

# DIGITALES ARCHIV

ZBW – Leibniz-Informationszentrum Wirtschaft  
*ZBW – Leibniz Information Centre for Economics*

Tanattrin Bunnag

## Article

# Environmental Kuznets curve model for the United States : a consideration of foreign direct investment variable

## Provided in Cooperation with:

International Journal of Energy Economics and Policy (IJEPP)

**Reference:** Tanattrin Bunnag (2023). Environmental Kuznets curve model for the United States : a consideration of foreign direct investment variable. In: International Journal of Energy Economics and Policy 13 (4), S. 130 - 138.  
<https://www.econjournals.com/index.php/ijeep/article/download/14385/7382/33789>.  
doi:10.32479/ijeep.14385.

This Version is available at:  
<http://hdl.handle.net/11159/631244>

## Kontakt/Contact

ZBW – Leibniz-Informationszentrum Wirtschaft/Leibniz Information Centre for Economics  
Düsternbrooker Weg 120  
24105 Kiel (Germany)  
E-Mail: [rights\[at\]zbw.eu](mailto:rights[at]zbw.eu)  
<https://www.zbw.eu/econis-archiv/>

## Standard-Nutzungsbedingungen:

Dieses Dokument darf zu eigenen wissenschaftlichen Zwecken und zum Privatgebrauch gespeichert und kopiert werden. Sie dürfen dieses Dokument nicht für öffentliche oder kommerzielle Zwecke vervielfältigen, öffentlich ausstellen, aufführen, vertreiben oder anderweitig nutzen. Sofern für das Dokument eine Open-Content-Lizenz verwendet wurde, so gelten abweichend von diesen Nutzungsbedingungen die in der Lizenz gewährten Nutzungsrechte.  
<https://zbw.eu/econis-archiv/terms-of-use>

## Terms of use:

*This document may be saved and copied for your personal and scholarly purposes. You are not to copy it for public or commercial purposes, to exhibit the document in public, to perform, distribute or otherwise use the document in public. If the document is made available under a Creative Commons Licence you may exercise further usage rights as specified in the licence.*



# Environmental Kuznets Curve Model for the United States: A Consideration of Foreign Direct Investment Variable

Tanattrin Bunnag\*

Faculty of Science and Social Sciences, Burapha University, Thailand. \*Email: [ratanan@buu.ac.th](mailto:ratanan@buu.ac.th)

Received: 20 March 2023

Accepted: 22 June 2023

DOI: <https://doi.org/10.32479/ijeeep.14385>

## ABSTRACT

This paper analyzes the causal link between CO<sub>2</sub> emission, energy consumption, GDP, the square of GDP, and foreign direct investment in the Environmental Kuznets Curve for the United States from 1979-2021. Three steps are used: bound tests to verify the presence of cointegration, autoregressive distributed lag (ARDL) model to check the effects of the dependent variables on the independent variable in the short run and long run, and finally, the vector error correction (VECM) was used to detect the causal relationships among variables. We found that the coefficients of energy consumption and foreign direct investments variables were significant at the 10% level. The variables GDP and GDP<sup>2</sup> were found to be insignificant. Energy consumption positively impacts CO<sub>2</sub> emissions, while FDI negatively influences CO<sub>2</sub> emissions. In addition, in causal analysis, it is found that GDP and GDP<sup>2</sup> indirectly affect CO<sub>2</sub> emissions. GDP and GDP<sup>2</sup> impact energy consumption and FDI; later, FDI was passed through CO<sub>2</sub> emission. Finally, the federal government should accelerate investment policies, tax credits, regulatory actions, state policies, research and development, and market trends to drive significant renewable deployment.

**Keywords:** CO<sub>2</sub> Emissions, Energy Consumption, GDP, Foreign Direct Investment, The Environmental Kuznets Curve

**JEL Classifications:** C54, Q4, Q5

## 1. INTRODUCTION

A consequence of the study of the relationship of variables in the Environmental Kuznets curve by empirical evidence of a long-run environmental Kuznets curve (EKC) for Ecuador by Zambrano-Monserrate et al. (2016), including Bunnag (2021) and Bunnag (2023) was a case study in Thailand. It later expanded its interest to the United States, the world's second-largest carbon emitter, second to China.

This empirical study discusses the environmental degradation of one of the six superpowers and one of the most developed countries-the United States of America, which comprises 52 well-developed states. The GDP of the United States is ranked first globally. Moreover, it ranks eighth in gross domestic product per capita. Due to its highly developed economy, the United States has to face the effects of energy pollutants and carbon emissions, mainly caused by the financial sector, economic activity,

urbanization rate, industrialization speed, and the utilization of advanced technology (Khan et al., 2019a).

Climate change already inflicts severe damage on the United States and other regions (Murshed et al.), particularly the most vulnerable that are least equipped to adapt. The science is precise that, without faster global action, these impacts will become much more frequent and severe. Two recent reports from the Intergovernmental Panel on Climate Change IPCC (2018) and IPCC (2021) affirm with complete scientific confidence the need to keep warming under 1.5°C to reduce the most extraordinary global risks and avoid significant, wide-ranging, and severe impacts. To keep 1.5°C within reach, the United States aims to achieve net-zero emissions economy-wide by 2050 (United States Department of State (2021)).

The United States is planning multiple pathways to a net-zero economy by 2050 (United States Department of State (2021);

United States Executive Office of the President (2021); G7 (2021)). It confirms how actions are taken now and through this decade are critical to making these net-zero pathways possible by mobilizing to achieve net-zero will deliver benefits for all Americans.

Driving down GHGs will spur investments that modernize the American economy, address the distributional inequities of environmental pollution and climate vulnerability, improve public health in every community, and reduce climate change's severe costs and risks. Benefits include:

Firstly, public health: reducing air pollution through clean energy will avoid 85,000-300,000 premature deaths and health and climate damages of \$150-250 billion through 2030. It will prevent \$1-3 trillion in damages through 2050 in the United States alone. These measures will also help alleviate the pollution burdens proportionately borne by communities of color, low-income communities, and indigenous communities.

Secondly, economic growth: Investments in nascent clean industries will enhance competitiveness and propel sustained growth. The United States can lead in crucial clean technologies like batteries, electric vehicles, and heat pumps without sacrificing critical worker protections.

Thirdly, reduced conflict: Drought, floods, and other disasters fueled by climate change have caused large-scale displacements and conflict. The United States Department of Defense recognizes climate change as a vital, globally destabilizing national security threat (United States Department of Defense, 2021). Early action by the United States will encourage faster global climate action, including driving down the costs of carbon-free technologies. These actions will ultimately support security and stability worldwide.

Fourthly, the quality of life: Modernizing the American economy to achieve net zero can improve our lives. High-speed rail and transit-oriented development reduce emissions and create more connected, accessible, and healthier communities.

Many factors affecting the Environmental Kuznets curve, whether it is energy consumption, economic growth, or an additional variable included in this study is a foreign direct investment that affects the United States carbon emissions. As a powerful tool for transferring technology, financial capital, and other skills, foreign direct investments (FDIs) have three economic, political, and social impacts. The political effects focus mainly on the insecurity of national independence, and the social effects are primarily concerned with the possibility of the cultural transformation of society. On the other hand, economic effects imply various outcomes regarding output, the balance of payments, and market structure (Moosa, 2002). Most studies agree that FDI contributes to economic growth by providing capital, increasing productivity, creating new job probabilities, and boosting competitiveness (Choong and Lam, 2010). However, some studies have explained that there is no direct impact of FDI on economic growth (Carkovic and Levine, 2002; Durham, 2004).

To further this research, we investigate the impact of foreign direct investments, energy consumption, and economic growth on CO<sub>2</sub>

emissions using the autoregressive distributed lag (ARDL) modeling approach to cointegrate and causality analysis. The study aims to explore the relationship between the environment, foreign direct investments, economic growth, and energy consumption in the short and long run to support the United States government in making a policy. The following content consists of a literature review on the nexus of related variables and the primary methodologies used in the analysis. It continues with the findings and finalizes with a conclusion.

## 2. REVIEW OF LITERATURE

The relationship between economic growth and carbon emission has been widely investigated since the 1990s. Initially, this relationship was derived from the final work of Simon Kuznets in 1955. He showed that income inequality has increased along with revenue growth, fixed at a specific criterion, then decreased, representing an inverted U-shaped relationship between these two variables (Kuznets, 1955). Environmental economists have hypothesized a relationship between income growth and environmental degradation. For example, Grossman and Kruger examined the relationship between economic growth, sulfur dioxide, and carbon dioxide emission intensity as environmental pollution. Their results confirm an upward trend in pollutants as per capita income rises to a certain level and then a decreasing trend among high-income groups (Grossman and Krueger, 1991). In 1992, Shafik and Bandyopadhyay demonstrated a U-shaped relationship between environmental pollution and economic growth (Shafik and Bandyopadhyay, 1992). Economic development in developing and developed countries is called Environmental Kuznets Curve (EKC). His results confirmed the inverted U-shaped relationship between the two countries' groups at different turning points (Panayotou, 1993).

It should be noted that there is extensive literature consisting of empirical studies of the EKC hypothesis; those studies have yet to produce consensus results. In addition to analyzing the relationship between these variables, the researchers also included additional economic variables to avoid the problem of omitted variables such as energy consumption, capital, labor, exports, imports, trade openness, and foreign direct investment (FDI) (Al-Mulali and Ozturk, 2015; Apergis and Payne, 2009). Research on the environmental Kuznets curve hypothesis has included using renewable energy as one of the variables under study. Evidence shows that increased use of renewable energy can help reduce carbon emissions and dependence on fossil fuels (Al-Mulali and Ozturk, 2016; Zoundi, 2017).

Research on FDI inflows and carbon emissions, for example, over the past decade, there is a growing body of literature on the role of FDI inflows in carbon emissions. However, the impact of FDI inflows on carbon emissions has long been debated. The latest research on this topic primarily includes the following three categories.

Firstly, several previous studies have examined the direct effects of FDI inflows on carbon emissions and proposed a hypothesis for the pollution refuge. This suggests that inflows of FDI are associated with higher carbon emissions, on the one hand, to increase profits. Developed countries tend to invest in developing

countries with less stringent environmental regulations or lower environmental taxes. This leads to transferring polluting industries to these regions (Aller et al., 2021). As a result, host countries' carbon emissions increase with FDI-led economic activity expansion (Mahadevan and Sun, 2020). Grimes and Kentor (2003) proposed that FDI inflows significantly accelerated carbon emission growth in less developed countries. Finally, Cole et al. (2006) used data from 33 countries to examine the link between FDI inflows and environmental policy austerity, local carbon emissions will increase. This is because multinationals may lobby local governments for lax ecological policies.

Secondly, many previous studies have proposed a conflicting pollution radius hypothesis. This indicates that the influx of FDI can bring cleaner and more efficient technologies to the destination country, significantly reducing positive CO<sub>2</sub> emissions. Zhu et al. (2016) suggested that the effect of FDI influx on emissions was negative and became significant at higher doses in Indonesia, Malaysia, the Philippines, Singapore, and Thailand.

Thirdly, some studies have reached broad conclusions. For example, using panel data from 32 OECD countries, Alshubiri and Elheddad's (2019) cohort data cited a nonlinear relationship between FDI inflows and carbon emissions at the left end of the turning point. FDI inflows are positively correlated with carbon emissions. On the contrary, at the far right of the influx, FDI inflows are negatively associated with carbon emissions. Shahbaz et al. (2015) utilized data from 99 countries, and empirical results suggested that the impacts of FDI inflows on carbon emissions are heterogeneous due to differences in national income. Moreover, an upside-U-shaped link exists between FDI inflows and carbon emissions in middle-income countries. The influx of FDI could reduce carbon emissions, while in low-income countries, the relationship was reversed (Shahbaz et al., 2015).

Many previous studies have documented earlier studies on other factors. Other factors influence carbon emissions, such as FDI inflows and other aspects of CO<sub>2</sub> emissions. For example, studies have not explored the relationship between economic development and carbon emissions. Some people know the hypothesis of the Environmental Kuznets Curve, purported to be a U-shaped inversion between income and environmental pollution. Governments may sacrifice the environment when the economy is underdeveloped (for example, by increasing CO<sub>2</sub> emissions) to grow the economy. However, when the country has higher incomes, environmental oversight costs are reduced, making people pay more attention to the quality of the environment. Thus, the government should choose a more environmentally friendly approach (Ren et al., 2021). Grossman and Krueger (1992) summarized three effects of economic development on the environment. The first is the scale effect. It indicates that increased economic activity without technological innovation is associated with a greater demand for natural resources. This leads to more waste and carbon emissions. In this case, the rapid growth of economic activity hurts the environment. The second is the composition effect. This means that wealth accumulation coincides with a change in the structure of production institutions. In industrial society, environmental degradation is exacerbated when

the economic structure shifts from rural to urban but is reversed with the structural change from energy-intensive industries to technical and knowledge-based services.

### 3. THEORETICAL AND MODELING FRAMEWORK

The paper follows the framework of Halicioglu (2009), Jalil and Mehmud (2009), and Shahbaz et al. (2011) in estimating an environmental degradation equation. These studies evaluated the emissions-growth and energy-growth nexus in a single equation model. In addition, we include energy consumption and foreign direct investment as variables to proxy for reflecting the rapid movements from the economy's growth. In Equation 1, we suggest that CO<sub>2</sub> emission (CO<sub>2</sub>) in the United States depends on energy consumption (electric power consumption) (EC), GDP, the square of GDP (GDP<sup>2</sup>), and Foreign Direct Investment (FDI).

$$CO_2 = f(EC, GDP, GDP^2, FDI) \quad (1)$$

We convert the linear specification of the model into a log-linear specification. It is noted that log-linear specification provides more relevant and efficient results than the simple linear functional form of the model. Furthermore, a logarithmic form of variables gives direct elasticities for interpretations in Equation 2.

$$\ln CO_2 = \alpha_1 + \alpha_{EC} \ln EC + \alpha_{GDP} \ln GDP + \alpha_{GDP^2} \ln GDP^2 + \alpha_{FDI} \ln FDI + \mu \quad (2)$$

Where  $\mu$  is stood for residual or error term, we hypothesize that economic activity is positively stimulated by increased electric power consumption or energy use, resulting in increased environmental pollutants or carbon emissions, leading us to expect  $\alpha_{EC} > 0$ . The EKC hypothesis suggests that  $\alpha_{GDP} > 0$  and  $\alpha_{GDP^2} < 0$  or  $\alpha_{GDP^2} > 0$ , according to the study of Hatmanu et al. (2022), the sign of  $\alpha_{FDI} < 0$  is followed by the analysis of Melane-Lavado et al. (2018).

#### 3.1. ARDL Approach Specification

The empirical methodology that we use in this paper is the autoregressive distributive lag (ARDL) bounds test proposed by Pesaran and Pesaran (1997) and Pesaran et al. (2001). Then, the error correction model (ECM) can be easily derived from the ARDL framework, making it possible to estimate the long-run adjustment process toward equilibrium. One of the advantages of this method is that the time series regression can be carried out regardless of the nature of variables, whether they are I(1) or I(0). Given that most macroeconomic variables are proved to be either of those two orders, this methodology is convenient with the aim of examining long-run relationships. However, as Pesaran and Shin (1999) demonstrated, another tremendous advantage is that serial correlation and endogeneity problems are removed when long-run and short-run components are simultaneously taken with appropriate lags.

The relationship among CO<sub>2</sub> per capita, energy consumption, GDP per capita, the square of GDP, and foreign direct investment (FDI)



postulated in Equation 3 follows a time path before a long-term nexus is achieved. Thus, Equation 3 would be written as an unrestricted error correction representation:

$$\begin{aligned}\Delta \ln CO_{2t} = & \alpha_0 + \sum_{i=1}^p \beta_i \Delta \ln CO_{2t-i} + \sum_{i=1}^p \phi_i \Delta \ln EC_{t-i} \\ & + \sum_{i=1}^p \gamma_i \Delta \ln GDP_{t-i} + \sum_{i=1}^p \delta_i (\ln GDP_{t-i})^2 \\ & + \sum_{i=1}^p \theta_i \Delta \ln FDI_{t-i} + \gamma_1 \ln CO_{2t-1} + \gamma_2 \ln EC_{t-1} \\ & + \gamma_3 \ln GDP_{t-1} + \gamma_4 \ln FDI_{t-1} + \mu_t\end{aligned}\quad (3)$$

Where  $\mu_t$  are the new serially independent errors. The estimation procedures used here involve two stages. In the first stage, we will analyze, through the ARDL bound tests, whether or not there is evidence of a cointegration relationship. With this purpose, the null hypothesis of no cointegration among the variables ( $H_0: \gamma_1 = \gamma_2 = \gamma_3 = \gamma_4 = 0$ ) should be tested against the alternative ( $H_1: \gamma_1 \neq \gamma_2 \neq \gamma_3 \neq \gamma_4 = 0$ ). Ordinary least squares report F-statistics, compared to the critical values given in Pesaran and Shin (1996) and Pesaran et al. (2001). If they go beyond the upper bound, the null hypothesis will be rejected, and there will be a cointegrating relationship among the variables.

On the contrary, if the F-statistics are below the lower bound, the null hypothesis will not be rejected. The test result should be inconclusive if the F-statistics are between the upper and lower critical values. The second stage is to estimate the long-run coefficients of the cointegrating relation and make inferences about their values.

Finally, the empirical methodology involves the modeling of a restricted error correction representation, which takes a similar form to Equation 4 but now includes the long-run terms in the error correction variable lagged one period:

$$\begin{aligned}\Delta \ln CO_{2t} = & \alpha_0 + \sum_{i=1}^p \beta_i \Delta \ln CO_{2t-i} + \sum_{i=1}^p \phi_i \Delta \ln EC_{t-i} \\ & + \sum_{i=1}^p \gamma_i \Delta \ln GDP_{t-i} + \sum_{i=1}^p \delta_i (\ln GDP_{t-i})^2 \\ & + \sum_{i=1}^p \theta_i \Delta \ln FDI_{t-i} + \gamma ECT_{t-1} + \mu_t\end{aligned}\quad (4)$$

Where  $ECT_{t-1}$  is the error correction term represented by the OLS residuals series from the long-run cointegration relationship, the coefficient indicates the speed of  $\gamma$  adjustment towards this long-run equilibrium. Diagnostic and stability tests will reveal the soundness of the model.

### 3.2. Causality Analysis

ARDL cointegration method tests the existence or absence of a long-run relationship between all variables. It does not indicate the direction of causality. Once estimating the long-run model in Equation 4 obtains the estimated residuals, the next step is to evaluate a Vector Error Correction Model (VECM), with the variables in first differences and including the long-run relationships as the error correction term in the system. Therefore, the following dynamic VECM is estimated to investigate the Granger causality (Granger, 1969) between the variables in

Equations 5, 6, 7, 8, and 9, respectively:

$$\begin{aligned}\Delta \ln CO_{2t} = & \alpha_1 + \sum_{i=1}^p \beta_{1i} \Delta \ln CO_{2t-i} + \sum_{i=1}^p \phi_{1i} \Delta \ln EC_{t-i} \\ & + \sum_{i=1}^p \gamma_{1i} \Delta \ln GDP_{t-i} + \sum_{i=1}^p \delta_{1i} (\ln GDP_{t-i})^2 \\ & + \sum_{i=1}^p \theta_{1i} \Delta \ln FDI_{t-i} + \pi_1 ECT_{t-1} + \mu_{1t}\end{aligned}\quad (5)$$

$$\begin{aligned}\Delta \ln EC_t = & \alpha_2 + \sum_{i=1}^p \beta_{2i} \Delta \ln EC_{t-i} + \sum_{i=1}^p \phi_{2i} \Delta \ln GDP_{t-i} \\ & + \sum_{i=1}^p \gamma_{2i} \Delta (\ln GDP_{t-i})^2 + \sum_{i=1}^p \delta_{2i} \Delta \ln FDI_{t-i} \\ & + \sum_{i=1}^p \theta_{2i} \Delta \ln CO_{2t-i} + \pi_2 ECT_{t-2} + \mu_{2t}\end{aligned}\quad (6)$$

$$\begin{aligned}\Delta \ln GDP_t = & \alpha_3 + \sum_{i=1}^p \beta_{3i} \Delta \ln GDP_{t-i} + \sum_{i=1}^p \phi_{3i} \Delta (\ln GDP_{t-i})^2 \\ & + \sum_{i=1}^p \gamma_{3i} \Delta \ln FDI_{t-i} + \sum_{i=1}^p \delta_{3i} \Delta \ln EC_{t-i} + \sum_{i=1}^p \theta_{3i} \Delta \ln CO_{2t-i} \\ & + \pi_3 ECT_{t-3} + \mu_{3t}\end{aligned}\quad (7)$$

$$\begin{aligned}\Delta (\ln GDP_t)^2 = & \alpha_4 + \sum_{i=1}^p \beta_{4i} \Delta (\ln GDP_{t-i})^2 + \sum_{i=1}^p \phi_{4i} \Delta \ln FDI_{t-i} \\ & + \sum_{i=1}^p \gamma_{4i} \Delta \ln GDP_{t-i} + \sum_{i=1}^p \delta_{4i} \Delta \ln EC_{t-i} + \sum_{i=1}^p \theta_{4i} \Delta \ln CO_{2t-i} \\ & + \pi_4 ECT_{t-4} + \mu_{4t}\end{aligned}\quad (8)$$

$$\begin{aligned}\Delta \ln FDI_t = & \alpha_5 + \sum_{i=1}^p \beta_{5i} \Delta \ln FDI_{t-i} + \sum_{i=1}^p \phi_{5i} \Delta (\ln GDP_{t-i})^2 \\ & + \sum_{i=1}^p \gamma_{5i} \Delta \ln GDP_{t-i} + \sum_{i=1}^p \delta_{5i} \Delta \ln EC_{t-i} + \sum_{i=1}^p \theta_{5i} \Delta \ln CO_{2t-i} \\ & + \pi_5 ECT_{t-5} + \mu_{5t}\end{aligned}\quad (9)$$

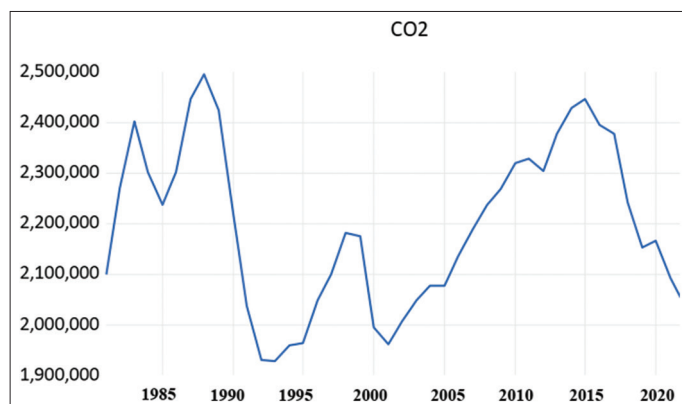
Where  $\alpha_1$  to  $\alpha_5$ ,  $\beta, \phi, \gamma, \delta$ , and  $\theta$  represent the coefficients to be estimated.  $\pi_1$  to  $\pi_5$  is the coefficient of long-run equilibrium of the dependent variables, while ECT is the error correction term of a long run, and  $\mu_1$  to  $\mu_5$  represent the white noise term error.

## 4. DATA COLLECTION AND VARIABLES

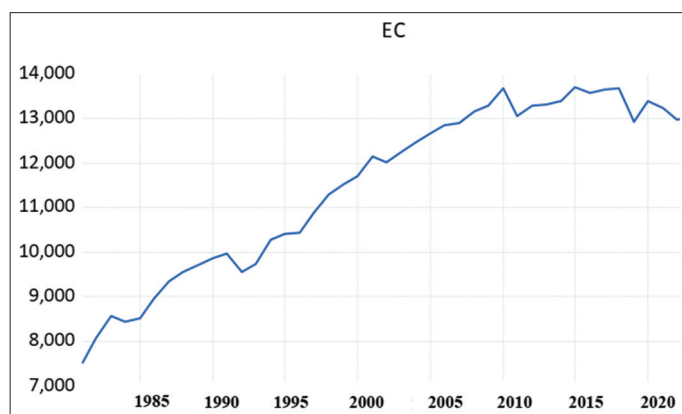
We have used yearly data on CO<sub>2</sub> emissions, energy consumption (electric power consumption), GDP per capita, and foreign direct investment in the United States from 1979 to 2021. The United States Census Bureau (USCB) has been the data source for all variables, such as CO<sub>2</sub> emission was measured in kt, energy consumption per capita was measured in kWh, gross domestic product per capita data was measured in the constant LCU, and inflows of foreign direct investment were estimated in current USD. The movement of CO<sub>2</sub> emission, energy consumption, GDP, and foreign direct investment can show in Figures 1-4, respectively.

## 5. EMPIRICAL ANALYSIS AND RESULTS

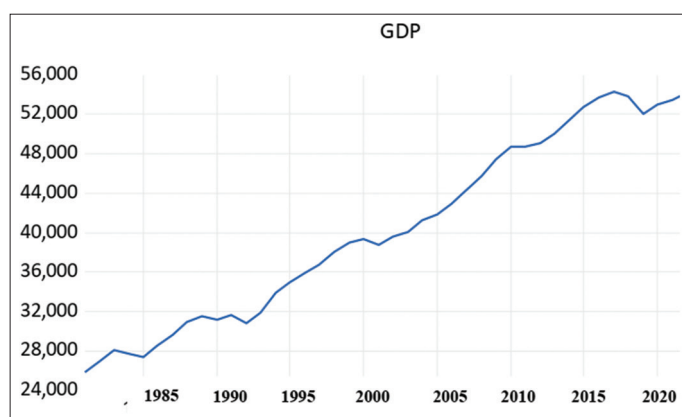
In this part of this study, we try to analyze the different relationships between variables. However, generally, in time series analysis, the primary stage is to investigate the integrated order of the study

**Figure 1:** The movement of CO<sub>2</sub> emissions in the United States from 1979 to 2021

Source: The United States Census Bureau (USCB), 2022

**Figure 2:** The movement of energy consumption in the United States from 1979 to 2021

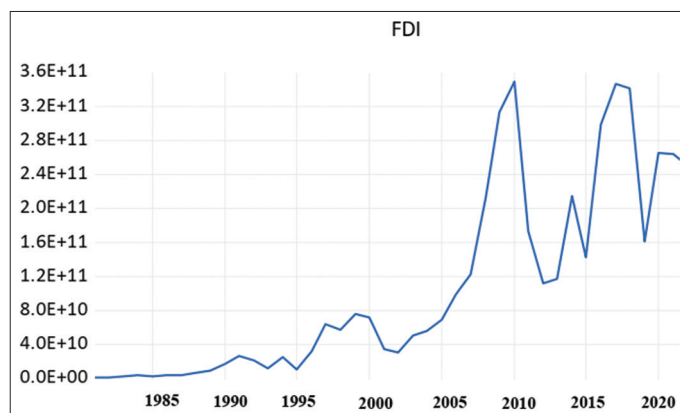
Source: The United States Census Bureau (USCB), 2022

**Figure 3:** The movement of the GDP of the United States from 1979 to 2021

Source: The United States Census Bureau (USCB), 2022

variables. ADF (see Dickey and Fuller, 1981) and PP (see Phillips and Perron, 1988) approaches have been used in this study to check the order of integration. Finally, we want to test the hypothesis of the existence of a unit root. The null and alternative hypotheses can be formulated as follows:

$$H_0: \alpha = 1 \text{ (unit root)}$$

**Figure 4:** The movement of foreign direct investment in the United States from 1979 to 2021

Source: The United States Census Bureau (USCB), 2022

$$H_1: \alpha < 1 \text{ (Integrated of order zero)}$$

These two tests are based on the null of non-stationarity, which indicates the presence of a unit root, and the alternative hypothesis of the non-existence of a unit root, which means that the variable examined is stationary.

### 5.1. Results of the Unit Root Test

All data for CO<sub>2</sub> emissions, energy consumption, GDP, GDP<sup>2</sup>, and foreign direct investment variables have been converted into a log form and shown in Table 1. The different results of the stationarity test are indicated in Table 1. The results show that all variables are stationary in the first difference, meaning that there are integrated into order one I(1). In this case, we can reject the null hypothesis of the presence of unit root, and we can accept the alternative hypothesis. After determining the order of integration, we will verify the existence of cointegration between variables using the bound test.

### 5.2. Results of the ARDL Model

We now estimate  $(p+1)^k$ , the number of regressions, where  $p$  is the maximum number of lags and  $k$  is the number of variables in the model, to determine the model lag selection. To select the optimum lag order for the model, we focus on the Akaike Information Criterion (AIC) and the Schwarz Bayesian Criterion (SBC). We use a high enough order to ensure that the optimal one is not exceeded. As shown in Table 2, the optimum lag order is (2, 0, 0, 1, 0) according to the AIC and is the same as the lag according to SBC, so we finally chose the order selected from said before.

Once the properties of the time series have been analyzed, the optimum lag order is determined. We must check whether a cointegrating relationship (long-run nexus) exists in the ARDL model and estimate the long-run coefficients. Therefore, a bounds test is carried out. As shown in Table 3, the computed F-statistics (4,42) equal to 5.031 indicate the cointegrating relationship among  $\ln\text{CO}_2$ ,  $\ln\text{EC}$ ,  $\ln\text{GDP}$ ,  $\ln\text{GDP}^2$ , and  $\ln\text{FDI}$  at a 1% level. It means that there are long-run relationships among these variables. Moreover, Table 3 presents the estimated ARDL model that has passed several diagnostic tests that indicate no serial correlation

**Table 1: Unit root test for  $\ln\text{CO}_2$ ,  $\ln\text{EC}$ ,  $\ln\text{GDP}$ ,  $\ln\text{GDP}^2$  and  $\ln\text{FDI}$** 

Variables	ADF test statistic				PP test statistic			
	Intercept		Intercept and trend		Intercept		Intercept and trend	
	I (0)	I (1)	I (0)	I (1)	I (0)	I (1)	I (0)	I (1)
$\ln\text{CO}_2$	-3.090**	-4.056***	-3.071	-3.958***	-1.667	-3.865***	-2.005	-3.727**
$\ln\text{EC}$	-3.549**	-6.464***	-1.347	-7.578***	-3.700***	-6.481***	-1.294	-8.110***
$\ln\text{GDP}$	-1.079	-4.929***	-2.055	-4.967***	-1.863	-4.775***	-1.624	-4.839***
$\ln\text{GDP}^2$	-1.011	-4.913***	-2.145	-4.933***	-1.668	-4.751***	-1.677	-4.782***
$\ln\text{FDI}$	-3.304**	-4.780***	-2.771	-6.057***	-2.933**	-7.503***	-2.730	-10.932***

\*\*=5% significant level, \*\*\*=1% significant level

**Table 2: Optimum lag order for model selection**

Order for ARDL model selection	AIC	SBC
$\text{CO}_2=f(\text{EC}, \text{GDP}, \text{GDP}^2, \text{FDI})$	(2,0,0,1,0)	(2,0,0,1,0)
Standard error of the regression	0.023	0.023

**Table 3: Cointegration results and estimation of the ARDL (2,0,0,1,0) model**

Variables	Coefficient	t-statistics		
C	26.912	1.056		
lnCO <sub>2</sub> (-1)	1.135***	10.047		
lnCO <sub>2</sub> (-2)	-0.324***	-2.456		
lnEC	0.258	1.473		
lnGDP	-4.911	-1.015		
lnGDP <sup>2</sup>	0.270	1.216		
lnGDP <sup>2</sup> (-1)	-0.039***	-3.544		
lnFDI	-0.021**	-2.419		
F-bounds test	Value	Significant	I (0)	I (1)
F-statistic (4,42)	5.031	10%	2.20	3.09
		5%	2.56	3.49
		2.5%	2.88	3.87
		1%	3.29	4.37
LM test	Value	Prob.		
F-statistic (2,32)	0.672	0.517		
Heteroskedasticity test: Breusch-Pagan-Godfrey (HT)	Value	Prob.		
F-statistic (7,34)	1.441	0.221		

\*\*\*=1% significant level, \*\*=5% significant level

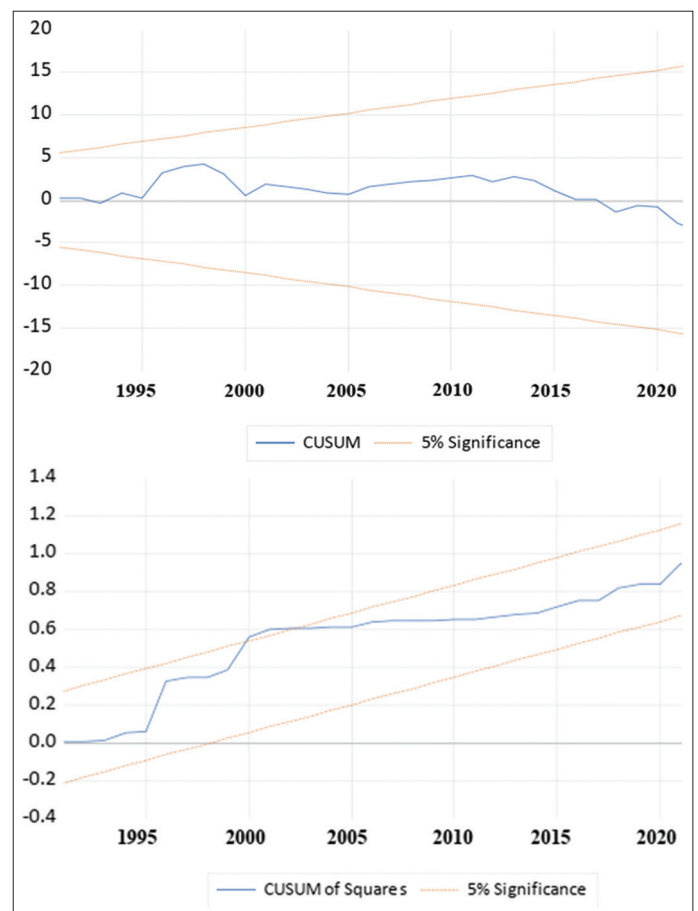
and heteroscedasticity by considering from LM test equal to 0.672 and HT equal to 1.441, respectively.

F-bounds test is the ARDL cointegration test. The critical values for the lower I(0) and upper I(1) bounds are taken from Narayan (2005). LM is the Lagrange multiplier test for serial correlation with a  $\chi^2$  distribution with two degrees of freedom. HT is the Heteroskedasticity test with a  $\chi^2$  distribution.

In addition, due to the structural changes in the economies of the United States, the macroeconomic series is likely subject to one or multiple structural breaks. For this purpose, the stability of the short-run and long-run coefficients is checked through the cumulative sum (CUSUM) and cumulative sum of squares (CUSUMSQ) test proposed by Brown et al. (1975). Figure 5 presents the United States CUSUM and CUSUMSQ test statistics plotting within the critical bounds of 5% significance. This result implies that the estimated parameters are stable from 1979 to 2021.

**Table 4: Long run estimates of the ARDL model**

Variable	Coefficient	t-statistic	P-value
C	142.308	1.350	0.185
$\ln\text{EC}$	1.367	1.680	0.100
$\ln\text{GDP}$	-25.972	-1.268	0.212
$\ln\text{GDP}^2(-1)$	1.223	1.301	0.201
$\ln\text{FDI}$	-0.112	-1.645	0.100

**Figure 5:** Presents the plot of CUSUM and CUSUMSQ test statistics for the United States from 1979 to 2021

Based on our consideration of the F-bound test, we confirmed that the relationship between the independent and dependent variables was long-run. However, we can prove from the long-run estimation from Table 4 that we look at the relationship between the independent and dependent variables in a long-run relationship. We found that the coefficients of energy consumption and foreign direct investments variables were significant at the 10% level. The variables GDP and  $\text{GDP}^2$  were found to be insignificant.

**Table 5: Error correction representation for the selected model**

Variable	Coefficient	t-statistic	P-value
$\Delta \ln \text{CO}_2 (-1)$	0.324	3.358	0.001
$\Delta \ln \text{GDP}^2$	0.270	6.307	0.000
$\text{ECT}(-1)$	-0.189	-5.884	0.000

Energy consumption positively impacts  $\text{CO}_2$  emissions, while FDI negatively influences  $\text{CO}_2$  emissions. We can interpret this as follows: A 1% increase in energy consumption would result in a 1.367% increase in  $\text{CO}_2$  emissions, and a 1% increase in FDI would result in a 0.112% decrease in  $\text{CO}_2$  emissions. In addition, from the previous long-run relationship, it can be seen that the relationship between GDP and  $\text{CO}_2$  emission, including  $\text{GDP}^2$  and  $\text{CO}_2$  emission were insignificant. Therefore, to further prove the relationship, we will use the Granger causal analysis method to help to support it. And finally, considering the elasticity of carbon emissions on various factors, it was found that energy consumption on carbon emissions was highly flexible. Therefore, the United States must focus on controlling this factor.

### Statistics

$R^2 = 0.651$ , Adjusted  $R^2 = 0.633$ , S.E. of regression = 0.021 and F-statistic = 36.435.

In terms of the relationship between the independent and dependent variables in a long-run relationship, a short-run relationship is likely to happen. Table 5 shows a relationship between  $\text{GDP}^2$  and  $\text{CO}_2$  emissions of 0.270 with a significant coefficient at a 1% level. We can interpret this as follows: A 1% increase in  $\text{GDP}^2$  would result in a 0.270% increase in  $\text{CO}_2$  emissions. Additionally, values for the ECT (-1) coefficients are statistically significant and negative. This result provides evidence of a cointegration relationship among the variables established by the ARDL Bounds testing procedure. The coefficient of the ECT term represents the proportion by which the long-run disequilibrium in the dependent variable is corrected in each short-run period. The coefficients of the ECT terms are equal to -0.189, meaning that the deviation from the long-run path of  $\text{CO}_2$  emissions is corrected by 18.90% each year.

### 5.3. Empirical Findings from the Granger Causality Test

The different results are reported in Table 6. In the case of the United States, the results indicate that three unidirectional causal relationships exist in the short run. The first relationship is between FDI and  $\text{CO}_2$  emission, the second is between  $\text{CO}_2$  emission and GDP, and the third is between  $\text{CO}_2$  emission and  $\text{GDP}^2$ .

The results of long-run causal relationships show two bidirectional causal relationships between GDP and FDI, including  $\text{GDP}^2$  and FDI. Moreover, there are three unidirectional relationships: FDI influences  $\text{CO}_2$  emission, GDP affects energy consumption, and  $\text{GDP}^2$  influences energy consumption.

According to the previous ARDL method, the coefficients of GDP and  $\text{GDP}^2$  were insignificant. But on causal analysis, it is found

**Table 6: Shows granger causality tests among variables in the environmental Kuznets Curve model for the United States**

The null hypotheses	Chi-square (P-value)
Short-run Granger causality	
$\Delta \ln \text{EC} \rightarrow \Delta \ln \text{CO}_2$	0.142 (0.705)
$\Delta \ln \text{GDP} \rightarrow \Delta \ln \text{CO}_2$	0.283 (0.594)
$\Delta \ln \text{GDP}^2 \rightarrow \Delta \ln \text{CO}_2$	0.301 (0.583)
$\Delta \ln \text{FDI} \rightarrow \Delta \ln \text{CO}_2$	4.515 (0.033)**
$\Delta \ln \text{CO}_2 \rightarrow \Delta \ln \text{EC}$	1.754 (0.185)
$\Delta \ln \text{GDP} \rightarrow \Delta \ln \text{EC}$	1.153 (0.282)
$\Delta \ln \text{GDP}^2 \rightarrow \Delta \ln \text{EC}$	1.213 (0.270)
$\Delta \ln \text{FDI} \rightarrow \Delta \ln \text{EC}$	0.332 (0.564)
$\Delta \ln \text{CO}_2 \rightarrow \Delta \ln \text{GDP}$	10.209 (0.001)***
$\Delta \ln \text{EC} \rightarrow \Delta \ln \text{GDP}$	0.011 (0.913)
$\Delta \ln \text{GDP}^2 \rightarrow \Delta \ln \text{GDP}$	0.015 (0.900)
$\Delta \ln \text{FDI} \rightarrow \Delta \ln \text{GDP}$	1.794 (0.180)
$\Delta \ln \text{CO}_2 \rightarrow \Delta \ln \text{GDP}^2$	10.284 (0.001)***
$\Delta \ln \text{EC} \rightarrow \Delta \ln \text{GDP}^2$	0.023 (0.878)
$\Delta \ln \text{GDP} \rightarrow \Delta \ln \text{GDP}^2$	0.001 (0.975)
$\Delta \ln \text{FDI} \rightarrow \Delta \ln \text{GDP}^2$	1.767 (0.183)
$\Delta \ln \text{CO}_2 \rightarrow \Delta \ln \text{FDI}$	0.234 (0.628)
$\Delta \ln \text{EC} \rightarrow \Delta \ln \text{FDI}$	0.003 (0.952)
$\Delta \ln \text{GDP} \rightarrow \Delta \ln \text{FDI}$	0.282 (0.595)
$\Delta \ln \text{GDP}^2 \rightarrow \Delta \ln \text{FDI}$	0.291 (0.589)
Long-run Granger causality	
$\ln \text{EC} \rightarrow \ln \text{CO}_2$	0.795 (0.372)
$\ln \text{GDP} \rightarrow \ln \text{CO}_2$	0.136 (0.712)
$\ln \text{GDP}^2 \rightarrow \ln \text{CO}_2$	0.155 (0.693)
$\ln \text{FDI} \rightarrow \ln \text{CO}_2$	8.632 (0.003)***
$\ln \text{CO}_2 \rightarrow \ln \text{EC}$	0.000 (0.986)
$\ln \text{GDP} \rightarrow \ln \text{EC}$	3.625 (0.056)**
$\ln \text{GDP}^2 \rightarrow \ln \text{EC}$	3.586 (0.058)**
$\ln \text{FDI} \rightarrow \ln \text{EC}$	1.509 (0.219)
$\ln \text{CO}_2 \rightarrow \ln \text{GDP}$	1.234 (0.266)
$\ln \text{EC} \rightarrow \ln \text{GDP}$	0.038 (0.843)
$\ln \text{GDP}^2 \rightarrow \ln \text{GDP}$	0.131 (0.716)
$\ln \text{FDI} \rightarrow \ln \text{GDP}$	2.580 (0.100)*
$\ln \text{CO}_2 \rightarrow \ln \text{GDP}^2$	1.159 (0.281)
$\ln \text{EC} \rightarrow \ln \text{GDP}^2$	0.032 (0.858)
$\ln \text{GDP} \rightarrow \ln \text{GDP}^2$	0.169 (0.680)
$\ln \text{FDI} \rightarrow \ln \text{GDP}^2$	2.582 (0.100)*
$\ln \text{CO}_2 \rightarrow \ln \text{FDI}$	1.183 (0.276)
$\ln \text{EC} \rightarrow \ln \text{FDI}$	1.227 (0.268)
$\ln \text{GDP} \rightarrow \ln \text{FDI}$	6.649 (0.010)***
$\ln \text{GDP}^2 \rightarrow \ln \text{FDI}$	6.552 (0.010)***

\* is significant at the 10% level, \*\* is significant at the 5% level, and \*\*\* is significant at the 1% level

that GDP and  $\text{GDP}^2$  indirectly affect  $\text{CO}_2$  emissions. GDP and  $\text{GDP}^2$  impact energy consumption and FDI; later, FDI was passed through  $\text{CO}_2$  emission.

## 6. CONCLUSION

This study uses data from the World Bank indicator to examine the causal link between  $\text{CO}_2$  emission, energy consumption, GDP, the square of GDP, and foreign direct investment in the Environmental Kuznets Curve for the United States from 1979 to 2021. Three steps are used: bound tests to verify the presence of cointegration, autoregressive distributed lag (ARDL) model to check the effects of the dependent variables on the independent variable in the short run and long run, and finally, the vector error correction (VECM) was used to detect the causal relationships among variables.



Based on our consideration of the F-bound test, we confirmed that the relationship between the independent and dependent variables was long-run. We found that the coefficients of energy consumption and foreign direct investments variables were significant at the 10% level. The variables GDP and GDP<sup>2</sup> were found to be insignificant. Energy consumption positively impacts CO<sub>2</sub> emissions, while FDI negatively influences CO<sub>2</sub> emissions. In addition, from the previous long-run relationship, it can be seen that the relationship between GDP and CO<sub>2</sub> emission, including GDP<sup>2</sup> and CO<sub>2</sub> emission were insignificant. Therefore, to further prove the relationship, we will use the Granger causal analysis method to help to support it. In causal analysis, it is found that GDP and GDP<sup>2</sup> indirectly affect CO<sub>2</sub> emissions. GDP and GDP<sup>2</sup> impact energy consumption and FDI; later, FDI was passed through CO<sub>2</sub> emission.

Therefore, from the results of both short-run and long-run studies of the relationship of variables in the EKC model, it was found that energy consumption, economic growth, and foreign direct investment affect increasing carbon emissions. Therefore, in terms of policy, the electricity sector in the United States should be decarbonizing rapidly, with significant increases in renewable deployment.

In addition, the sum of coal and natural gas generation should also decline, pointing to the critical role of renewable energy.

One of the challenges to reaching the 2050 net-zero goal (as well as the 2035 100% clean electricity goal) is the large amount of new zero-emission capacity (primarily renewables) that will need to be deployed annually to enable an increasingly large share of clean electricity generation, especially solar and wind capacity additions. Moreover, the federal government should accelerate investment policies, tax credits, regulatory actions, state policies, research and development, and market trends to drive significant renewable deployment.

## REFERENCES

- Aller, C., Ductor, L., Grechyna, D. (2021), Robust determinants of CO<sub>2</sub> emissions. *Energy Economics*, 96, 105154.
- Al-Mulali, U., Ozturk, I. (2015), The effect of energy consumption, urbanization, trade openness, industrial output, and political stability on the environmental degradation in the MENA (Middle East and North Africa) region. *Energy*, 84, 382-389.
- Al-mulali, U., Ozturk, I. (2016), The investigation of environmental Kuznets curve hypothesis in the advanced economies: The role of energy prices. *Renewable and Sustainable Energy Reviews*, 54(C), 1622-1631.
- Alshubiri, F., Elheddad's, M. (2019), Foreign finance, economic growth, and CO<sub>2</sub> emissions Nexus in OECD countries. *International Journal of Climate Change Strategies and Management*, 12(2), 161-181.
- Apergis, N., Payne, J. (2009), Energy consumption and economic growth: Evidence from the common wealth of independent states. *Energy Economics*, 31, 641-647.
- Brown, R.L., Durbin, J., Evans, J.M. (1975), Techniques for testing the constancy of regression relationships over time. *Journal of the Royal Statistical Society*, 37(2), 149-192.
- Bunnag, T. (2021), The causal relationship among CO<sub>2</sub> emission, oil consumption, and economic Growth in Thailand: ARDL bound testing approach. *International Journal of Energy Economics and Policy*, 11(6), 427-431.
- Bunnag, T. (2023), Analyzing short-run and Long-run causality relationship among CO<sub>2</sub> emission, energy consumption, GDP, square of GDP, and foreign direct investment in environmental Kuznets Curve for Thailand. *International Journal of Energy Economics and Policy*, 13(2), 341-348.
- Carkovic, M., Levine, R. (2002), Does Foreign Direct Investment Accelerate Economic Growth? Working Paper. Minneapolis, and Saint Paul: University of Minnesota.
- Choong, C., Lam, S. (2010), The determinants of foreign direct investment in Malaysia: A Revisit. *Global Economic Review*, 39(2), 175-195.
- Cole, M.A., Elliott, R.J.R., Fredriksson, P.G. (2006), Endogenous pollution havens: Does FDI Influence environmental regulations? *Scandinavian Journal Economics*, 108, 157-178.
- Dickey, D.A., Fuller, W.A. (1981), Likelihood ratio statistics for autoregressive time series with unit root. *Econometrica*, 49, 1057-1072.
- Durham, J.B. (2004), Absorptive capacity and the effects of foreign direct investment and equity foreign portfolio investment on economic growth. *European Economic Review*, 48, 285-306.
- G7. (2021), Carbis Bay G7 Summit Communique. Available from: <https://www.whitehouse.gov/briefing-room/statements-releases/2021/06/13/carbis-bay-g7-summit-communique>
- Granger, C.W.J. (1969), Investigating causal relations by econometric models and cross-spectral methods. *Econometrica*, 37(3), 424-438.
- Grimes, P., Kentor, J. (2003), Exporting the greenhouse: Foreign capital penetration and CO<sub>2</sub> emissions 1980-1996. *Journal of World-Systems Research*, 9(2), 261-275.
- Grossman, G.M., Krueger, A.B. (1991), Environmental Impacts of a North American free Trade Agreement. NBER Working Paper No. w3914. Available from: SSRN: <https://ssrn.com/abstract=232073>
- Grossman, G.M., Krueger, A.B. (1992), Environmental Impacts of A North American Free Trade Agreement. Vol. 8. United States: Social Science Electronic Publishing. p223-250.
- Halicioglu, F. (2009), An econometric study of CO<sub>2</sub> emissions, energy consumption, income and Foreign trade in Turkey. *Energy Policy*, 37, 1156-1164.
- Hatmanu, M., Cautisanu, C., Cobuta, A.O. (2022), On the relationships between CO<sub>2</sub> emissions and their determinants in Romania and Bulgaria. An ARDL approach. *Applied Economics*, 54(22), 2582-2595.
- IPCC. (2018), Global Warming of 1.5C. Cambridge UK: Cambridge University Press.
- IPCC. (2021), Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge UK: Cambridge University Press. Available from: <https://www.ipcc.ch/report/ar6/wg1>
- Jalil, A., Mahmud, S. (2009), Environment Kuznets Curve for CO<sub>2</sub> emissions: A co-integration analysis for China. *Energy Policy*, 37, 5167-5172.
- Khan, H., Khan, I., Binh, T.T. (2019a), The heterogeneity of renewable energy consumption, carbon emission and financial development in the globe: A panel quantile regression approach. *Energy Reports*, 6, 859-867.
- Kuznets, S. (1955), Economic growth and income inequality. *The American Economic Review*, 45(1), 1-28.
- Mahadevan, R. and Sun, Y. (2020), Effects of foreign direct investment on carbon emissions: Evidence from China and its Belt and Road countries. *Journal Environmental Management*, 276, 111321.
- Melane-Lavado, A., Álvarez-Herranz, A., González-González, I. (2018), Foreign direct investment as a way to guide the innovative process

- towards sustainability. *Journal Cleaner Production*, 172, 3578-3590.
- Moosa, I.A. (2002), Theories of foreign direct investment. In: *Foreign Direct Investment*. London: Palgrave Macmillan.
- Murshed, M., Ahmed, R., Kumpamool, C., Bassim, M., Elheddad, M. (2021), The effects of regional trade integration and renewable energy transition on environmental quality: Evidence from South Asian neighbors. *Business Strategy and the Environment*, 30, 4154-4170.
- Narayan, P.K. (2005), The saving and investment nexus for China: Evidence from co-integration tests. *Applied Economics*, 37, 1979-1990.
- Panayotou, T. (1993), Empirical Tests and Policy Analysis of Environmental Degradation at Different Stages of Economic Development. Working Paper WP238, Technology, and Employment Programme. Geneva: International Labour Office.
- Pesaran, M.H., Shin, Y. (1996), Cointegration and speed of convergence to equilibrium. *Journal of Econometrics*, 71(1-2), 117-143.
- Pesaran, M.H., Shin, Y. (1999), An Autoregressive Distributed Lag Modelling Approach to Co-integration Analysis. In: Strom, S., editors. Chapter 11 in *Econometrics and Economic Theory in the 20<sup>th</sup> Century the Ragnar Frisch Centennial Symposium*. Cambridge: Cambridge University Press. p371-413.
- Pesaran, M.H., Shin, Y., Smith, R.J. (2001), Bounds testing approaches to the analysis of level relationships. *Journal of Applied Econometrics*, 16(3), 289-326.
- Pesaran, M.H., Pesaran, B. (1997), *Working with Microfit 4.0: Interactive Econometric Analysis*; Windows Version. Oxford: Oxford University Press.
- Phillips, P.C., Perron, P. (1988), Testing for a unit root in time series regression. *Biometrika*, 75(2), 335-346.
- Ren, X., Cheng, C., Wang, Z., Yan, C. (2021), Spillover and dynamic effects of energy transition and economic growth on carbon dioxide emissions for the European union: A dynamic spatial panel model. *Sustainable Development*, 29, 228-242.
- Shafik, N., Bandyopadhyay, S. (1992), Economic Growth and Environmental Quality: TIME Series and Cross-country Evidence. World Bank Policy Research Working Paper WPS904, Washington DC.
- Shahbaz, M., Lean, H.H., Shahbaz, M. (2011), Environmental Kuznets Curve and the Role of Energy Consumption in Pakistan. Discussion Paper DEVDP 10/05, Monash University.
- Shahbaz, M., Mallick, H., Mahalik, M.K., Loganathan, N. (2015), Does globalization impede Environmental quality in India? *Ecological Indicators*, 52, 379-393.
- United States Department of Defense. (2021), Office of the Undersecretary for Policy (Strategy, Plans, and Capabilities), Department of Defense Climate Risk Analysis. Report Submitted to National Security Council. Washington, D.C.: United States Department of Defense.
- United States Department of State. (2021), The United States' Nationally Determined Contribution: Reducing Greenhouse Gases in the United States: A 2030 Emissions Target, Washington, D.C.: United States Department of State.
- United States Executive Office of the President. (2021), "Executive Order 14008: Tackling the Climate Crisis at Home and Abroad" Federal Register. Washington, D.C.: United States Executive Office of the President. Available from: <https://www.federalregister.gov/documents/2021/02/01/2021-02177/tackling-the-climate-crisis-at-home-and-abroad>
- Zambrano-Monserrate, M.A., Garcia-Alban, F.F., Henk-Vera, K.A. (2016), Bounds testing approach to analyze the existence of an environmental kuznets curve in Ecuador. *International Journal of Energy Economics and Policy*, 6(2), 159-166.
- Zhu, Z., Piao, S., Myneni, R.B., Huang, M., Zeng, Z., Canadell, J.G., Ciais, P., Sitch, S., Friedlingstein, P., Arneeth, A., Cao, C., Cheng, L., Kato, E., Koven, C., Li, Y., Lian, X., Liu, Y., Liu, R., Mao, J., Pan, Y., Peng, S., Peñuelas, J., Poulter, B., Pugh, T.A.M., Stocker, B.D., Viovy, N., Wang, X., Wang, Y., Xiao, Z., Yang, H., Zaehle, S., Zeng, N. (2016), Greening of the Earth and its drivers. *Nature Climate Change*, 6, 791-795.
- Zoundi, Z. (2017), CO<sub>2</sub> emissions, renewable energy and the environmental Kuznets Curve, a panel co-integration approach. *Renewable and Sustainable Energy Reviews*, 72, 1067-1075.