | CPIE (+), IQ (+), FID has an inverted U-shaped relation, GDP (–) |
| Pata and Caglar (2021) | China | CO ₂ , GDP, GDP ² , HC, REC, GLOB, EF, TO | Augmented ARDL | GLOB (–), TO (–), GDP (–), HC (+) |
| Ahmed et al. (2020) | China | CF, EF, GDP, NR, URB | Bayer-Hanck cointegration, ARDL | NR (–), URB (–), GDP (–), HC (+) |
| Khan Z. U et al. (2020) | Brazil, Russia, India, China | CO ₂ , GDP, REM, EC, FDI | CCEMG, FMOLS | REM (–), FDI (–), EC (–) |
| Wawrzyniak and Doryń (2020) | 93 EMDE | CO ₂ , GDP, GDP ² , REC, REM, FF, FDI, IQ | GMM | FF (–), REC, REM, FDI (no impact), IQ (+) |
| Ahmad et al. (2019) | China | CO ₂ , REM | NARDL | The positive shock in the REM (–), the negative shock in the REM (+) |

CF, carbon footprint; CPIE, CPI-based energy price; ECGL, economic globalization; EF, ecological footprint; FDI, foreign direct investment; FF, fossil fuel consumption; FGLOB, financial globalization; FID, fiscal decentralization; GCF, gross capital formation; HC, human capital; INNV, innovation; NR, natural resource rent; PLGL, political globalization; REC, renewable energy consumption; REM, remittance; SCGL, social globalization; TI, technological innovation; TO, trade openness; TRD, trade; CCEMG, common correlated effect mean group; CCR, canonical cointegrating regression; CS-ARDL, Cross-section augmented auto-regressive distributed lags; DARDL, dynamic autoregressive distributed lag; DOLS, dynamic ordinary least square; FMOLS, fully-modified ordinary least square; GMM, generalized method of moments; NARDL, non-linear autoregressive distributed lag; EMDE, emerging market and developing economies.

greenhouse gases in the form of an abundance of carbon dioxide (CO₂) and other related poisonous gases, i.e., methane, nitrous oxide, and the gases from sulfur hexafluoride, etc. Additionally, fluorinated gases are the leading cause of Ozone layer depletion. These pollutant energies will become a cause of severe environmental issues in the future which may influence energy and power policies.

This empirical study is based on the discussion of the environmental degradation of one of the six superpowers, and one the most developed countries—the United States of America, which comprises 52 well-developed states. The GDP of the US is ranked first globally. And it ranks eighth in gross domestic product per capita. Due to its highly developed economy, the USA has to face the effects of energy pollutants and carbon emissions, which are mainly caused by the financial sector, economic activity, urbanization rate, industrialization speed, and the utilization of advanced technology (Khan et al., 2019a).

Remittances (REM) boost the economy and are prominent as a significant cash flow and income source (Kandil and Mirzaie, 2008; Meyer and Shera, 2017). The inflow of REM accelerates FD

and economic growth (EG), raises the Energy Consumption-(EC) demand in agricultural, manufacturing, and industrial sectors, and increases carbon emissions. Using the non-linear type of autoregressive distributed lag (NARDL) model, Neog and Yadava (2020) demonstrated the direct asymmetric relationship between REM and CO₂ with other harmful emissions. In contrast, Ahmad et al. (2019) assumed that the inflow of REM, which occurs in five different stages, positively but indirectly links to CO₂ emissions through Economic Growth-(EG) and EC.

Financial development (FD) is another crucial variable studied in this research. It is a dynamic causation method of accelerating economic growth, leading to enhanced clean energy consumption and degradation of the environment (Shahzad and Qin, 2019). Therefore, the lack of appropriate environmental regulations in this sector may elevate the scale of energy pollution, degrade the environment, and cause uncontrollable carbon emissions. Charfeddine and Kathia (2019), showed the few reasons due to which the rate of renewable energy consumption (REC) and percent of Financial Development (FD) per unit of Economic Growth (EG) and level of average emissions of CO₂ changed for 24 countries in the distinct climatic regions of the Middle East

and North Africa (MENA) from the year 1980–2015 (Shahzad et al., 2021a). Guo et al. (2019) confirmed a negative impact of change in Financial Development (FD), share trading, and stock marketing on CO₂ emissions in the provinces of China from 1997 to 2015.

Ehigiamusoe and Lean (2019) showed the FD's direct and adverse impact on CO₂ with other harmful gases emissions in a data set of panel types for 122 countries (Sharma et al., 2021). Tamazian and Rao (2010) indicated the positive impact of FD on the environmental and climatic zone-specific qualities for the BRICS countries (Brazil-BR, Russia-RU, India-IN, China-CN, and South Africa-SA) (Wang et al., 2021a). However, Ahmad et al. (2018) showed an inconclusive result when involving the changes of Financial Development (FD) on CO₂ with harmful gases emission in countries like China (Bashir et al., 2021). Acheampong (2019) declared that Financial Development (FD) tends to increase CO₂ type harmful gas emission in a panel data set for around 46 African countries by moderating EC and EG (Shakoor et al., 2020).

EG is still another crucial factor in environmental sciences. Keeping this in view, we observe that FD and EG serve as direct indicators for environmental degradation. Gökmenoğlu and Taspınar (2016) presented the positive and, in some cases, negative impacts of Energy Consumption (EC) and Economic Growth (EG) on Turkey's CO₂ plus other harmful gases emissions, respectively. The EKC is meant to measure the role and impact of economic growth factors on the deterioration of climatic conditions and environmental quality. Much research has been done, and models are designed to illustrate the inclination and declination in the EKC hypothesis curve (Rafique et al., 2021).

For instance, Ur Rahman et al. (2019) and Rahman et al. (2019) validated the highly famous EKC type of hypothesis for measuring the environmental quality in Pakistan, which shows the U-shaped type of curves with a specific relationship between the Economic Growth (EG) and its drivers on the qualities of the environment with a significant degradation in environmental resources (Bashir et al., 2020).

Urbanization (URB) is a prominent indicator influencing CO₂ and other carbon-emitting gas emission and causing variation in the condition of the environment (Doğan et al., 2020). Pata (2018) pointed out that growth in URB and industrialization leads to more outstanding FD and EG that are the leading causes of CO₂ emissions. URB stimulates the energy demand in the residential and industrial sectors (Lee et al., 2018). Kwakwa and Alhassan (2018) claimed that adopting energy-efficient technology can moderate the environmental impact of EC (Ghazouani et al., 2020). Salahuddin et al. (2019) showed the bidirectional causal and logical relationship between URB and CO₂ with other harmful gases emission. Sun and Huang (2020) explored an inverted U-shaped trend linking URB and CO₂ with other gas emissions (Fatima et al., 2021).

Shahbaz et al. (2015) showed a significant and positive link between the trend of globalization (GLOB) and the climatic change in terms of environmental degradation. Phong (2019) as well reported a positive significant accord between a GLOB

and the emission of CO₂ with other harmful gasses, while others showed an insignificant relationship between them (Destek and Sarkodie, 2019; Xu et al., 2018; Olowu et al., 2018; Haseeb et al., 2018; Shahbaz et al., 2018a; Paramati et al., 2017). Lamla (2009), Shahbaz et al. (2018b), Shahbaz et al. (2018c) explained the trade-GLOB-CO₂ emissions nexus in detail. However, scant empirical work has been done to investigate the possible effects of this factor. Tamazian and Rao (2010) explained that globalization increases low emission production by changing industrial sectors and introducing eco-friendly technologies in the production and manufacturing sectors.

Farzanegan and Markwardt (2018) opined that CO₂ emissions could be controlled by enhancing the quality of institutions in the MENA region. Solarin et al. (2017) showed the crucial role of institutional quality (IQ) on CO₂ with other harmful gasses emissions in Ghana. Le and Ozturk (2020) designed the EKC type of model for around 74 emerging markets and developing economies (EMDEs) from 1990 to 2014 to evaluate the impact of IQ on CO₂ emissions. Their findings revealed that IQ decreases environmental quality. Shah et al. (2019) determined that the lower the IQ, the lower the development process, the higher the CO₂ and other carbon-emitting gasses emissions (Shahzad, 2020; Shahzad et al., 2020).

Therefore, This study contributes to the literature in two aspects: 1) To achieve a high level of author practice and knowledge, it is one of the first and foremost studies which attempts to evaluate the rate of change for the measuring the impact of most macroeconomic drivers of CO₂ emissions, such as EG, IQ, GLOB, EC, FD, and REM, in the case of the USA, from 1985 to 2020 (Shahzad et al., 2021b). 2) Unlike previous studies that used different traditional econometric models, this study employs a newly dynamic autoregressive distributed lag simulation model, which is more efficient in results estimation and prediction through graphs in both the short and long run.

LITERATURE REVIEW

The relationship between economic growth and environmental quality has been widely investigated since the 1990s. Initially, this relationship was derived from the seminal work of Simon Kuznets in 1955. He showed that income inequality increases along with income growth, stabilizes at a certain threshold, and then decreases, indicating the inverted-U-shaped relationship between these two variables (Kuznets, 1955). Inspired by this concept, environmental economists have postulated the relationship between income growth and environmental degradation. For instance, Grossman and Krueger examined the relationship between economic growth and sulfur dioxide and carbon dioxide emission concentrations as environmental pollutants. Their results confirmed an upward trend of pollutants as per capita income increased to a certain level and then a downward trend with high-income levels (Grossman and Krueger, 1991). In 1992, Shafik and Bandyopadhyay demonstrated a U-shaped relationship between environmental

TABLE 2 | Variable description.

| Acronym | Variables | Unit |
|-----------------|--------------------------|---|
| CO ₂ | Carbon dioxide emissions | Measured as millions of tons per capita |
| IQ | Institutional quality | Measured by using principal component analysis (PCA) in terms of bureaucracy quality, democratic accountability, corruption, political stability, and law and order |
| FD | Financial development | Measured as a % of GDP of domestic credit provided by banks to the private sector |
| EC | Energy consumption | Measured as a % of the total of fossil fuel energy consumption |
| REM | Remittance | Measured as a % of GDP of personal remittances received |
| EG | Economic growth | Measured as annual % of GDP growth |
| GLOB | Globalization | Measured by using PCA considering economic, social, and political aspects |
| URB | Urbanization | Measured as a % of annual population growth |

pollution and economic growth (Shafik and Bandyopadhyay, 1992). Panayotou evaluated the relationship between deforestation and air pollution as environmental degradation and economic growth in developing and developed countries and called it the Environmental Kuznets Curve (EKC); his results confirmed the inverted-U shaped relationship in both groups of countries with a different turning point (Panayotou, 1993). The most related recent studies are illustrated in **Table 1**.

DATA AND METHODOLOGY

Data

Based on some previous facts and the latest available data, this study further applies the methods of investigations for measuring the changes with the environmental impact of the institutional quality (IQ), the financial development (FD), urbanization (URB), remittance (REM) within the EKC hypothesis for the USA from 1985 to 2020. The data on CO₂ with other carbon-emitting gasses emission, FD, EG, and REM are retrieved from the World Bank (2020). IQ is gathered from the International Country Risk (ICRG) database ICRG (2021), GLOB is collected from KOFGI Index (Dreher 2006), EC is taken from the World Bank (2020) and BP (2020). The description of variables, units, and sources is listed in **Table 2**.

Methodology

The empirical approach for this study has been undertaken in line with earlier pragmatic studies that researched the effect of economic factors (independent variables) on the dependent variable of CO₂ and other carbon-emitting gasses emission using the dynamic autoregressive distribution lags simulation (DARDLS) approach. Several academics have studied the independent variables. For instance, Khan et al. (2019b) considered GLOB, EC, FD, URB, and EG. Sarkodie et al. (2019) reviewed EC, Food, and EG. Nwani and Omoke (2020) analyzed EG, EC, GLOB, and Bank Credit. Khan M. I. et al. (2020) examined EG, Foreign Direct Investment (FDI), EC, Domestic Credit, and the Stock market. Danish and ULUCAK (2021) scrutinized biomass energy consumption. Zhang et al. (2021a), Zhang et al. (2021b) considered human capital, natural resources, and EG. Abbasi et al. (2021) measured URB, EC, Industrial Growth, and EG. Islam et al. (2021) investigated EG, Trade, EC, URB, GLOB, FDI, and Innovation. This study scrutinizes the relationship of the considered left side dependent and the figured right side

independent variables, which can also be incorporated in the form of **Eq. 1**.

$$CO_{2t} = \beta_0 + \beta_1 IQ_t + \beta_2 GLOB_t + \beta_3 FD_t + \beta_4 EC_t + \beta_5 EG_t + \beta_6 EG_t^2 + \beta_7 REM_t + \beta_8 URB_t + \varepsilon_t \quad (1)$$

Where β_0 is constant, IQ stands for institutional quality; GLOB presents globalization; FD exhibits financial development; EC is energy consumption; EG and EG^2 are economic growth and square of economic growth, respectively; REM shows remittance; URB is urbanization; $\beta_1 - \beta_8$ indicate the independent variables' coefficients, ε_t is a white noise error term (Pata and Isik, 2021). The research design is illustrated in **Figure 1**.

As can be seen in **Figure 1**, conducting the dynamic ARDL model requires taking several steps that would be explained as follows:

1. Checking the variables are stationary/identifying the optimal lag length/specifying the ARDL model. Testing the models for stationary among various variables is essential to avoid spurious regression-related problems. Like the ARDL model, the DARDL model can be estimated if the dependent variable is stationary at the first level, and regressors/control variables are stationary at a different level or the first level of difference or both (Oryani et al., 2021a). In this study, whether the variables are stationary has been checked using the famous Augmented Dicky Fuller (ADF) test; the other is Phillips-Peron (PP). The null hypotheses indicate the unit root in time series against the alternative, which shows the variable is stationary. As the second step, the optimal lag length must be identified. There are several criteria to select, such as Schwarz information criteria (SIC), Hannan-Quinn information criteria, Akaike information criterion (AIC), Adjusted R-squared, and final prediction error (FPE). The model with the lowest criteria value or the largest R-squared value is selected as the best model. It must be noted that in a sample of up to 60 observations, the FPE and AIC are the most appropriate criteria over others (Shahbaz et al., 2018). In the next step, considering the identified optimal lag length, the ARDL model could be specified.
2. Checking the residuals' diagnostic tests. The diagnostic statistics are applied to check the results' reliability. In this regard, the residual normality, heteroscedasticity, and serial correlation have been checked.
3. Cointegration test (Bounds Test). Followed by Pesaran et al. (2001), the first step in applying the DARDL model is

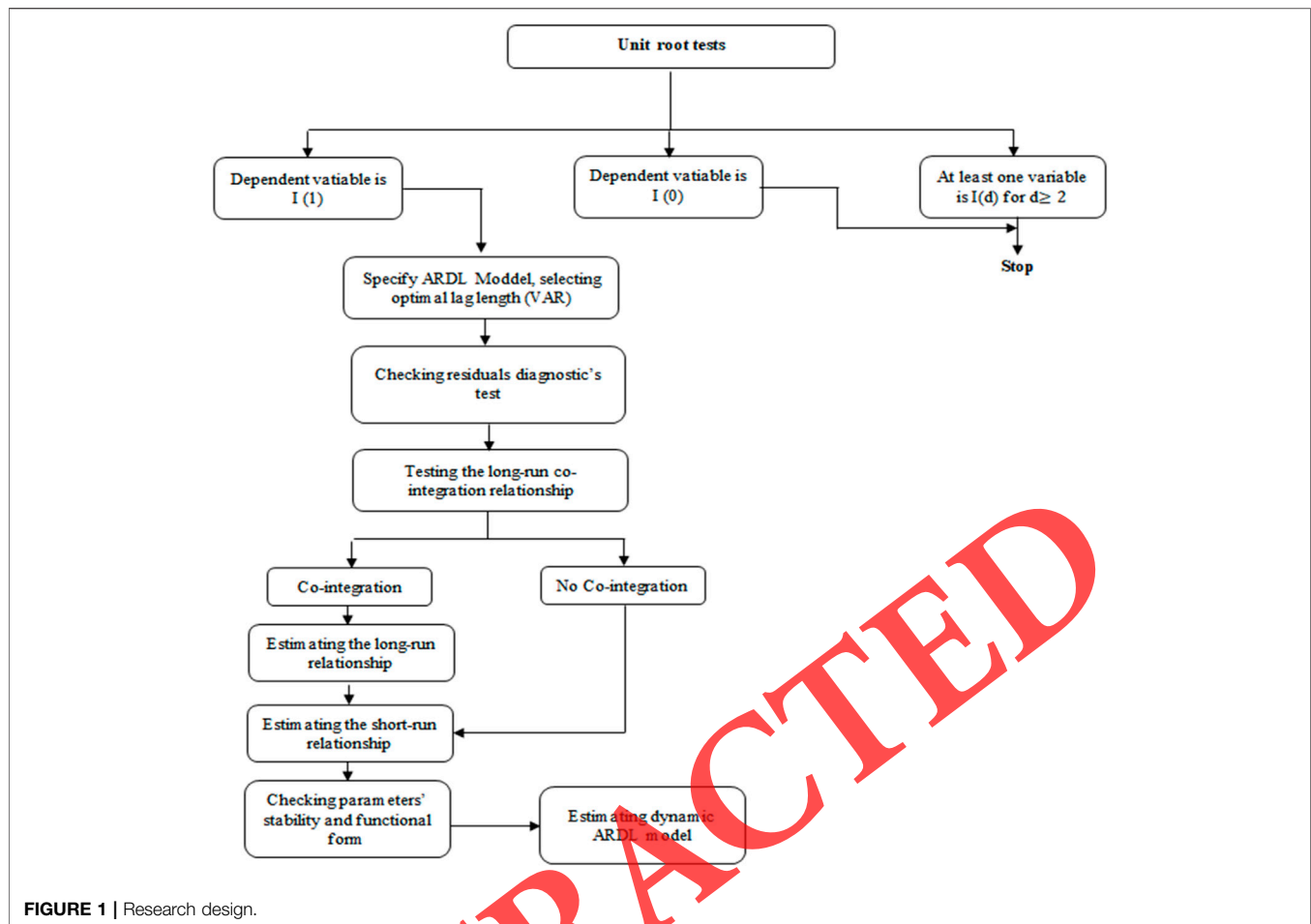


FIGURE 1 | Research design.

estimating the long-run cointegration of the unconditional but the linear correction model, also known as by its short form (ULCM) using another model of the ARDL with its different bounds for testing approach as shown in (Eq. 2):

$$\begin{aligned} \Delta(y)_t = & \alpha_0 + \theta_0(y)_{t-1} + \theta_1(x_1)_{t-1} + \dots + \theta_k(x_k)_{t-1} \\ & + \sum_{i=1}^p (\alpha_i) \Delta(y)_{t-i} + \sum_{i=1}^{q_1} (\beta_{1i}) \Delta(x_1)_{t-i} + \dots \\ & + \sum_{i=1}^{q_k} (\beta_{ki}) \Delta(x_k)_{t-i} + \varepsilon_t \end{aligned} \quad (2)$$

Where Δ signifies the first differential operator; y indicates the dependent variable (CO_2 emissions) and x_1, \dots, x_k shows explanatory variables, which includes IQ, GLOB, FD, EG, EG^2 , REM, and URB; p and q_k present the optimal lag length of the dependent and explanatory variables, respectively. $\theta_1 - \theta_k$ and $\beta_1 - \beta_k$ stand for long and short-term coefficients. Long-run cointegration between variables studied is tested and available for using the F-statistics bounds test for validity and compare with the upper fixed and lower fixed critical bound for establishing the

test proposed by Pesaran et al. (2001). The null against alternative hypotheses is considered for testing the F-statistics is as follows:

$$\begin{aligned} H_0: & \theta_1 = \dots = \theta_k = 0 \\ H_0: & \theta_1 \neq \dots \neq \theta_k \neq 0 \end{aligned}$$

Three possible results by comparing the calculated F-statistics and proposed upper and lower bounds tests are as follows:

- $F\text{-statistics} > \text{critical value of the upper bound}$, implying the long-run cointegration
 - $F\text{-statistics} < \text{critical value of the lower bound}$, indicating the lack of the long-run type of cointegration
 - The calculated F-statistics falls in the lower and upper limits of bound; it is a kind of inconclusive. However, the negative and significant error correction coefficient can confirm the long-run cointegration (Oryani et al., 2021b).
4. Error correction model (ECM). Suppose the cointegration between the investigated variables is established. In that case, the proper ECM estimates in the second phase indicate the speed of adjustment of deviation from short-

TABLE 3 | Descriptive statistics and correlation matrix.

| | CO ₂ | FD | EC | EG | EG ² | GLOB | IQ | REM | URB |
|-----------------|-----------------|-------|-------|-------|-----------------|-------|-------|-------|------|
| Mean | 18.20 | 51.55 | 85.07 | 2.62 | 9.05 | 76.58 | 0.98 | 0.03 | 0.93 |
| Std. Dev. | 1.91 | 4.13 | 1.87 | 1.50 | 6.23 | 4.92 | 0.38 | 0.01 | 0.24 |
| Minimum | 13.56 | 44.37 | 81.28 | -2.54 | 0.01 | 67.87 | 0.26 | 0.03 | 0.43 |
| Maximum | 20.18 | 59.78 | 88.30 | 4.75 | 22.60 | 82.32 | 1.55 | 0.05 | 1.39 |
| Correlation | | | | | | | | | |
| CO ₂ | 1.00 | — | — | — | — | — | — | — | — |
| FD | -0.04 | 1.00 | — | — | — | — | — | — | — |
| EC | 0.93 | 0.11 | 1.00 | — | — | — | — | — | — |
| EG | 0.37 | -0.23 | 0.378 | 1.00 | — | — | — | — | — |
| EG ² | 0.49 | -0.21 | 0.50 | 0.81 | 1.00 | — | — | — | — |
| GLOB | -0.68 | 0.008 | -0.83 | -0.36 | -0.43 | 1.00 | — | — | — |
| IQ | 0.51 | -0.22 | 0.62 | 0.45 | 0.57 | -0.85 | 1.00 | — | — |
| REM | -0.19 | -0.12 | -0.44 | -0.29 | -0.30 | 0.76 | -0.70 | 1.00 | — |
| URB | 0.82 | -0.43 | 0.70 | 0.24 | 0.39 | -0.63 | 0.57 | -0.23 | 1.00 |

run toward long-run equilibrium. Therefore, the short-run model is presented in Eq. 3

$$\Delta(y)_t = \alpha_0 + \theta_0(y)_{t-1} + \theta_1(x_1)_{t-1} + \dots + \theta_k(x_k)_{t-1} + \sum_{i=1}^p (\alpha_i)\Delta(y)_{t-i} + \sum_{i=1}^{q_1} (\beta_{1i})\Delta(x_1)_{t-i} + \dots + \sum_{i=1}^{q_k} (\beta_{ki})\Delta(x_k)_{t-i} + \eta_1 ECT_{t-1} + \varepsilon_t \quad (3)$$

Where φ_1 - φ_9 present the short-term relationship among variables studied. The ECT must be negative and significant to adjust any shock in the short run toward the long-run equilibrium.

5. Checking parameters' stability and appropriateness of functional form. The appropriateness of the specified short-run model is checked by conducting the Ramsey Regression Equation Specification Error Test (RESET). Finally, the Cumulative Sum of Recursive Residuals (CUSUM) test and Cumulative Sum of Recursive Residuals of Square (CUSUMSQ) test are applied to check the stability of the parameters.

6. Dynamic ARDL with corrected simulations. The initial models suggested by Jordan and Philips (2018) emerged and were developed by the replica of the DARDL model to overcome the problems inhibited in the traditional ARDL model in examining the short and long-run interlinkages among variables. According to Jordan and Philips (2018), Sarkodie et al. (2019), Khan et al. (2019a), and Danish and ULUCAK (2021), the new DARDL model is an effective method to stimulate and examine both short and long runs to measure the levels of shocks. It can automatically organize the graph, which shows the changes in the regressor and their impact on regressand, by keeping the other independent variables constant. The DARDL model is shown in Eq. 4:

TABLE 4 | Unit root tests.

| Variable | Dickey-Fuller test | | Phillips-Perron test | |
|-----------------|--------------------|---------|----------------------|---------|
| | t-statistic | Outcome | t-statistic | Outcome |
| CO ₂ | 1.828 | — | 1.918 | — |
| FD | -1.416 | — | -1.935 | — |
| EC | -0.072 | — | -0.039 | — |
| EG | -3.558*** | I (0) | -3.503*** | I (0) |
| EG ² | -3.150*** | I (0) | -3.086** | I (0) |
| GLOB | -1.849 | — | -1.862 | — |
| IQ | -1.947 | — | -1.747 | — |
| REM | -3.848*** | I (0) | -3.748*** | I (0) |
| URB | 0.454 | — | -0.207 | — |
| CO ₂ | -4.489*** | I (1) | 4.484*** | I (1) |
| FD | -2.977** | I (1) | -3.083** | I (1) |
| EC | -5.524*** | I (1) | -5.529*** | I (1) |
| GLOB | -5.374*** | I (1) | -5.411*** | I (1) |
| IQ | -5.988*** | I (1) | -6.614*** | I (1) |
| URB | -3.201** | I (1) | -3.211** | I (1) |

***, ** significant level presented at 1 and 5%, respectively.

TABLE 5 | ARDL model-bounds test.

| Test-statistic | Value | K |
|---------------------------|----------------------|----------------------|
| F-statistic | 5.30 | 8 |
| Critical-value for bounds | | |
| Significance | I ₀ Bound | I ₁ Bound |
| 10% | 1.951 | 3.064 |
| 5% | 2.228 | 3.391 |
| 2.5% | 2.482 | 3.72 |
| 1% | 2.794 | 4.14 |

$$\Delta(y)_t = \alpha_0 + \theta_0(y)_{t-1} + \theta_1(x_1)_{t-1} + \dots + \theta_k(x_k)_{t-1} + \beta_1 \Delta(x_1)_t + \dots + \beta_k \Delta(x_k)_t + \eta_1 ECT_{t-1} + \varepsilon_t \quad (4)$$

TABLE 6 | Diagnostic test.

| Test | Results | |
|-------------------|------------------|------|
| ARCH | Prob. Chi-Square | 0.74 |
| Breusch-Godfrey | Prob. Chi-Square | 0.13 |
| Ramsey Reset Test | F-statistic | 0.31 |

TABLE 7 | Dynamic ARDL simulations (simulation: 5,000).

| Variables | Coef. | Std. Err. | T | P>t |
|--------------------------------|-------------------|-----------|----------|--------|
| L1_CO ₂ | -0.5037 | 0.1573 | -3.2017 | 0.0029 |
| FD _t | 0.6906 | 0.1696 | 4.0729 | 0.0003 |
| Fi FD _{t-1} | 0.2701 | 0.0208 | 13.0139 | 0.0000 |
| EC _t | 0.1968 | 0.0712 | 2.7639 | 0.0090 |
| EC _{t-1} | 0.7358 | 0.1752 | 4.1997 | 0.0002 |
| EG _t | 0.6699 | 0.0742 | 9.0241 | 0.0000 |
| EG _{t-1} | 0.8710 | 0.1049 | 8.3052 | 0.0000 |
| EG _t ² | -0.2263 | 0.0156 | -14.5138 | 0.0000 |
| EG _{t-1} ² | -0.8784 | 0.0212 | -41.4388 | 0.0000 |
| GLOB _t | 0.8162 | 0.1041 | 7.8414 | 0.0000 |
| GLOB _{t-1} | 0.1224 | 0.0479 | 2.5537 | 0.0152 |
| IQ _t | -0.1766 | 0.0811 | -2.1785 | 0.0362 |
| IQ _{t-1} | -0.2961 | 0.1049 | -2.8233 | 0.0078 |
| REM _t | 10.2523 | 0.7633 | 13.4309 | 0.0000 |
| REM _{t-1} | 54.6186 | 0.9584 | 56.9918 | 0.0000 |
| URB _t | 1.2386 | 0.5359 | 2.3111 | 0.0268 |
| URB _{t-1} | 1.4376 | 0.1609 | 8.9345 | 0.0000 |
| Constant | -6.1881 | 0.7096 | -8.7207 | 0.0000 |
| R-square | 0.8704 | | | |
| F (17, 17) = 6.72 | Prob > F = 0.0001 | | | |

Variables with *t* indicates the long-run effect while *t*-1 indicates the short-run results;
L1_CO₂ emission indicates the ECT term.

Where β and θ refer to long-run and short-run coefficients, respectively.

RESULTS AND DISCUSSIONS

Table 3 shows the descriptive statistic of investigated variables and their correlation. From **Table 3**, we see GLOB and EC have the utmost mean and SD. Accordingly, the lowest mean and SD was related to remittances.

As illustrated in **Table 3**, the negative relationship between CO₂ emissions and FD (-0.044), GLOB (-0.676), and REM (-0.816) is verified. As expected, EC (0.926), URB (0.816), IQ (0.503), EG² (0.488), and EG (0.366) positively impact CO₂ emissions, in descending order. **Table 3** presents the stationary results for unit root tests of Dickey-Fuller and Phillips-Perron. According to **Table 4**, none of the variables are stationary at the second difference. In other words, the dependent variable is integrated of order one [I (1)], and regressors are mutually stationary at the level or the first difference; therefore, the possibility of employing the ARDL model is verified. Based on the different lag length criteria, the maximum lag length of 1 is identified.

The results of F-statistics to check the validity of long-run cointegration between two different variables are reported in **Table 5**.

From **Table 5**, the cointegration exists between the dependent variable and regressors since the calculated F-statistics exceed the critical value of the upper bound test at all significant levels. **Table 6** presents the results of the DARDL simulation model to evaluate the impact of positive and negative shocks in each independent variable on the dependent variable. From **Table 7**, EG and EG² impact CO₂ emissions positively and negatively in the short and long run, respectively, supporting the inverse U-shaped relationship between environmental degradation and income. This result is in line with Jun et al. (2021) for selected South Asian economies.

The study further applied the fully-modified format of ordinary least square, also known for its short form (FMOLS) technique; the authors empirically designed the model to present the results and show how REC, GLOB, and EG impact CO₂ emissions. The validity of EKC has been confirmed in the study of Haseeb et al. (2018) for BRICS countries. The results have verified the positive change in the impact of FD on CO₂ with other carbon gasses emissions in the short run for the considered model and the long run to support the extension of the model. Indeed, a 1% increase in FD raises CO₂ with other carbon gasses emissions about 0.69 and 0.27% in the long and short run, respectively. This

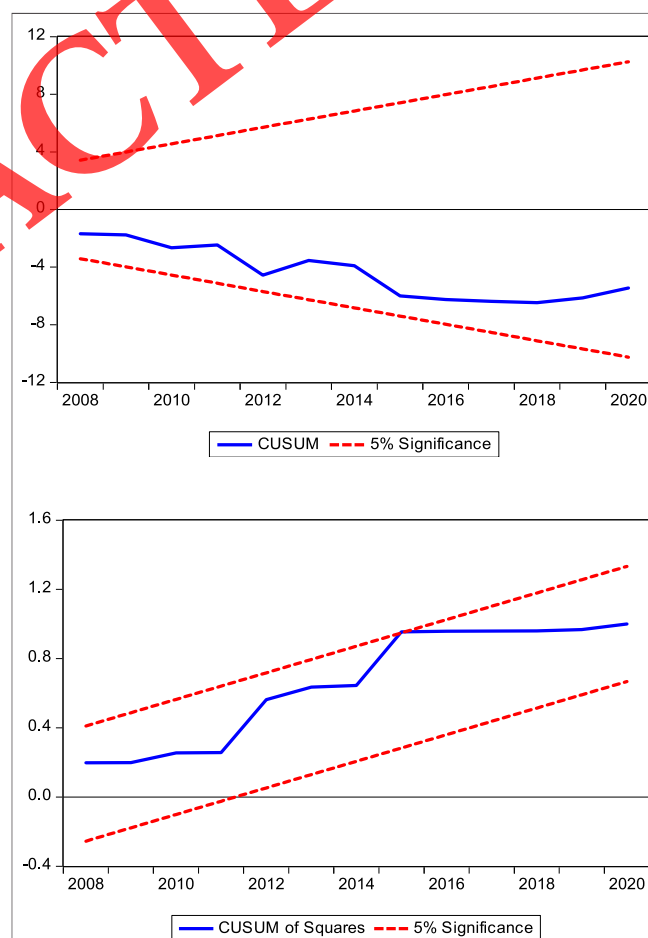


FIGURE 2 | The plot of the cumulative sum of the recursive residuals and the plot of cumulative sum of recursive residuals of square.

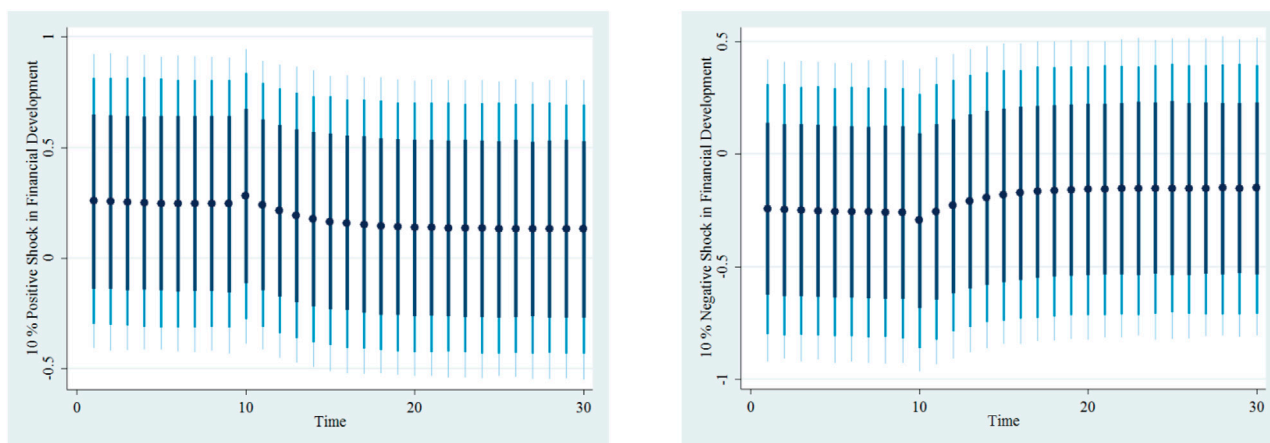


FIGURE 3 | Financial development and carbon dioxide emission. The average prediction value has been exhibited via dots, while the CI at 75, 90, and 95% have been shown by the dark blue to the light blue lines, respectively.

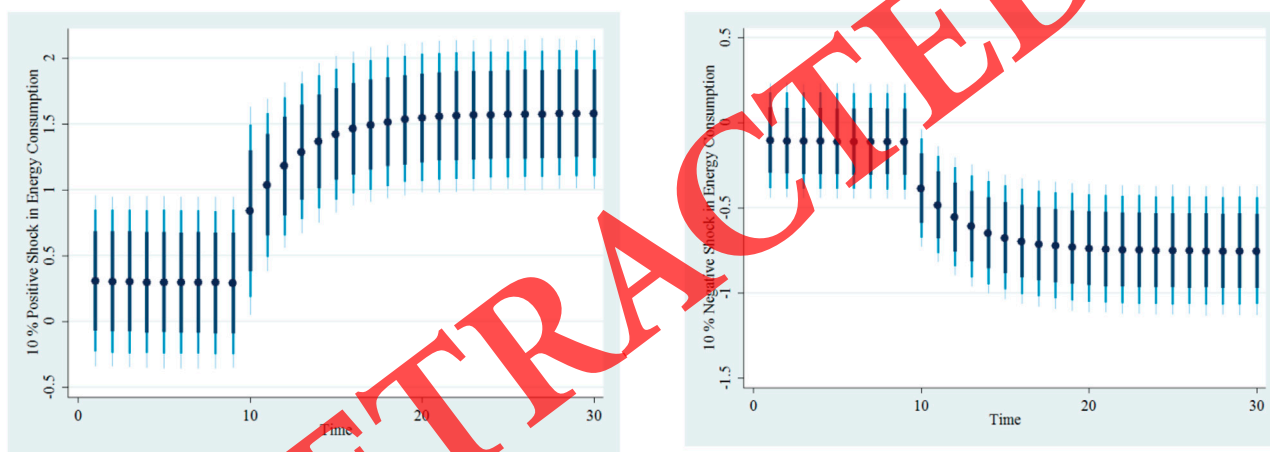


FIGURE 4 | Energy consumption and carbon dioxide emission. The average prediction value has been exhibited via dots, while the CI at 75, 90, and 95% have been shown by the dark blue to the light blue lines, respectively.

finding consists of Haseeb et al. (2018), which showed the positive impact of FD on environmental degradation.

However, it contradicts Zaidi et al. (2019) for Asia Pacific Economic Cooperation countries (APEC). The study further focused on testing the dynamic relationship between CO₂ with other harmful gasses emission, GLOB, and FD, considering energy intensity (EI) and EG within the EKC framework. Their results demonstrated that FD improves environmental quality. EC is positively linked to CO₂ with other carbon gasses emissions in the short and long run. Indeed, a 1% increase in EC harms the environment about 0.2% in the long run, while the impact is higher in the short-run (0.74%). This result is similar to the findings of Haseeb et al. (2018).

GLOB degrades the environment in the short run and long run. As a matter of fact, a 1% increase in globalization increases CO₂ and other carbon gas emissions by about 0.82 and 0.12% in the short and long run, respectively. This result aligns with Jun

et al. (2021), which verified the positive impact of GLOB on CO₂ with other carbon gasses emissions. However, it contradicts the results of Zaidi et al. (2019). From empirical findings, IQ has been negatively linked with CO₂ and other carbon gas emissions in the short and long run. A 1% increase in institutional quality reduces CO₂ with other carbon gasses emissions by about 0.18 and 0.30% in the short term and long run, respectively. This outcome is opposite to Teng et al. (2021) in 10 economies. They explored the impact of electricity consumption (ELC), FDI, EG, REC, IQ, and GLOB on CO₂ and other carbon gas emissions. Their results demonstrated that the REC improves environmental quality. However, on the contrary, FDI, ELC, IQ, and EG increase CO₂ emissions. Moreover, the results confirmed GLOB's positive and negative impacts on CO₂ emissions reduction in the long and short run. It is commensurate with the findings of Salman et al. (2019) regarding Indonesia, Thailand, and South Korea. They

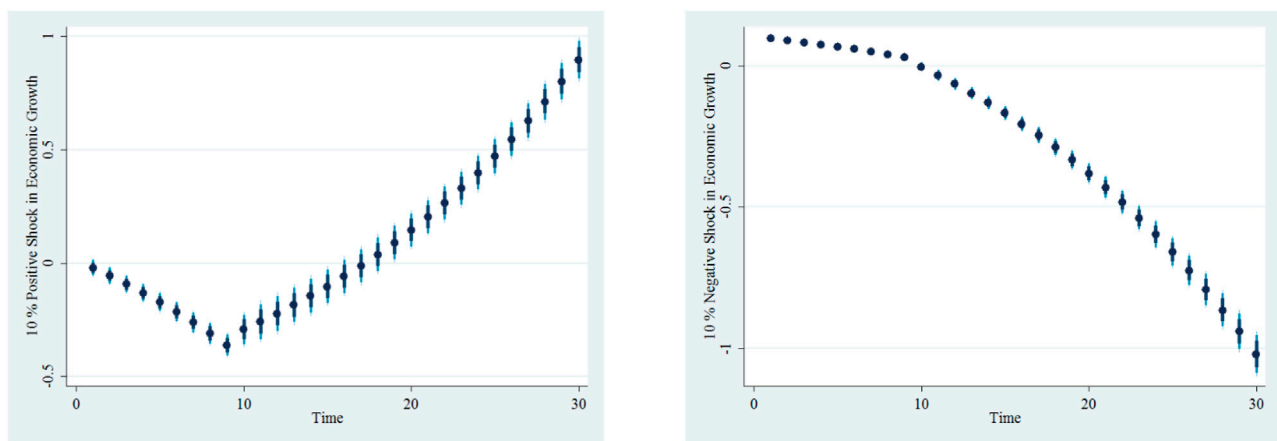


FIGURE 5 | Economic growth and carbon dioxide emission. The average prediction value has been exhibited *via* dots, while the CI at 75, 90, and 95% have been shown by the dark blue to the light blue lines, respectively.

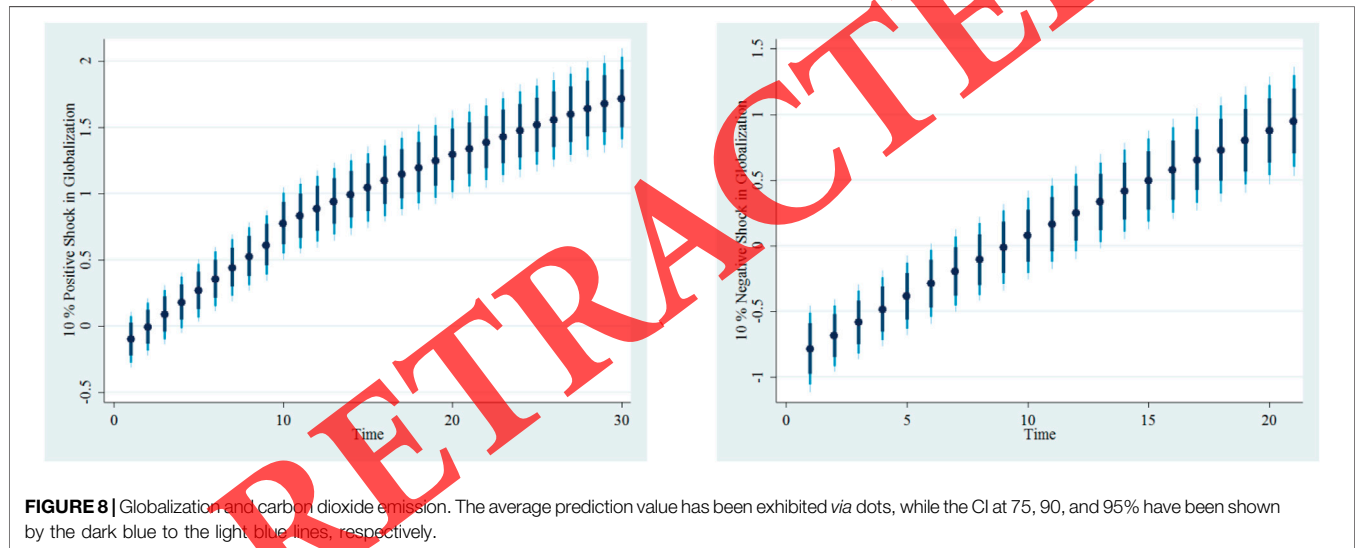
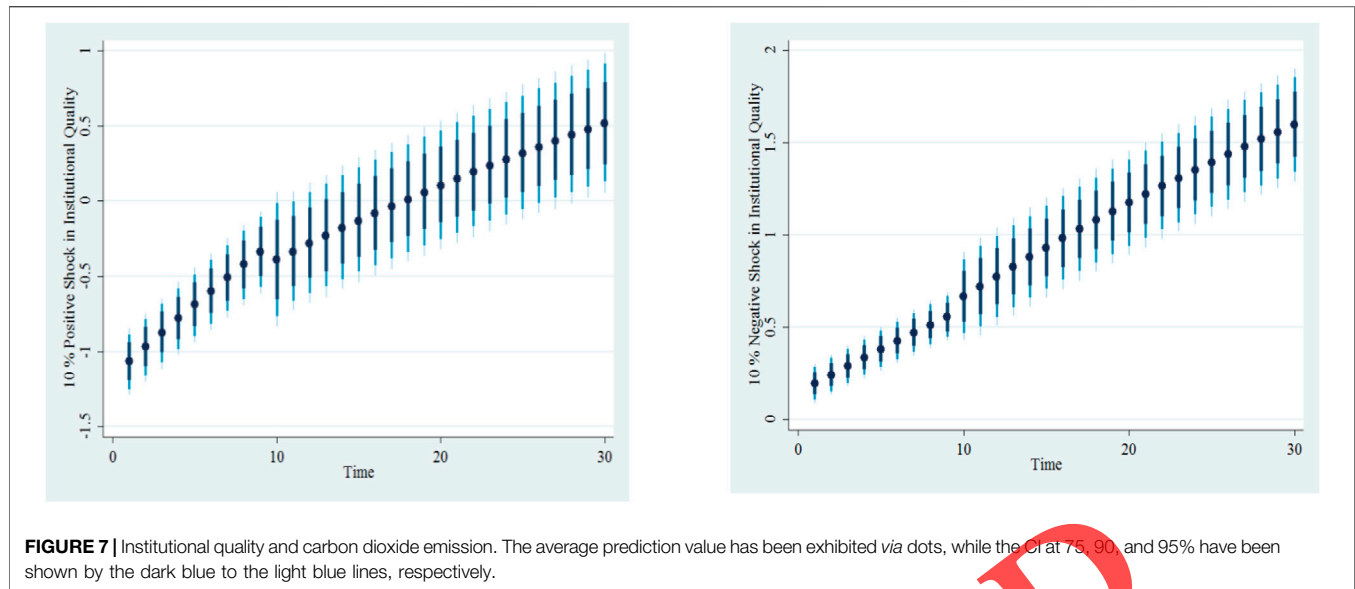


FIGURE 6 | Economic growth square and carbon dioxide emission. The average prediction value has been exhibited *via* dots, while the CI at 75, 90, and 95% have been shown by the dark blue to the light blue lines, respectively.

analyzed the impact of IQ on the emissions-growth nexus. However, they have incorporated TO and EC into the model. Their results confirmed the desirable effects of IQ on environmental quality.

REM deteriorates the environment in the short and long run. Notably, its negative impact on the environment in the short run (54.7%) is higher than in the long run (10.3%). This result aligns with Wang et al. (2021b) for India, the Philippines, Egypt, Pakistan, and Bangladesh. Incorporating EG, FD, industrial value-added, and agricultural value-added, they have examined the environmental impacts of the REM. The results confirmed the positive effects of received REM on environmental quality. However, improving the FD leads to a higher level of CO₂ with other carbon gasses emissions. However, it conflicts with Usman and Jahanger (2021) results for the 39 countries worldwide. They investigated the environmental impacts of FDI, IQ, FD, REM, and TO from 1990 to 2016.

The results verified the positive impacts of REM in the 5th–70th quantiles, and it becomes negative at the 80th–95th. Moreover, their results verified the existence of the EKC hypothesis. As expected, the results show the positive impact of URB on CO₂ emissions in the short and long run. Indeed, a 1% increase in URB leads to a 1.4 and 1.5% increase in CO₂ emissions in the long and short run, respectively. Indeed, CO₂ emissions could be affected by URB through energy efficiency, final EC structure, and EG. This result contradicts the findings of Raggad (2018), which investigated the existence of EKC and short-run for the considered model and long-run to support the extension of the model for presenting the relationship among EG, EC, CO₂ emissions, and URB in Saudi Arabia. His results confirmed the negative impact of URB on CO₂ emissions. However, it confirms the findings of Ali et al. (2019) and Liu and Bae (2018) for Pakistan and China, respectively. The results confirmed the positive effects of URB on environment degradation in short



and long run in Pakistan. Moreover, the results for China confirmed the negative environmental impacts of URB. Indeed, a 1% increase in CO₂ emissions is caused by a 1% increase in URB. Finally, the perfectness of the model is checked by conducting the residual diagnostic test (Table 6).

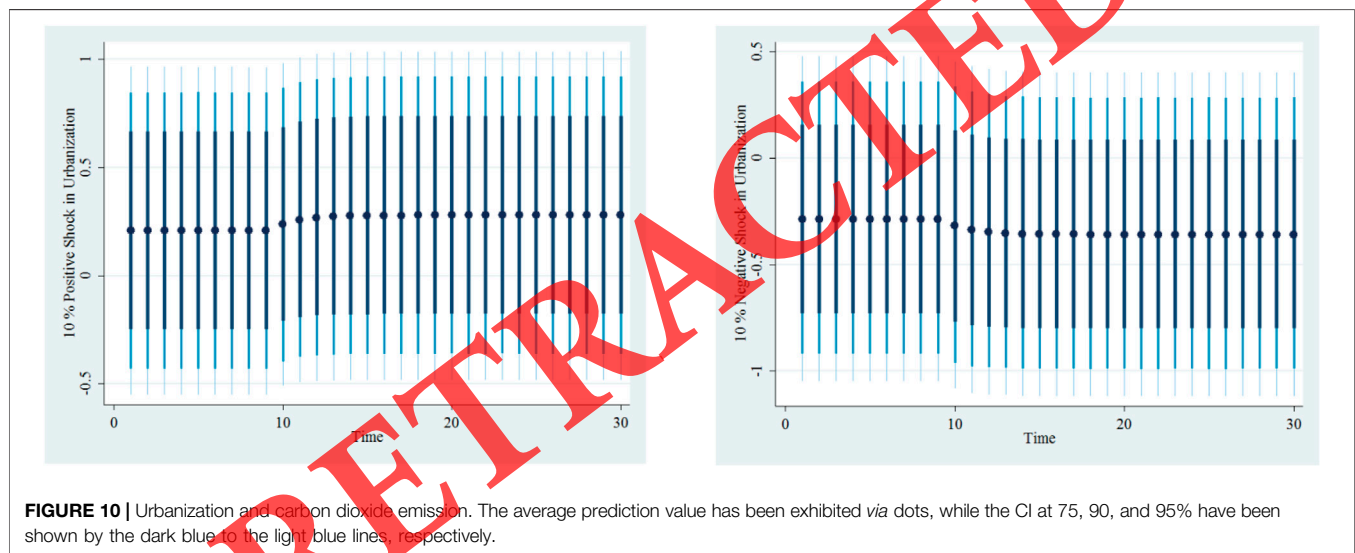
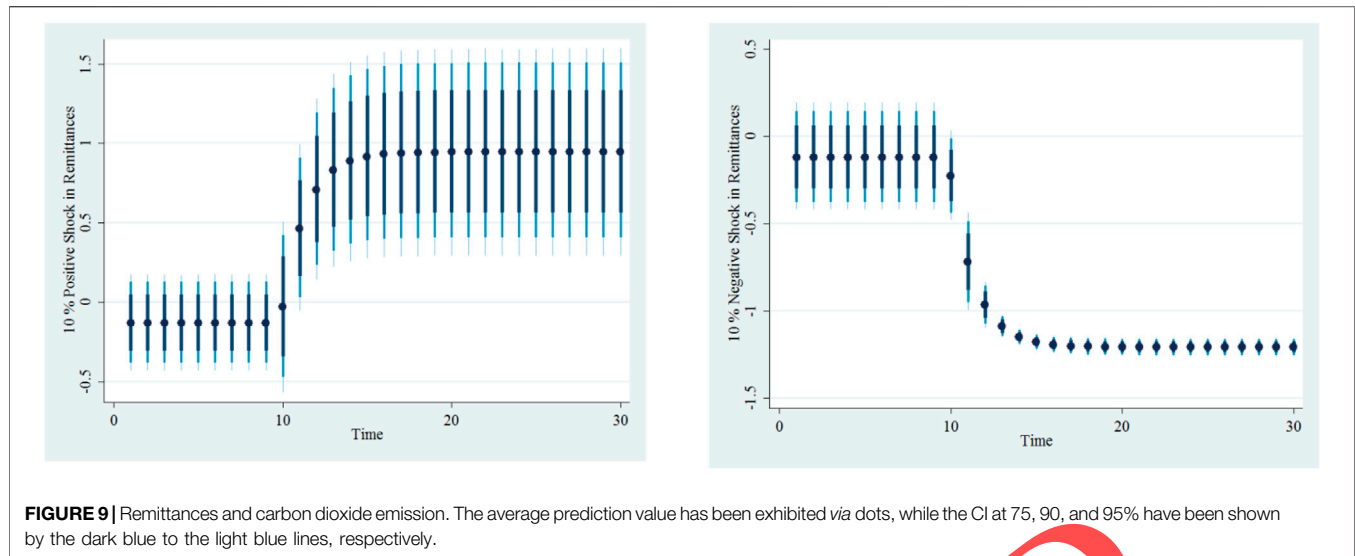
ARCH and Breusch-Godfrey tests are employed to check the estimated heteroscedasticity and serial correlation of each model. From the results, the estimated model is free of heteroscedasticity and serial correlation problems. The robustness of the results is examined through the CUSUM and CUSUM squares (Figure 2).

From Figure 1, since the continuous line, which shows the plots of the CUSUM and CUSUM squares placed within the upper and lower critical bounds (dashed line), the consistency of the parameters and the lack of structural break is proved at a 5%

confidence level. The impact of positive and negative changes in independent variables on the dependent variable is illustrated in Figures 3–10.

The impulse response plot of FD and CO₂ with other carbon gasses emissions is depicted in Figure 3. It demonstrates the positive link between a 10% increase in FD and CO₂ and other carbon gas emissions in the short and long terms. However, a 10% decrease in FD negatively affects the CO₂ with other carbon gasses emissions and improves environmental quality.

Figure 4 shows the 10% positive and negative shocks in EC and their impacts on CO₂ and other carbon gas emissions. As illustrated in the first graph, a 10% increase in EC is positively linked to CO₂ and other carbon gas emissions in the short and long run. However, a 10% decrease in the short run has a positive effect, but EC improves the environmental quality



through CO₂ and other carbon gas emission reduction in the long run.

Figure 5 exhibits the impact of positive and negative shocks in EG on CO₂ and other carbon gas emissions. In the short run, a 10% boost in EG lowers the CO₂ and other carbon gas emission while it degrades the environment in the long term. Contrarily, a 10% decrease in EG does not affect the CO₂ and other carbon gas emissions in the short run. At the same time, it improves environmental quality in the long run.

The impulse response plot of EG² and CO₂ with other carbon gasses emissions is depicted in **Figure 6**. A 10% boost in EG² does not link to the CO₂ and other carbon gas emissions in the short run, while it affects the long run negatively. Indeed, promoting the EG² relieves environmental degradation in the long run. However, a 10% reduction in EG² degrades the environment in the short run and improves it in the long run.

Figure 7 shows how CO₂ and other carbon gas emissions can be affected by positive and negative shocks in IQ. The negative effect of a 10% increase in IQ on environment degradation in the short run is revealed from the first graph. While in the long term, a 10% increase in IQ diminishes the environmental quality. The second graph validates the positive effects of a 10% decrease in IQ on CO₂ and other carbon gas emissions in the short and long run. However, it is noteworthy the positive impact of the reduction in IQ, in the long run, is higher than the increase in IQ.

The impulse response plot of GLOB and CO₂ with other carbon gasses emissions is presented in **Figure 8**. A 10% increase in GLOB is positively linked to CO₂ and other carbon gas emissions in the short and long run. However, the positive impact of the increase in GLOB on CO₂ and other carbon gas emissions is dominant over the same reduction in GLOB. Nevertheless, on the contrary, a 10% reduction in GLOB

improves the environmental quality in the short run and harms the environment in the long run.

The positive and negative effects of REM on CO₂ and other carbon gas emissions are shown in **Figure 8**. A 10% increase in REM, in the short run, influences the CO₂ and other carbon gas emission negatively. Contrarily, it degrades the environment in the long run. The inverse conclusion is accurate for the case of reduction in REM. Indeed, a 10% decrease in REM has positive and negative impacts on CO₂ and other carbon gas emissions in the short and long run, respectively.

The impulse response plot of URB and CO₂ and other carbon gas emissions is presented in **Figure 10**. It can be revealed that a 10% increase in the independent variable (URB) has positive impacts on CO₂ and other carbon gas emissions in the short and long run. Contrarily, a 10% decrease in URB improves environment quality in the short and long run.

CONCLUSION AND RECOMMENDATIONS

This study scrutinized the environmental impact of economic growth, institutional quality, globalization, energy consumption, financial development, and remittance within the EKC framework in the United States of America from 1985 to 2020 (based on the latest data availability). The ADF and PP unit root test results verified the probability of applying the ARDL model, implying that the dependent variable is stationary at the first differences and explanatory (control) variables are integrated of order (0) or (1) or a mixture of both. The maximum lag length was identified based on the different criteria. The F-bounds testing approach proposed by Pesaran et al. (2001) confirmed the cointegration between dependent and regressors (control variables) in the long term. Moreover, the impact of positive and negative shocks in each regressor (control) variable on the dependent variable, keeping other variables unchanged, was investigated using the novel stimulated dynamic ARDL model. The residuals diagnostic test, Ramsey RESET test, CUSUM, and CUSUMSQ results confirmed the robustness and parameter stability of the selected model.

The results affirmed the EKC hypothesis in the USA since economic growth is positively linked to CO₂ emissions in the short and long term. In contrast, the economic growth square is linked negatively to the environmental degradation indicator.

Based on this finding, energy consumption, financial development, globalization, remittance, and urbanization increase pollution in the USA while the institutional quality improves the sustainable environmental quality there. These results have practical policy implications for the government and policymakers as follows:

- Energy consumption boosts CO₂ emission directly and indirectly through urbanization and remittances. Indeed, the positive CO₂ emissions-urbanization nexus indicates environmental side effects of the growing urban population. Therefore, the government must switch from conventional

fuels to renewable sources to meet the increasing energy needs of the population, control the environmental side effects of burning fossil fuels, and achieve sustainable development goals and improve energy security and efficiency. For instance, the government could provide research and development incentives in green and renewable energy by waiving a portion of R&D costs. Furthermore, according to the role of globalization in boosting CO₂ emissions, the government needs to consider this an effective economic tool to formulate and design an inclusive environment-economic national energy policy. Moreover, considering the positive impact of economic growth and the inevitable role of financial development in financing mechanisms, the government must prioritize environmental quality and maintain economic growth in designing financial restructuring packages. In this regard, the government must facilitate and support conducting eco-friendly energy projects. The CO₂ emissions-urbanization nexus is positive.

- The positive impact of institutional quality on sustainable environmental quality showed that the government could control CO₂ emissions by enhancing the institutional quality by diversifying the energy mix (increasing the share of renewable energy sources) and providing better economic freedom and a business environment.
- One of the major limitations of this study is that dynamic ARDL simulations model can only be used for one country that has time-series data, the scope of this study can be further enhanced by using the applications of dynamic ARDL simulations with a panel data model to predict the positive and negative shock through graphical representation. This study did not cover all elements of environmental degradation that impact the environment, further studies can be conducted by including socioeconomic factors and technological elements.

DATA AVAILABILITY STATEMENT

The original contributions presented in the study are included in the article/Supplementary Material, further inquiries can be directed to the corresponding authors.

AUTHOR CONTRIBUTIONS

MK: Conceptualization, Methodology, Writing—original draft, Review and Editing, Data Curation. MKK: Writing—Review and Editing, Software, formal analysis. VD: Writing—Review and Editing, Data Curation. BO: Writing—Review and Editing, Software, formal analysis. SA: Writing—Review and Editing. SS: Writing—Review and Editing, Investigation, Supervision. SD: Writing—Review and Editing, Investigation.

REFERENCES

- Abbasi, K. R., Shahbaz, M., Jiao, Z., and Tufail, M. (2021). How Energy Consumption, Industrial Growth, Urbanization, and CO₂ Emissions Affect Economic Growth in Pakistan? A Novel Dynamic ARDL Simulations Approach. *Energy* 221, 119793. doi:10.1016/j.energy.2021.119793
- Acheampong, A. O. (2019). Modelling for Insight: Does Financial Development Improve Environmental Quality. *Energ. Econ.* 83, 156–179. doi:10.1016/j.eneco.2019.06.025
- Adebayo, T. S., and Rjoub, H. (2021). A New Perspective into the Impact of Renewable and Nonrenewable Energy Consumption on Environmental Degradation in Argentina: a Time-Frequency Analysis. *Environ. Sci. Pollut. Res.* doi:10.1007/s11356-021-16897-6
- Adebola Solarin, S., Al-Mulali, U., and Ozturk, I. (2017). Validating the Environmental Kuznets Curve Hypothesis in India and China: The Role of Hydroelectricity Consumption. *Renew. Sust. Energ. Rev.* 80, 1578–1587. doi:10.1016/j.rser.2017.07.028
- Ahmad, M., Khan, Z., Ur Rahman, Z., and Khan, S. (2018). Does Financial Development Asymmetrically Affect CO₂ Emissions in China? an Application of the Nonlinear Autoregressive Distributed Lag (NARDL) Model. *Carbon Manage.* 9 (6), 631–644. doi:10.1080/17583004.2018.1529998
- Ahmad, M., Ul Haq, Z., Khan, Z., Khattak, S. I., Ur Rahman, Z., and Khan, S. (2019). Does the Inflow of Remittances Cause Environmental Degradation? Empirical Evidence from China. *Econ. Research-Ekonomska Istraživanja* 32 (1), 2099–2121. doi:10.1080/1331677x.2019.1642783
- Ahmed, Z., Asghar, M. M., Malik, M. N., and Nawaz, K. (2020). Moving towards a Sustainable Environment: the Dynamic Linkage between Natural Resources, Human Capital, Urbanization, Economic Growth, and Ecological Footprint in China. *Resour. Pol.* 67, 101677. doi:10.1016/j.resourpol.2020.101677
- Akadir, S. S., and Adebayo, T. S. (2021). Asymmetric Nexus Among Financial Globalization, Non-renewable Energy, Renewable Energy Use, Economic Growth, and Carbon Emissions: Impact on Environmental Sustainability Targets in India. *Environ. Sci. Pollut. Res.* 14. doi:10.1007/s11356-021-16849-0
- Ali, R., Bakhsh, K., and Yasin, M. A. (2019). Impact of Urbanization on CO₂ Emissions in Emerging Economy: Evidence from Pakistan. *Sust. Cities Soc.* 48, 101553. doi:10.1016/j.scs.2019.101553
- Bashir, M. A., Sheng, B., Doğan, B., Sarwar, S., and Shahzad, U. (2020). Export Product Diversification and Energy Efficiency: Empirical Evidence from OECD Countries. *Struct. Change Econ. Dyn.* 55, 232–243. doi:10.1016/j.strueco.2020.09.002
- Bashir, M. F., Ma, B., Shahbaz, M., Shahzad, U., and Vo, X. V. (2021). Unveiling the Heterogeneous Impacts of Environmental Taxes on Energy Consumption and Energy Intensity: Empirical Evidence from OECD Countries. *Energy* 226, 120366. doi:10.1016/j.energy.2021.120366
- BP (2020). *BP Statistical Review of World Energy 2020*.
- Danish, D., and Ulucak, R. (2021). A Revisit to the Relationship between Financial Development and Energy Consumption: Is Globalization paramount. *Energy* 227, 120337. doi:10.1016/j.energy.2021.120337
- Doğan, B., Driha, O. M., Balsalobre Lorente, D., and Shahzad, U. (2020). The Mitigating Effects of Economic Complexity and Renewable Energy on Carbon Emissions in Developed Countries. *Sust. Dev.* 29, 1–12. doi:10.1002/sd.2125
- Dreher, A. (2006). Does Globalization Affect Growth? Evidence from a New index of Globalization. *Appl. Econ.* 38 (10), 1091–1110. doi:10.1080/00036840500392078
- Ehigiamusoe, K. U., and Lean, H. H. (2019). Effects of Energy Consumption, Economic Growth, and Financial Development on Carbon Emissions: Evidence from Heterogeneous Income Groups. *Environ. Sci. Pollut. Res.* 26 (22), 22611–22624. doi:10.1007/s11356-019-05309-5
- Farzanegan, M. R., and Markwardt, G. (2018). Development and Pollution in the Middle East and North Africa: Democracy Matters. *J. Pol. Model.* 40 (2), 350–374. doi:10.1016/j.jpolmod.2018.01.010
- Fatima, T., Shahzad, U., and Cui, L. (2021). Renewable and Nonrenewable Energy Consumption, Trade and CO₂ Emissions in High Emitter Countries: Does the Income Level Matter. *J. Environ. Plann. Manage.* 64 (7), 1227–1251. doi:10.1080/09640568.2020.1816532
- Ghazouani, A., Xia, W., Ben Jebli, M., and Shahzad, U. (2020). Exploring the Role of Carbon Taxation Policies on CO₂ Emissions: Contextual Evidence from Tax Implementation and Non-implementation European Countries. *Sustainability* 12 (20), 1–16. doi:10.3390/su12208680
- Gökmenoğlu, K., and Taspinar, N. (2016). The Relationship between CO₂ Emissions, Energy Consumption, Economic Growth and FDI: the Case of Turkey. *J. Int. Trade Econ. Dev.* 25 (5), 706–723.
- Grossman, G., and Krueger, A. (1991). “Environmental Impacts of a North American Free Trade Agreement,” in *National Bureau of Economic Research* (Cambridge, MA: National Bureau of Economic Research). doi:10.3386/w3914
- Guo, M., Hu, Y., and Yu, J. (2019). The Role of Financial Development in the Process of Climate Change: Evidence from Different Panel Models in China. *Atmos. Pollut. Res.* 10 (5), 1375–1382. doi:10.1016/j.apr.2019.03.006
- Haseeb, A., Xia, E., Danish, M. A., Baloch, M. A., and Abbas, K. (2018). Financial Development, Globalization, and CO₂ Emission in the Presence of EKC: Evidence from BRICS Countries. *Environ. Sci. Pollut. Res.* 25 (31), 31283–31296. doi:10.1007/s11356-018-3034-7
- ICRG. (2021). International Country Risk. Available at: <https://www.prsgroup.com/explore-our-products/international-country-risk-guide/>
- Islam, M. M., Khan, M. K., Tareque, M., Jehan, N., and Dagar, V. (2021). Impact of Globalization, Foreign Direct Investment, and Energy Consumption on CO₂ Emissions in Bangladesh: Does Institutional Quality Matter. *Environ. Sci. Pollut. Res.* 28, 1–21. doi:10.1007/s11356-021-13441-4
- Jordan, S., and Philips, A. Q. (2018). Cointegration Testing and Dynamic Simulations of Autoregressive Distributed Lag Models. *Stata J.* 18 (4), 902–923. doi:10.1177/1536867x1801800409
- Jun, W., Mughal, N., Zhao, J., Shabbir, M. S., Niedbala, G., Jain, V., et al. (2021). Does Globalization Matter for Environmental Degradation? Nexus Among Energy Consumption, Economic Growth, and Carbon Dioxide Emission. *Energy Policy* 153, 112230.
- Kandil, M., and Mirzaie, I. (2008). The Impact of Capital and Remittances Flows on Economic Performance in MENA Countries. *World Econ.* 10 (3), 159–192.
- Khan, M. I., Teng, J. Z., and Khan, M. K. (2020). The Impact of Macroeconomic and Financial Development on Carbon Dioxide Emissions in Pakistan: Evidence with a Novel Dynamic Simulated ARDL Approach. *Environ. Sci. Pollut. Res.* 27 (31), 39560–39571. doi:10.1007/s11356-020-09304-z
- Khan, M. K., Teng, J. Z., and Khan, M. I. (2019a). Asymmetric Impact of Oil Prices on Stock Returns in Shanghai Stock Exchange: Evidence from Asymmetric ARDL Model. *PLoS ONE* 14 (6), e0218289. doi:10.1371/journal.pone.0218289
- Khan, M. K., Teng, J. Z., Khan, M. I., and Khan, M. O. (2019b). Impact of Globalization, Economic Factors and Energy Consumption on CO₂ Emissions in Pakistan. *Sci. Total Environ.* 688, 424–436. doi:10.1016/j.scitotenv.2019.06.065
- Khan, Z. U., Ahmad, M., and Khan, A. (2020). On the Remittances-Environment Led Hypothesis: Empirical Evidence from BRICS Economies. *Environ. Sci. Pollut. Res.* 27 (14), 16460–16471. doi:10.1007/s11356-020-07999-8
- Kuznets, S. (1955). Economic Growth and Income Inequality. *Am. Econ. Rev.* 45 (1), 1–28.
- Kwakwa, P. A., and Alhassan, H. (2018). The Effect of Energy and Urbanisation on Carbon Dioxide Emissions: Evidence from Ghana. *OPEC Econ. Rev.* 42 (4), 301–330. doi:10.1111/opec.12133
- Lama, M. J. (2009). Long-run Determinants of Pollution: A Robustness Analysis. *Ecol. Econ.* 69 (1), 135–144. doi:10.1016/j.ecolecon.2009.08.002
- Le, H. P., and Ozturk, I. (2020). The Impacts of Globalization, Financial Development, Government Expenditures, and Institutional Quality on CO₂ Emissions in the Presence of Environmental Kuznets Curve. *Environ. Sci. Pollut. Res.* 27 (18), 22680–22697. doi:10.1007/s11356-020-08812-2
- Lee, C. T., Lim, J. S., Fan, Y. V., Liu, X., Fujiwara, T., and Klemeš, J. J. (2018). Enabling Low-Carbon Emissions for Sustainable Development in Asia and beyond. *J. Clean. Prod.* 176, 726–735. doi:10.1016/j.jclepro.2017.12.110
- Liu, X., and Bae, J. (2018). Urbanization and Industrialization Impact of CO₂ Emissions in China. *J. Clean. Prod.* 172, 178–186. doi:10.1016/j.jclepro.2017.10.156
- Neog, Y., and Yadava, A. K. (2020). Nexus Among CO₂ Emissions, Remittances, and Financial Development: a NARDL Approach for India. *Environ. Sci. Pollut. Res.* 27 (35), 44470–44481. doi:10.1007/s11356-020-10198-0
- Nwani, C., and Omoke, P. C. (2020). Does Bank Credit to the Private Sector Promote Low-Carbon Development in Brazil? an Extended STIRPAT Analysis Using Dynamic ARDL Simulations. *Environ. Sci. Pollut. Res.* 27, 31408–31426. doi:10.1007/s11356-020-09415-7

- Oryani, B., Koo, Y., Rezaia, S., and Shafiee, A. (2021a). Investigating the Asymmetric Impact of Energy Consumption on Reshaping Future Energy Policy and Economic Growth in Iran Using Extended Cobb-Douglas Production Function. *Energy* 216, 119187. doi:10.1016/j.energy.2020.119187
- Oryani, B., Koo, Y., Rezaia, S., Shafiee, A., Khan, M. K., and Mahdavian, S. M. (2021b). *The Role of Electricity Mix and Transportation Sector in Designing a Green-Growth Strategy in Iran*. Amsterdam, Netherlands: Energy, 121178.
- Panayotou, T. (1993). *Empirical Tests and Policy Analysis of Environmental Degradation at Different Stages of Economic Development*. Geneva, Switzerland: International Labour Organization.
- Paramati, S. R., Apergis, N., and Ummalla, M. (2017). Financing Clean Energy Projects through Domestic and Foreign Capital: The Role of Political Cooperation Among the EU, the G20 and OECD Countries. *Energ. Econ.* 61, 62–71. doi:10.1016/j.eneco.2016.11.001
- Pata, U. K., and Caglar, A. E. (2021). Investigating the EKC Hypothesis with Renewable Energy Consumption, Human Capital, Globalization and Trade Openness for China: Evidence from Augmented ARDL Approach with a Structural Break. *Energy* 216, 119220. doi:10.1016/j.energy.2020.119220
- Pata, U. K., and Isik, C. (2021). Determinants of the Load Capacity Factor in China: A Novel Dynamic ARDL Approach for Ecological Footprint Accounting. *Resour. Pol.* 74, 102313. doi:10.1016/j.resourpol.2021.102313
- Pata, U. K. (2018). The Effect of Urbanization and Industrialization on Carbon Emissions in Turkey: Evidence from ARDL Bounds Testing Procedure. *Environ. Sci. Pollut. Res.* 25 (8), 7740–7747. doi:10.1007/s11356-017-1088-6
- Pesaran, M. H., Shin, Y., and Smith, R. J. (2001). Bounds Testing Approaches to the Analysis of Level Relationships. *J. Appl. Econ.* 16 (3), 289–326. doi:10.1002/jae.616
- Phong, L. H. (2019). Globalization, Financial Development, and Environmental Degradation in the Presence of Environmental Kuznets Curve: Evidence from ASEAN-5 Countries. *Int. J. Energ. Econ. Pol.* 9 (2), 40–50.
- Rafique, M. Z., Dogan, B., Husain, S., Huang, S., and Shahzad, U. (2021). Role of Economic Complexity to Induce Renewable Energy: Contextual Evidence from G7 and E7 Countries. *Int. J. Green Energ.* 18 (7), 745–754. doi:10.1080/15435075.2021.1880912
- Raggad, B. (2018). Carbon Dioxide Emissions, Economic Growth, Energy Use, and Urbanization in Saudi Arabia: Evidence from the ARDL Approach and Impulse Saturation Break Tests. *Environ. Sci. Pollut. Res.* 25 (15), 14882–14898. doi:10.1007/s11356-018-1698-7
- Rahman, Z. I. A. U. R., Cai, H., and Ahmad, M. (2019). A New Look at the Remittances-FDI-Energy-Environment Nexus in the Case of Selected Asian Nations. *Singapore Econ. Rev.* 1–19. doi:10.1142/s0217590819500176
- Salahuddin, M., Gow, J., Ali, M. I., Hossain, M. R., Al Azami, K. S., Akbar, D., et al. (2019). Urbanization-globalization-CO2 Emissions Nexus Revisited: Empirical Evidence from South Africa. *Heliyon* 5 (6), e01974. doi:10.1016/j.heliyon.2019.e01974
- Salman, M., Long, X., Dauda, L., and Mensah, C. N. (2019). The Impact of Institutional Quality on Economic Growth and Carbon Emissions: Evidence from Indonesia, South Korea and Thailand. *J. Clean. Prod.* 241, 118331. doi:10.1016/j.jclepro.2019.118331
- Sarkodie, S. A., Strezov, V., Weldekidan, H., Asamoah, E. F., Owusu, P. A., and Doyi, I. N. Y. (2019). Environmental Sustainability Assessment Using Dynamic Autoregressive-Distributed Lag Simulations-Nexus between Greenhouse Gas Emissions, Biomass Energy, Food and Economic Growth. *Sci. Total Environ.* 668, 318–332. doi:10.1016/j.scitotenv.2019.02.432
- Shafik, N., and Bandyopadhyay, S. (1992). *Economic Growth and Environmental Quality: Time-Series and Cross-Country Evidence*, 904. Washington, DC: World Bank Publications.
- Shah, W. U. H., Yasmeen, R., and Padda, I. U. H. (2019). An Analysis between Financial Development, Institutions, and the Environment: a Global View. *Environ. Sci. Pollut. Res.* 26 (21), 21437–21449. doi:10.1007/s11356-019-05450-1
- Shahbaz, M., Haouas, I., Sbiba, R., and Ozturk, I. (2018a). *Financial Development-Environmental Degradation Nexus in the United Arab Emirates: The Importance of Growth*. Amsterdam, Netherlands: Globalization and Structural Breaks, 87365.
- Shahbaz, M., Mallick, H., Mahalik, M. K., and Loganathan, N. (2015). Does Globalization Impede Environmental Quality in India. *Ecol. Indicators* 52, 379–393. doi:10.1016/j.ecolind.2014.12.025
- Shahbaz, M., Naem, M., Ahad, M., and Tahir, I. (2018b). Is Natural Resource Abundance a Stimulus for Financial Development in the USA. *Resour. Pol.* 55, 223–232. doi:10.1016/j.resourpol.2017.12.006
- Shahbaz, M., Shahzad, S. J. H., and Mahalik, M. K. (2018c). Is Globalization Detrimental to CO2 Emissions in Japan? New Threshold Analysis. *Environ. Model. Assess.* 23 (5), 557–568. doi:10.1007/s10666-017-9584-0
- Shahzad, U., Dogan, B., Sinha, A., and Fareed, Z. (2021a). Does Export Product Diversification Help to Reduce Energy Demand: Exploring the Contextual Evidences from the Newly Industrialized Countries. *Energy* 214, 118881. doi:10.1016/j.energy.2020.118881
- Shahzad, U. (2020). Environmental Taxes, Energy Consumption, and Environmental Quality: Theoretical Survey with Policy Implications. *Environ. Sci. Pollut. Res.* 27 (Issue 20), 24848–24862. doi:10.1007/s11356-020-08349-4
- Shahzad, U., Ferraz, D., Dogan, B., and Aparecida do Nascimento Rebelatto, D. (2020). Export Product Diversification and CO2 Emissions: Contextual Evidences from Developing and Developed Economies. *J. Clean. Prod.* 276, 124146. doi:10.1016/j.jclepro.2020.124146
- Shahzad, U., Lv, Y., Dogan, B., and Xia, W. (2021b). Unveiling the Heterogeneous Impacts of export Product Diversification on Renewable Energy Consumption: New Evidence from G-7 and E-7 Countries. *Renew. Energ.* 164, 1457–1470. doi:10.1016/j.renene.2020.10.143
- Shahzad, U., and Qin, F. (2019). New Terrorism and Capital Flight: Pre and post Nine Eleven Analysis for Asia. *Ann. Econ. Finance* 20 (1).
- Shakoor, A., Chen, X., Farooq, T. H., Shahzad, U., Ashraf, F., Rehman, A., et al. (2020). Fluctuations in Environmental Pollutants and Air Quality during the Lockdown in the USA and China: Two Sides of COVID-19 Pandemic. *Air Qual. Atmos. Health* 13 (11), 1335–1342. doi:10.1007/s11869-020-00888-6
- Shen, S., Ahmad, M., Tan, Z., Adebayo, T. S., Man Li, R. Y., and Kirikkaleli, D. (2021). The Role of Energy Prices and Non-linear Fiscal Decentralization in Limiting Carbon Emissions: Tracking Environmental Sustainability. *Energy* 234, 121243. doi:10.1016/j.energy.2021.121243
- Sharma, G. D., Shah, M. I., Shahzad, U., Jain, M., and Chopra, R. (2021). Exploring the Nexus between Agriculture and Greenhouse Gas Emissions in BIMSTEC Region: The Role of Renewable Energy and Human Capital as Moderators. *J. Environ. Manage.* 297 (May), 113316. doi:10.1016/j.jenvman.2021.113316
- Sun, W., and Huang, C. (2020). How Does Urbanization Affect Carbon Emission Efficiency? Evidence from China. *J. Clean. Prod.* 272, 122828. doi:10.1016/j.jclepro.2020.122828
- Tamazian, A., and Bhaskara Rao, B. (2010). Do economic, Financial and Institutional Developments Matter for Environmental Degradation? Evidence from Transitional Economies. *Energ. Econ.* 32 (1), 137–145. doi:10.1016/j.eneco.2009.04.004
- Teng, J.-Z., Khan, M. K., Khan, M. I., Chishti, M. Z., and Khan, M. O. (2021). Effect of Foreign Direct Investment on CO2 Emission with the Role of Globalization, Institutional Quality with Pooled Mean Group Panel ARDL. *Environ. Sci. Pollut. Res.* 28 (5), 5271–5282. doi:10.1007/s11356-020-10823-y
- Ur Rahman, Z., Chongbo, W., and Ahmad, M. (2019). An (A)symmetric Analysis of the Pollution haven Hypothesis in the Context of Pakistan: a Non-linear Approach. *Carbon Manage.* 10 (3), 227–239. doi:10.1080/17583004.2019.1577179
- Usman, M., and Jahanger, A. (2021). Heterogeneous Effects of Remittances and Institutional Quality in Reducing Environmental Deficit in the Presence of EKC Hypothesis: A Global Study with the Application of Panel Quantile Regression. *Environ. Sci. Pollut. Res.* 1–19. doi:10.1007/s11356-021-13216-x
- Wang, Z., ben Jebli, M., Madaleno, M., Dogan, B., and Shahzad, U. (2021a). Does export Product Quality and Renewable Energy Induce Carbon Dioxide Emissions: Evidence from Leading Complex and Renewable Energy Economies. *Renew. Energ.* 171, 360–370. doi:10.1016/j.renene.2021.02.066
- Wang, Z., Zaman, S., uz Zaman, Q., and Rasool, S. F. (2021b). Impact of Remittances on Carbon Emission: Fresh Evidence from a Panel of Five Remittance-Receiving Countries. *Environ. Sci. Pollut. Res.* 1–13. doi:10.1007/s11356-021-14412-5
- Wawrzyniak, D., and Doryń, W. (2020). Does the Quality of Institutions Modify the Economic Growth-Carbon Dioxide Emissions Nexus? Evidence from a Group of Emerging and Developing Countries. *Econ. Research-Ekonomska Istraživanja* 33 (1), 124–144. doi:10.1080/1331677x.2019.1708770
- World Bank. (2020). World Development Indicators. Available at: <http://databank.worldbank.org/data/reports.aspx?source%40worlddevelopment-%0Aindicators>

- Xu, Z., Baloch, M. A., Danish, F., Meng, F., Zhang, J., and Mahmood, Z. (2018). Nexus between Financial Development and CO2 Emissions in Saudi Arabia: Analyzing the Role of Globalization. *Environ. Sci. Pollut. Res.* 25 (28), 28378–28390. doi:10.1007/s11356-018-2876-3
- Zaidi, S. A. H., Zafar, M. W., Shahbaz, M., and Hou, F. (2019). Dynamic Linkages between Globalization, Financial Development and Carbon Emissions: Evidence from Asia Pacific Economic Cooperation Countries. *J. Clean. Prod.* 228, 533–543. doi:10.1016/j.jclepro.2019.04.210
- Zhang, L., Godil, D. I., Bibi, M., Khan, M. K., Sarwat, S., and Anser, M. K. (2021a). Caring for the Environment: How Human Capital, Natural Resources, and Economic Growth Interact with Environmental Degradation in Pakistan? A Dynamic ARDL Approach. *Sci. Total Environ.* 774, 145553. doi:10.1016/j.scitotenv.2021.145553
- Zhang, L., Li, Z., Kirikkaleli, D., Adebayo, T. S., Adeshola, I., and Akinsola, G. D. (2021b). Modeling CO2 Emissions in Malaysia: an Application of Maki Cointegration and Wavelet Coherence Tests. *Environ. Sci. Pollut. Res.* 28 (20), 26030–26044. doi:10.1007/s11356-021-12430-x

Conflict of Interest: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's Note: All claims expressed in this article are solely those of the authors and do not necessarily represent those of their affiliated organizations, or those of the publisher, the editors and the reviewers. Any product that may be evaluated in this article, or claim that may be made by its manufacturer, is not guaranteed or endorsed by the publisher.

Copyright © 2021 Khan, Kamran Khan, Dagar, Oryani, Akbar, Salem and Dildar. This is an open-access article distributed under the terms of the Creative Commons Attribution License (CC BY). The use, distribution or reproduction in other forums is permitted, provided the original author(s) and the copyright owner(s) are credited and that the original publication in this journal is cited, in accordance with accepted academic practice. No use, distribution or reproduction is permitted which does not comply with these terms.

RETRACTED