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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

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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 CO_2 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 CO_2 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 worstening 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
Kirikkaleli and Adebayo (2021)	Worldwide	CO_2, GDP, TI, REC, FD	FMOLS, DOLS, CCR, Bayer and Hanck cointegration, frequency-domain causality tests	GDP (–), TI (–), REC (+)
Akadiri 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 Kirikkaleli (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 distribute 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 (CO_2) 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 CO_2 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 CO_2 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 CO_2 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 Finacial Development (FD), share trading, and stock marketing on CO_2 emissions in the provinces of China from 1997to 2015.

Ehigiamusoe and Lean (2019) showed the FD's direct and adverse impact on CO_2 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 CO_2 with harmful gasses emission in countries like China (Bashir et al., 2021). Acheampong (2019) declared that Financial Development-(FD) tends to increase CO_2 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 Taspinar (2016) presented the positive and, in some cases, negative impacts of Energy Consumption-(EC) and Economic Growth-(EG) on Turkey's CO_2 plus other harmful gasses 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 CO_2 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 CO_2 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 CO_2 with other harmful gasses emission. Sun and Huang (2020) explored an inverted U-shaped trend linking URB and CO_2 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 CO_2 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-CO_2 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 CO_2 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 CO_2 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 CO_2 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 CO_2 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 CO_2 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 CO_2 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 CO_2 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**.

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

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

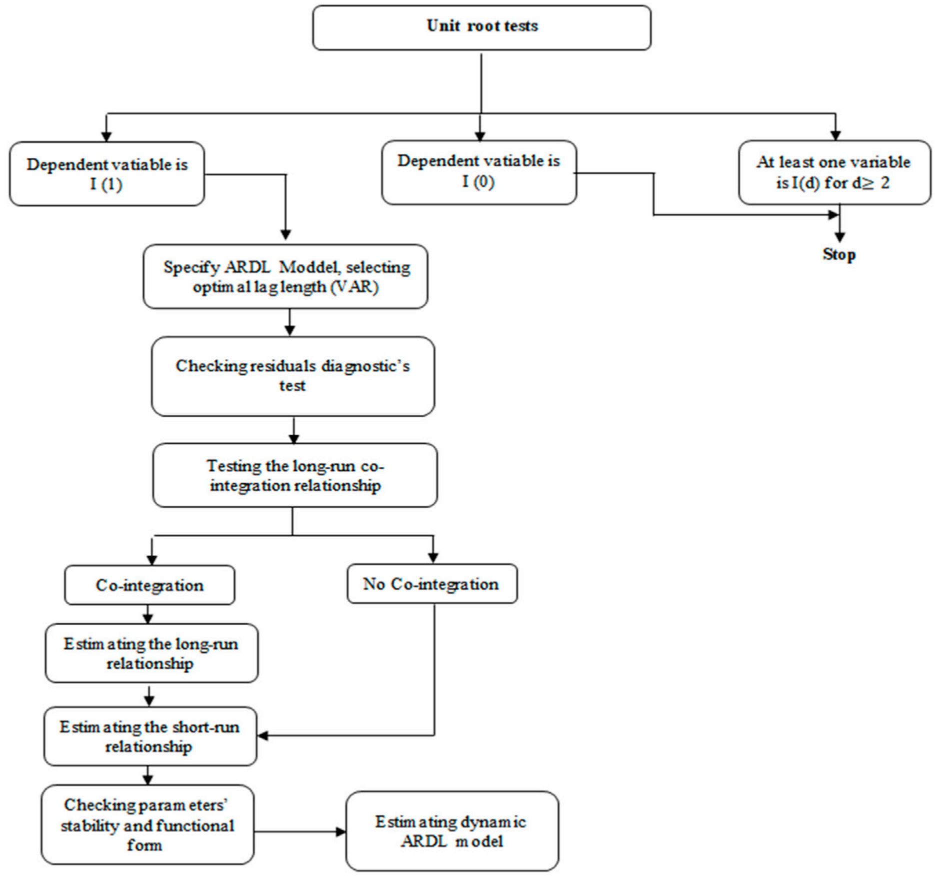

FIGURE 1 | Research design.

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**):

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

Where Δ signifies the first differential operator; y indicates the dependent variable (CO_2 emissions) and $x_1, \cdots, x_k$ 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:

$$H_0:\ \theta_1 = \cdots = \theta_k = 0$$
$$H_0:\ \theta_1 \neq \cdots \neq \theta_k \neq 0$$

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

- $F - statistics > critical\ value\ of\ the\ upper\ bound$, implying the long-run cointegration
- $F - statistics < critical\ value\ of\ the\ lower\ bound$, 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**

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

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**:

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

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	−3.555***	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

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; $L1\_CO_2$ 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 CO_2 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), EG^2 (0.488), and EG (0.366) positively impact CO_2 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 EG^2 impact CO_2 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 CO_2 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 CO_2 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 CO_2 with other carbon gasses emissions about 0.69 and 0.27% in the long and short run, respectively. This

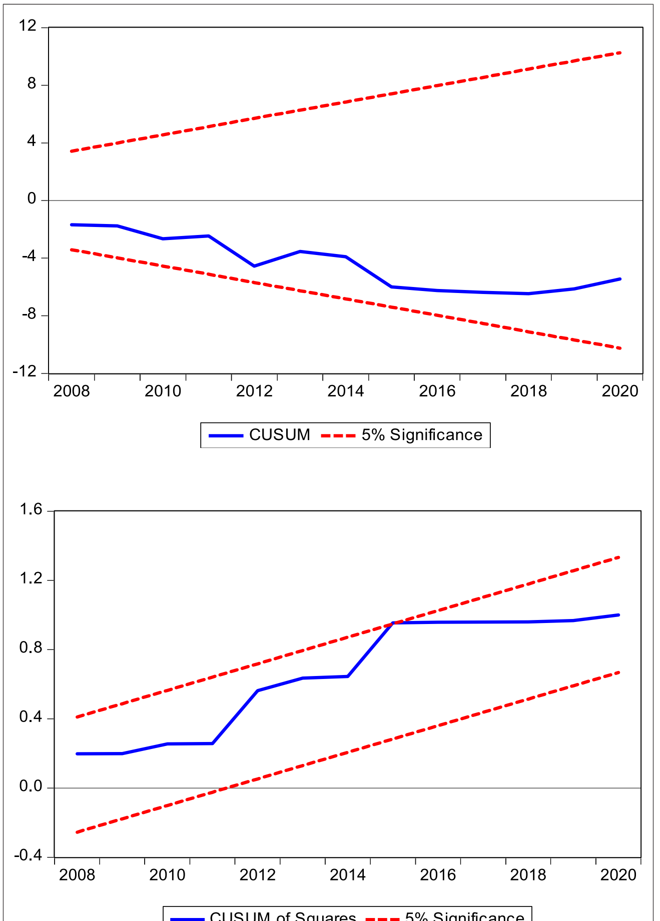

FIGURE 2 | The plot of the cumulative sum of the recursive residuals and the plot of cumulative sum of recursive residuals of square.

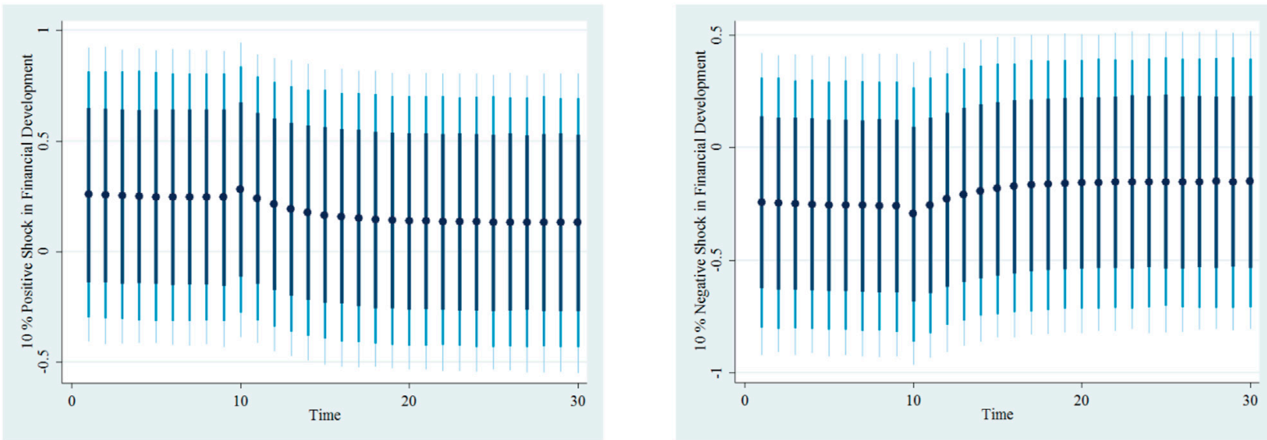

FIGURE 3 | Financial development and carbon dioxide emission. The average prediction value has been exhibited *via* dots, while the CI at 75, 90, and 95% have been shown by the dark blue to the light blue lines, respectively.

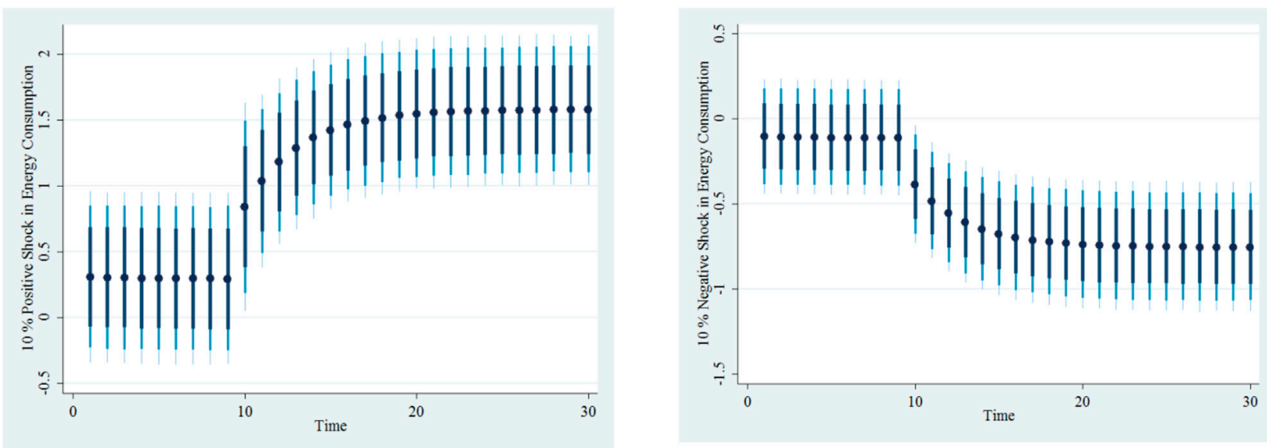

FIGURE 4 | Energy consumption and carbon dioxide emission. The average prediction value has been exhibited *via* dots, while the CI at 75, 90, and 95% have been shown by the dark blue to the light blue lines, respectively.

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 CO_2 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 CO_2 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 CO_2 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 CO_2 with other carbon gasses emissions. However, it contradicts the results of Zaidi et al. (2019). From empirical findings, IQ has been negatively linked with CO_2 and other carbon gas emissions in the short and long run. A 1% increase in institutional quality reduces CO_2 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 CO_2 and other carbon gas emissions. Their results demonstrated that the REC improves environmental quality. However, on the contrary, FDI, ELC, IQ, and EG increase CO_2 emissions. Moreover, the results confirmed GLOB's positive and negative impacts on CO_2 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

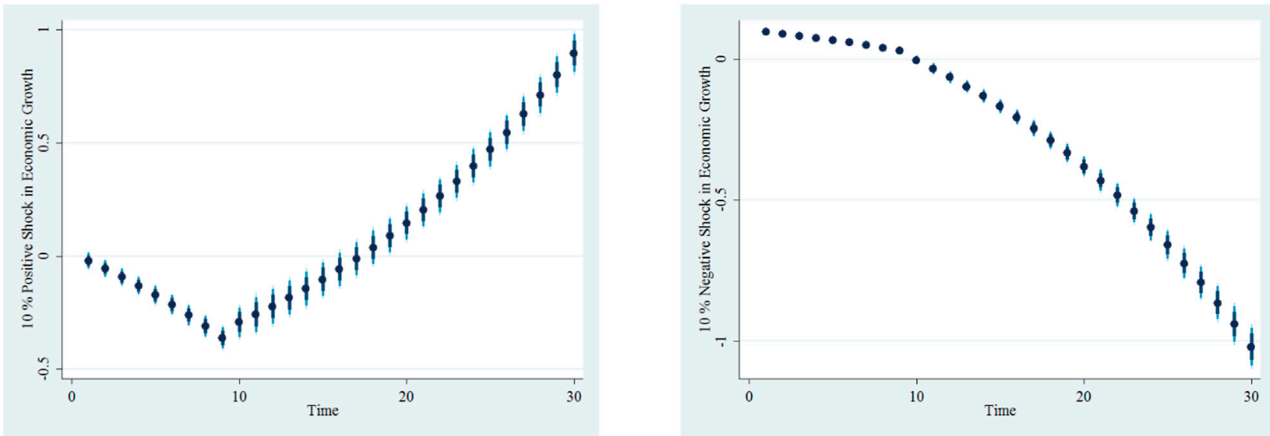

FIGURE 5 | Economic growth and carbon dioxide emission. The average prediction value has been exhibited *via* dots, while the CI at 75, 90, and 95% have been shown by the dark blue to the light blue lines, respectively.

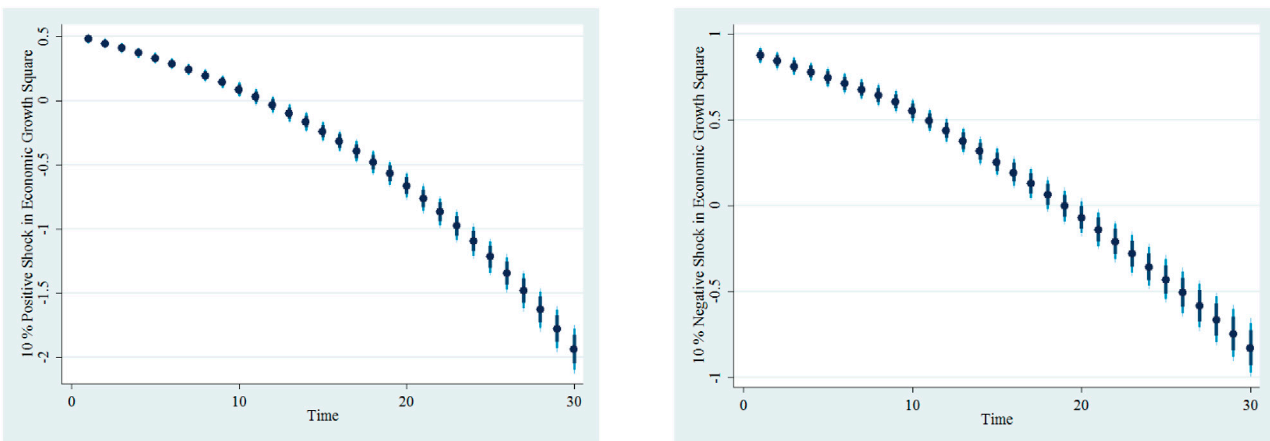

FIGURE 6 | Economic growth square and carbon dioxide emission. The average prediction value has been exhibited *via* dots, while the CI at 75, 90, and 95% have been shown by the dark blue to the light blue lines, respectively.

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 CO_2 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 CO_2 emissions in the short and long run. Indeed, a 1% increase in URB leads to a 1.4 and 1.5% increase in CO_2 emissions in the long and short run, respectively. Indeed, CO_2 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, CO_2 emissions, and URB in Saudi Arabia. His results confirmed the negative impact of URB on CO_2 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

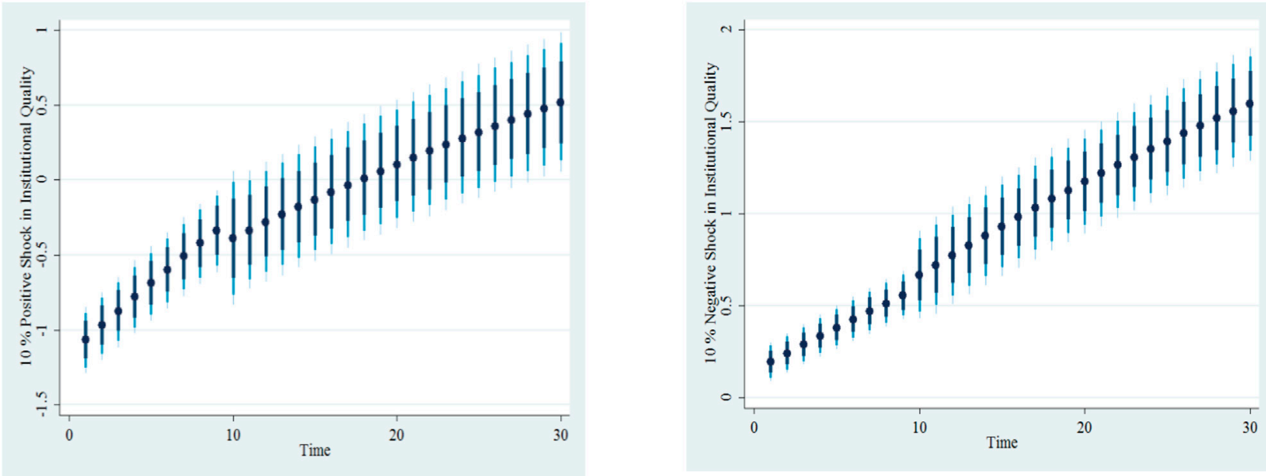

FIGURE 7 | Institutional quality and carbon dioxide emission. The average prediction value has been exhibited *via* dots, while the CI at 75, 90, and 95% have been shown by the dark blue to the light blue lines, respectively.

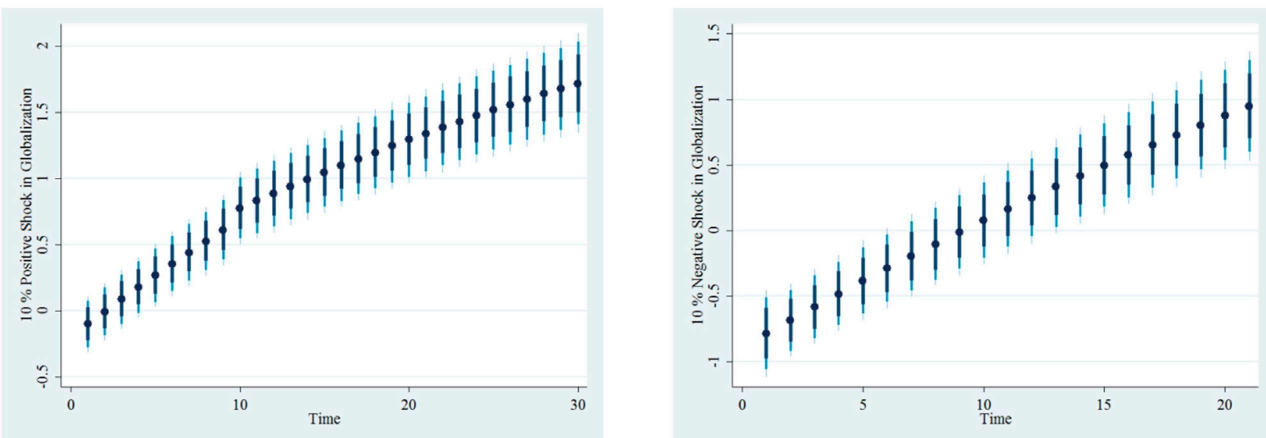

FIGURE 8 | Globalization and carbon dioxide emission. The average prediction value has been exhibited *via* dots, while the CI at 75, 90, and 95% have been shown by the dark blue to the light blue lines, respectively.

and long run in Pakistan. Moreover, the results for China confirmed the negative environmental impacts of URB. Indeed, a 1% increase in CO_2 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 CO_2 with other carbon gasses emissions is depicted in **Figure 3**. It demonstrates the positive link between a 10% increase in FD and CO_2 and other carbon gas emissions in the short and long terms. However, a 10% decrease in FD negatively affects the CO_2 with other carbon gasses emissions and improves environmental quality.

Figure 4 shows the 10% positive and negative shocks in EC and their impacts on CO_2 and other carbon gas emissions. As illustrated in the first graph, a 10% increase in EC is positively linked to CO_2 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

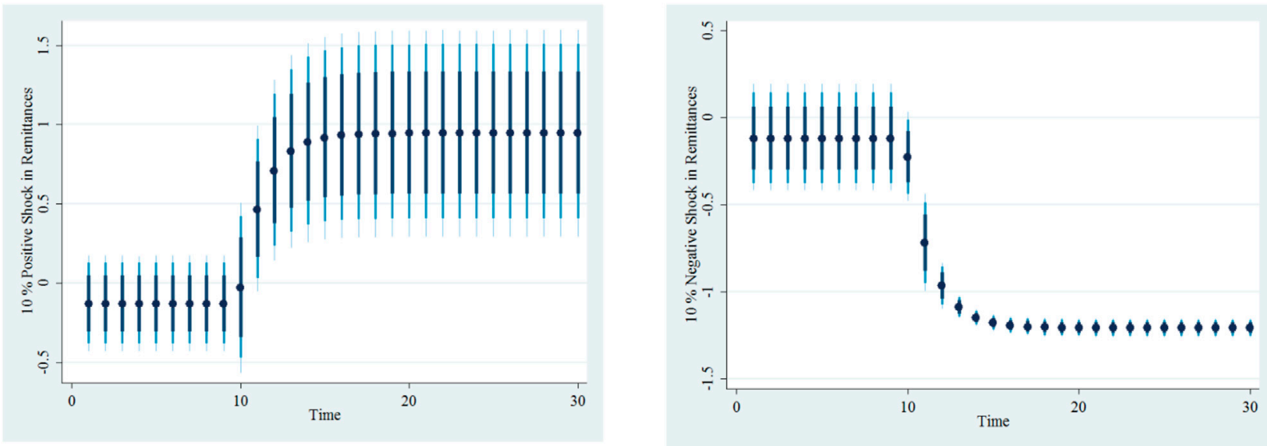

FIGURE 9 | Remittances and carbon dioxide emission. The average prediction value has been exhibited *via* dots, while the CI at 75, 90, and 95% have been shown by the dark blue to the light blue lines, respectively.

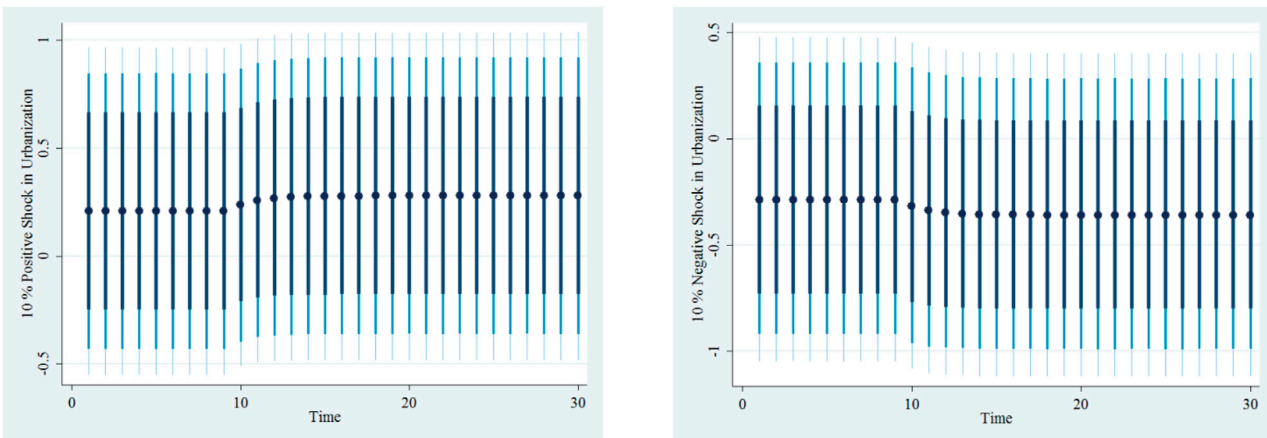

FIGURE 10 | Urbanization and carbon dioxide emission. The average prediction value has been exhibited *via* dots, while the CI at 75, 90, and 95% have been shown by the dark blue to the light blue lines, respectively.

through CO_2 and other carbon gas emission reduction in the long run.

Figure 5 exhibits the impact of positive and negative shocks in EG on CO_2 and other carbon gas emissions. In the short run, a 10% boost in EG lowers the CO_2 and other carbon gas emission while it degrades the environment in the long term. Contrarily, a 10% decrease in EG does not affect the CO_2 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 EG^2 and CO_2 with other carbon gasses emissions is depicted in **Figure 6**. A 10% boost in EG^2 does not link to the CO_2 and other carbon gas emissions in the short run, while it affects the long run negatively. Indeed, promoting the EG^2 relieves environmental degradation in the long run. However, a 10% reduction in EG^2 degrades the environment in the short run and improves it in the long run.

Figure 7 shows how CO_2 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 CO_2 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 CO_2 with other carbon gasses emissions is presented in **Figure 8**. A 10% increase in GLOB is positively linked to CO_2 and other carbon gas emissions in the short and long run. However, the positive impact of the increase in GLOB on CO_2 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 CO_2 and other carbon gas emissions are shown in **Figure 8**. A 10% increase in REM, in the short run, influences the CO_2 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 CO_2 and other carbon gas emissions in the short and long run, respectively.

The impulse response plot of URB and CO_2 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 CO_2 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 REST 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 CO_2 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 CO_2 emission directly and indirectly through urbanization and remittances. Indeed, the positive CO_2 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 CO_2 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 CO_2 emissions-urbanization nexus is positive.
- The positive impact of institutional quality on sustainable environmental quality showed that the government could control CO_2 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

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