IQTISODIY TARAQQIYOT VA TAHLIL ILMIY ELEKTRON JURNAL

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THE RELATIONSHIP BETWEEN FOREIGN DIRECT INVESTMENT AND CO_2 AND ECONOMIC GROWTH IN UZBEKISTAN

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Abstract. *This study examines the relationship between CO_2 emissions, energy use, GDP, GDP squared, and foreign direct investment for Uzbekistan between 1990 and 2022. Bound tests are used to confirm the existence of cointegration, the autoregressive distributed lag (ARDL) model is used to examine the short-term and long-term effects of the dependent variables on the independent variable, and finally, the vector error correction (VECM) method is used to identify the causal relationships between the variables. The coefficients for energy consumption and foreign direct investments were significant at the 10% level, according to our research. GDP and GDP^2 were shown to be unimportant variables. Energy use has a beneficial impact on CO_2 emissions, but FDI has a negative impact. Additionally, it is discovered through causal analysis that GDP and GDP^2 indirectly influence CO_2 emissions. Energy use and FDI are impacted by GDP and GDP^2, with FDI later being transmitted through CO^2 emission. In order to promote major renewable deployment, the federal government should speed up investment policies, tax credits, regulatory actions, state policies, research and development, and market trends.*

Key words: *CO_2 Emissions, Energy Consumption, GDP, Foreign Direct Investment, The Environmental Kuznets Curve.*

O'ZBEKISTONDA TO'G'RIDAN-TO'G'RI XORIJIY INVESTITSIYALAR VA CO_2 VA IQTISODIY O'SISH O'RASIDAGI BOG’LIQLIK

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Annotatsiya. *Ushbu tadqiqot CO_2 emissiyasi, energiya iste'moli, YaIM, YaIM kvadrati va O'zbekistonda 1990 yildan 2022 yilgacha bo'lgan to'g'ridan-to'g'ri xorijiy investitsiyalar o'rtasidagi bog'liqlikni o'rganadi. Kointegratsiya mavjudligini tasdiqlash uchun avtoregressiv taqsimlangan kechikish (ARDL) modeli qo'llaniladi. bog'liq o'zgaruvchilarning mustaqil o'zgaruvchiga qisqa muddatli va uzoq muddatli ta'sirini o'rganish uchun ishlatiladi va nihoyat, vektor xatolarni tuzatish usuli (VECM) o'zgaruvchilar o'rtasidagi sabab-oqibat munosabatlarini aniqlash uchun ishlatiladi. Bizning tadqiqotimizda energiya iste'moli va to'g'ridan-to'g'ri xorijiy investitsiyalar koeffitsientlari 10% darajasida sezilarli bo'ldi. YaIM va YaIM2 ahamiyatsiz o'zgaruvchilar ekanligi ko'rsatildi. Energiyadan foydalanish CO_2 emissiyasiga foydali ta'sir ko'rsatadi, ammo TTXI salbiy ta'sir ko'rsatadi. Bundan tashqari, sabab-oqibat tahlili orqali YaIM va YaIM2 CO_2 emissiyasiga bilvosita ta'sir ko'rsatishi aniqlandi. Energiya iste'moli va to'g'ridan-to'g'ri xorijiy investitsiyalar YAIM va YaIM2 ta'sirida bo'lib, keyinchalik to'g'ridan-to'g'ri investitsiyalar CO_2 emissiyasi orqali uzatiladi Qayta tiklanadigan energiyani keng miqyosda qo'llashni rag'batlantirish uchun federal hukumat investitsiya siyosati, soliq kreditlari, tartibga solish choralari, davlat siyosati, tadqiqot va ishlanmalar va bozor tendentsiyalarini tezlashtirishi kerak.*

Kalit so'zlar: *uglerod emissiyasi, energiya iste'moli, yalpi ichki mahsulot, to'g'ridan-to'g'ri xorijiy investitsiyalar, atrof-muhitning Kuznets egri chizig'i.*

СВЯЗЬ МЕЖДУ ПРЯМЫМИ ИНОСТРАННЫМИ ИНВЕСТИЦИЯМИ И CO_2 И ЭКОНОМИЧЕСКИМ РОСТОМ В УЗБЕКИСТАНЕ

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Аннотация. *В этом исследовании изучается взаимосвязь между выбросами CO_2, потреблением энергии, ВВП, квадратом ВВП и прямыми иностранными инвестициями в Узбекистан в период с 1990 по 2022 год. Чтобы подтвердить существование коинтеграции, используется модель авторегрессионного распределенного запаздывания (ARDL). используется для изучения краткосрочного и долгосрочного воздействия зависимых переменных на независимую переменную, и, наконец, метод векторной коррекции ошибок (VECM) используется для идентификации выявить причинно-следственные связи между переменными. По данным нашего исследования, коэффициенты энергопотребления и прямых иностранных инвестиций были значимыми на уровне 10%. Было показано, что ВВП и ВВП2 являются неважными переменными. Использование энергии оказывает благотворное влияние на выбросы CO_2, но FDDI имеет отрицательное влияние. Кроме того, посредством причинно-следственного анализа обнаружено, что ВВП и ВВП2 косвенно влияют на выбросы CO_2. На потребление энергии и ПИИ влияют ВВП и ВВП2, причем ППИ позже передаются через выбросы CO_2. Чтобы способствовать масштабному внедрению возобновляемых источников энергии, федеральному правительству следует ускорить инвестиционную политику, налоговые кредиты, нормативные меры, государственную политику, исследования и разработки и рыночные тенденции.*

Ключевые слова: *выбросы CO_2, энергопотребление, ВВП, прямые иностранные инвестиции, экологическая кривая Кузнеца.*

Introduction.

Uzbekistan, which consists of 13 regions, is one of the six superpowers and one of the most developing countries in Central Asia, according to this empirical analysis. Uzbekistan leads the world in terms of GDP. Additionally, it has a gross domestic product per person ranking of eight. The financial sector, economic activity, urbanization rate, industrialization speed, and use of advanced technology are the main causes of energy pollutants and carbon emissions in Uzbekistan as a result of its highly developed economy (Khan et al., 2019a).

According to Murshed et al. (2021), Uzbekistan and other regions have already suffered significant harm from climate change, especially the most vulnerable areas that lack the capacity to adapt. Without more rapid global action, the research is clear that these impacts will increase significantly in frequency and severity. The need to limit warming to 1.5°C is reaffirmed in two recent reports from the Intergovernmental Panel on Climate Change (IPCC) (2018) and IPCC (2021) with 100 percent scientific certainty in order to reduce the most extreme global risks and prevent large, broad-based, and catastrophic consequences. Uzbekistan wants to achieve net-zero emissions across the board by 2050 in order to prevent global warming to 1.5°C or less.

Reducing GHGs will encourage investments that modernize the Uzbekistan’s economy, address the disparities in environmental pollution and climatic vulnerability, enhance public health in every community, and lessen the significant costs and hazards associated with climate change. Benefits comprise:

Firstly, public health: until 2030, lowering air pollution through clean energy will prevent many premature lives and around $15 billion in health and climate losses. The environmental loads disproportionately carried by communities of color, low-income communities, and indigenous groups will also be lessened by these actions.

Secondly, investments in emerging clean industries will increase competitiveness and foster long-term economic growth. Without compromising essential worker rights, Uzbekistan can take the lead in key sustainable technology like heat pumps, electric vehicles, and batteries.

Thirdly, lessening conflict: Conflict and large-scale displacement have been brought on by drought, floods, and other natural calamities exacerbated by climate change. Climate change is a significant, globally disruptive national security danger. Uzbekistan's early action will stimulate more rapid global climate action, which will lower the cost of carbon-free solutions. In the end, these initiatives will contribute to global security and stability.

The fourth is life quality: Our lives can be bettered by modernizing the Uzbek economy to achieve net zero. Emissions are decreased and communities become more connected, accessible, and healthy thanks to high-speed rail and transit-oriented development.

Energy use, economic expansion, or a further component included in this study, a foreign direct investment that influences carbon emissions, are just a few of the variables that influence the Environmental Kuznets curve. Foreign direct investments (FDIs) have three economic, political, and social effects as a potent vehicle for transferring technology, capital, and other capabilities. The political effects mostly center on the unpredictability of national independence, whereas the social effects are mostly focused with the potential for societal cultural change. However, different consequences in terms of output, the balance of payments, and market structure are implied by economic effects (Moosa, 2002). According to the majority of research, FDI boosts competitiveness, increases productivity, creates new job opportunities, and increases the likelihood of economic growth (Choong and Lam, 2010). However, according to certain studies (Carkovic and Levine, 2002; Durham, 2004), FDI has no direct effect on economic growth.

To advance this research, we use the autoregressive distributed lag (ARDL) modeling approach to cointegrate and causality analysis to examine the effects of foreign direct investments, energy consumption, and economic growth on CO_2 emissions. In order to assist the government in formulating policy, the study aims to investigate the relationship between the environment, foreign direct investments, economic growth, and energy consumption in the short and long terms. An overview of previous research on the relationships between linked variables and the main analytical approaches is presented in the information that follows. It continues with the conclusions before moving on to the findings.

Literature review.

Since the 1990s, there has been extensive research on the connection between economic growth and carbon emissions. This relationship was first established from Simon Kuznets's final thesis, which was published in 1955. In an inverted U-shaped relationship between these two variables, he demonstrated how income inequality has risen alongside revenue growth, been fixed at a certain threshold, and then fallen (Kuznets, 1955). Environmental economists have proposed a link between rising income levels and environmental deterioration. Grossman and Kruger, for instance, looked at the connection between environmental pollution and the intensity of carbon dioxide, sulfur dioxide, and economic growth. Their findings are consistent with an increase in pollutants when per capita income increases to a certain level, followed by a decrease in pollutants among high-income populations (Grossman and Krueger, 1991). Environmental pollution and economic growth were shown to have a U-shaped relationship in 1992 by Shafik and Bandyopadhyay (Shafik and Bandyopadhyay, 1992). Environmental Kuznets Curve (EKC) describes how economies evolve in both emerging and industrialized nations. His findings supported the inverted U-shaped link that existed between the groups in the two countries at various turning points (Panayotou, 1993).

It should be noted that the EKC theory has been empirically studied extensively in the literature, but no general consensus has yet been reached. To avoid the issue of omitted variables like energy consumption, capital, labor, exports, imports, trade openness, and foreign direct investment (FDI), the researchers also included additional economic variables in addition to analyzing the relationship between these variables (Al-Mulali and Ozturk, 2015; Apergis and Payne, 2009). Renewable energy has been one of the variables studied in studies on the environmental Kuznets curve theory. According to the available data (Al-Mulali and Ozturk, 2016; Zoundi, 2017), increasing the usage of renewable energy can assist reduce carbon emissions and reliance on fossil fuels.

For instance, over the past ten years, there has been a growing amount of work on the connection between FDI inflows and carbon emissions. However, there has always been controversy over how FDI inflows affect carbon emissions. The following three categories make up the majority of the most recent research on this subject.

Firstly, a number of earlier research looked at the direct impacts of FDI inflows on carbon emissions and put up a theory for the pollution refuge. This shows that foreign direct investment inflows, on the one hand intended to boost profitability, are linked to increasing carbon emissions. Developed nations frequently make investments in emerging nations with laxer environmental laws or environmental taxes. As a result, polluting companies are moved to these areas (Aller et al., 2021). As a result, the development of FDI-led economic activity causes an increase in carbon emissions in the host nations (Mahadevan and Sun, 2020). According to Grimes and Kentor's 2003 hypothesis, FDI inflows greatly boosted the growth of carbon emissions in less developed nations. Finally, Cole et al. (2006) examined the relationship between FDI inflows and environmental policy austerity, local carbon emissions will grow using data from 33 nations. Because multinational corporations may influence local governments to adopt lenient environmental regulations.

Secondly, a competing pollution radius hypothesis has been put forth in a number of earlier investigations. This suggests that the entry of FDI can introduce greener, more effective technologies to the target nation, greatly reducing Carbon emissions. According to Zhu et al. (2016), FDI influx had a negative impact on emissions and started to matter at greater doses in Indonesia, Malaysia, the Philippines, Singapore, and Thailand.

Thirdly, several research has drawn generalizations from their findings. Alshubiri and Elheddad's (2019) cohort data, for instance, identified a nonlinear association between FDI inflows and carbon emissions at the left end of the turning point using panel data from 32 OECD nations. FDI inflows and carbon emissions are connected favorably. On the other hand, FDI inflows are adversely correlated with carbon emissions at the far right of the influx. Empirical findings by Shahbaz et al. (2015) using data from 99 countries revealed that the effects of FDI inflows on carbon emissions are varied because of variations in national wealth. Additionally, middle-income nations' carbon emissions and FDI inflows are linked in an upside-down U pattern. While the link was reversed in low-income nations, the influx of FDI could lower carbon emissions (Shahbaz et al., 2015).

Many earlier studies have provided evidence of past investigations on other aspects. FDI inflows and other characteristics of CO_2 emissions are some other factors that affect carbon emissions. Studies, for instance, have not looked into the connection between economic growth and carbon emissions. Some people are familiar with the Environmental Kuznets Curve hypothesis, which states that the relationship between income and environmental pollution inverts into a U shape. When the economy is still in its infancy, governments may compromise the environment to advance economic development (for instance, by raising CO_2 emissions). Higher income levels, however, result in lower expenses associated with environmental oversight, which encourages people to pay more attention to environmental quality. Therefore, the government ought to adopt a more ecologically friendly strategy (Ren et al., 2021). Three impacts of economic development on the environment were compiled by Grossman and Krueger in 1992. The scaling effect comes first. It suggests that rising economic activity without a corresponding rise in technological innovation is linked to rising demand for natural resources. More trash and carbon emissions result from this. In this instance, the environment is harmed by the rapid growth of economic activity. The composition effect is the second. This indicates that the organization of production institutions changes as money accumulates. When the economy in industrial society moves from rural to urban, environmental degradation increases, but it turns around when the economy switches from energy-intensive industries to technical and knowledge-based services.

Methodology.

In order to estimate an equation for environmental deterioration, the paper adopts the frameworks proposed by Halicioglu (2009), Jalil and Mehmud (2009), and Shahbaz et al. (2011). These research used a single equation model to analyze the relationship between emissions growth and energy growth. We also use energy consumption and foreign direct investment as variables to simulate the swift changes brought on by the expansion of the economy. According to Equation 1, the amount of Carbon emitted in the US is influenced by energy consumption (electric power consumption), GDP, GDP squared, and foreign direct investment (FDI).

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

By doing this, we transform the model's linear specification into a log-linear specification. It should be highlighted that compared to the model's simple linear functional form, the findings produced by log-linear specification are more pertinent and effective. Furthermore, direct elasticities for interpretations in Equation 2 are provided by a logarithmic version of the variables.

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

Where μ stands for residual or error term, we hypothesize that higher energy use or electric power consumption favorably stimulates economic activity, causing an increase in air pollutants or carbon emissions, which leads us to expect $\alpha_{EC} > 0$. The study of Hatmanu et al. (2022) and the analysis of Melane-Lavado et al. (2018) both support the EKC hypothesis that $\alpha_{EC} > 0$ and $\alpha_{EC}{}^2 < 0$ or $\alpha_{EC} > 0$, and that the sign $\alpha_{FDI} < 0$ is followed.

The Autoregressive Distributive Lag (ARDL) Bounds Test developed by Pesaran and Pesaran (1997) and Pesaran et al. (2001) serves as the empirical approach in this work. Then, the ARDL framework makes it simple to derive the error correction model (ECM), allowing one to predict the long-run adjustment process leading to equilibrium. One benefit of this approach is that time series regression can be done with either I(1) or I(0) variables, independent of their type. Given that the majority of macroeconomic variables are found to fall into one of those two orders, this methodology is useful for looking at long-term correlations. On the other hand, serial correlation and endogeneity issues are eliminated when long-run and short-run components are simultaneously obtained with the right lags, as Pesaran and Shin (1999) showed.

Before a long-term nexus is reached, the link between CO_2 per capita, energy consumption, GDP per capita, the square of GDP, and foreign direct investment (FDI) posited in Equation 3 follows a temporal path. Equation 3 would thus be expressed as an unrestricted representation for error correction:

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

where the new serially independent faults are denoted by μ_t. Here, there are two stages to the estimating processes. The ARDL bound tests will be used to determine whether or not there is proof of a cointegration relationship in the initial analysis. For this reason, the alternative $(\mathbf{H}_0 : \gamma_1 = \gamma_2 = \gamma_3 = \gamma_4 = 0)$ should be tested against the null hypothesis $\mathbf{H}_1 : \gamma_1 \neq \gamma_2 \neq \gamma_3 \neq \gamma_4 = 0)$, which states that there is no cointegration between the variables. In comparison to the crucial values stated in Pesaran and Shin (1996) and Pesaran et al. (2001), ordinary least squares report F-statistics. The null hypothesis will be rejected if they exceed the upper bound, and there will be a cointegrating relationship between the variables.

On the other hand, the null hypothesis won't be ruled out if the F-statistics are below the lower bound. If the F-statistics are between the higher and lower crucial values, the test result should be inconclusive. The second step entails estimating the cointegrating relation's long-run coefficients and drawing conclusions about their values.

The modeling of a restricted error correction representation, which has a structure akin to Equation 4 but now incorporates the long-run elements in the error correction variable lagged one period, completes the empirical methodology.

$$\begin{aligned}\Delta\ln CO_{2_t} &= \alpha_1 + \sum_{i=1}^{p}\beta_{1i}\Delta\ln CO_{2_{t-i}} + \sum_{i=1}^{p}\varphi_{1i}\Delta\ln EC_{t-i} \\ &+\sum_{i=1}^{p}\gamma_{1i}\Delta\ln GDP_{t-i} + \sum_{i=1}^{p}\delta_{1i}\Delta(\ln GDP_{t-i})^2 \\ &+\sum_{i=1}^{p}\theta_{1i}\Delta\ln FDI_{t-i} + \pi_1 ECT_{t-1} + \mu_{1t}\end{aligned} \quad (4)$$

The coefficient represents the rate of adjustment towards this long-run equilibrium, where ECT_{t-1} is the error correction term represented by the OLS residuals series from the long-run cointegration relationship. The effectiveness of the model will be revealed through diagnostic and stability testing.The ARDL cointegration approach examines if all variables have a long-term relationship or not. The causal chain's direction is not indicated. The next step is to evaluate a Vector Error Correction Model (VECM), which uses the variables in first differences and incorporates the long-run relationships as the error correction term in the system, after estimating the long-run model in Equation 4 to obtain the estimated residuals. In order to study the Granger causality (Granger, 1969) between the variables in Equations 5, 6, 7, 8, and 9, respectively, the following dynamic VECM is estimated:

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

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

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

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

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

Where α_1 to $\alpha_5, \beta, \phi, \gamma, \delta$, and θ represent the coefficients to be estimated. π_1 to π_2 is the coefficient of long-run equilibrium of the dependent variables, while ECT is the error correction term of a long run, and μ_1 to μ_5 represent the white noise term error.

Data analysis

From 1990 to 2022, we used annual statistics on Carbon emissions, energy use, GDP per person, and foreign direct investment in the US. All variables' data have been sourced from World Bank open data including CO_2 emission measurements in kt, energy consumption per person data in kWh, gross domestic product per person data in constant LCU, and inflows of foreign direct investment estimates in current USD. Figures 1-4, respectively, depict the changes in Carbon emissions, energy consumption, GDP, and foreign direct investment.

We attempt to analyze the various relationships between variables in this section of the study. In time series analysis, the integrated order of the studied variables is typically investigated as the first step.

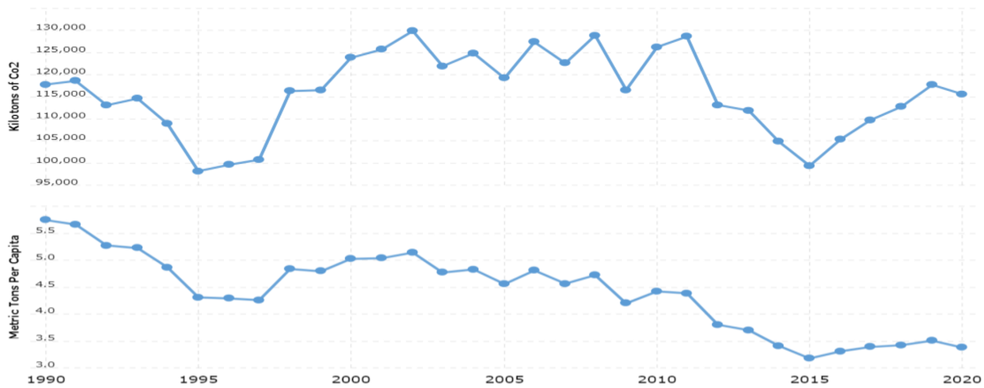

Figure 1. The movement of CO2 emissions in Uzbekistan from 1990 to 2022

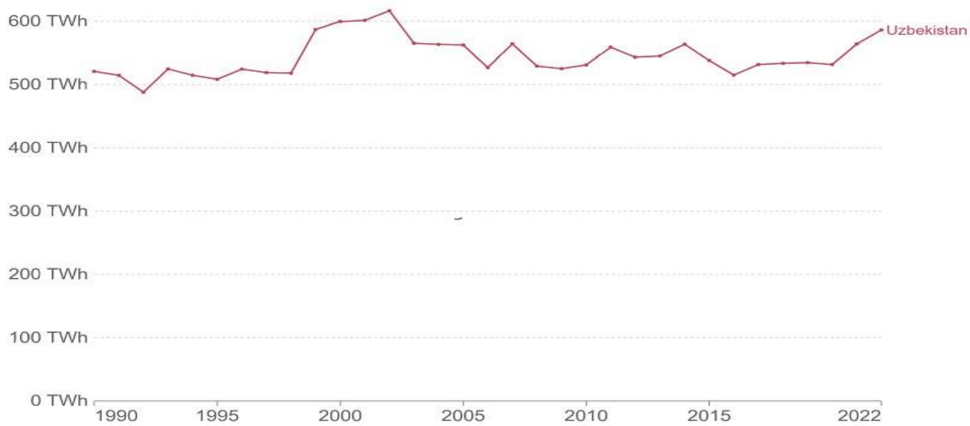

Figure 2. The movement of energy consumption in Uzbekistan from 1990 to 2022

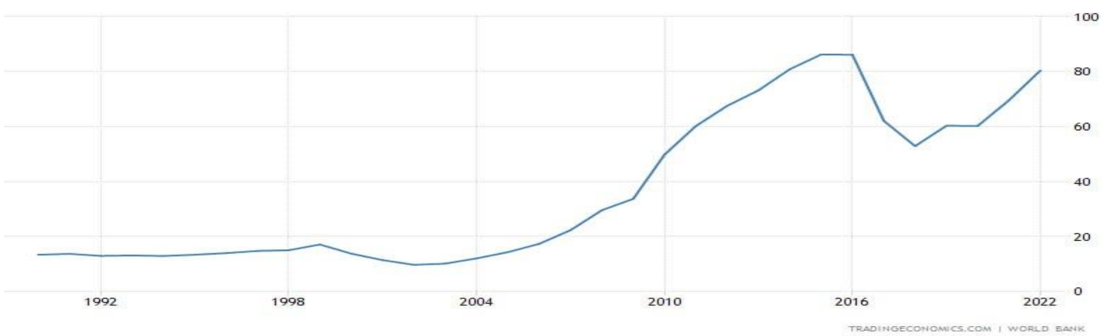

Figure 3. The movement of the GDP of Uzbekistan from 1990 to 2022

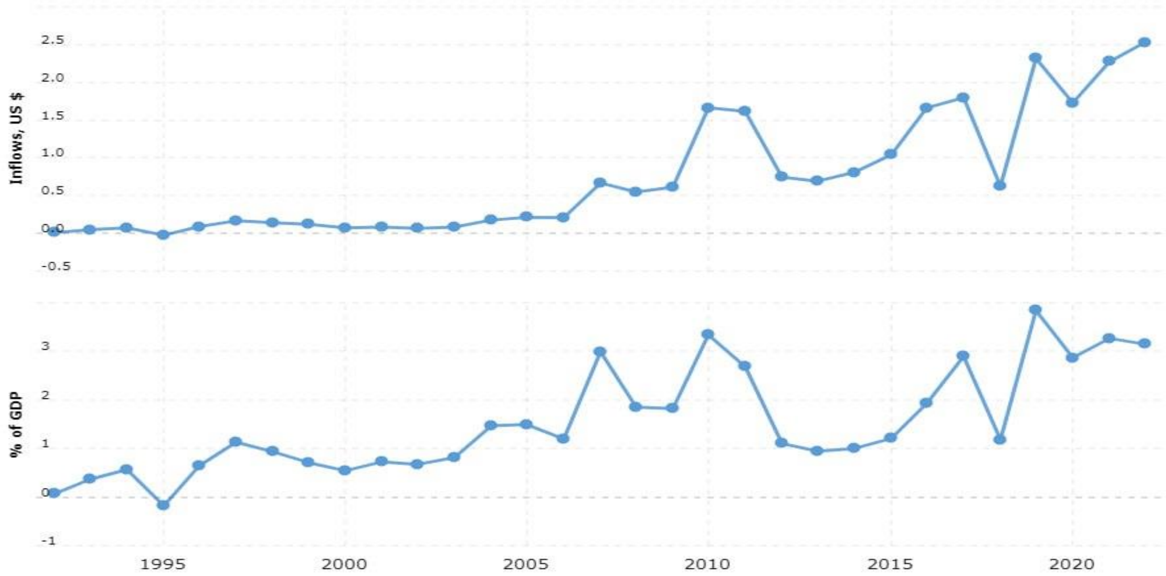

Figure 4. The movement of foreign direct investment in Uzbekistan from 1990 to 2022

This study used the ADF and PP techniques from Dickey and Fuller (1981) and Phillips and Perron (1988), respectively, to examine the order of integration. Finally, we wish to investigate the possibility that there is a unit root. The following formulations represent the null and alternative hypotheses:

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

$$H1: \alpha < 1 \text{ (Integrated of order zero)}$$

These two tests are based on the null of non-stationarity, which denotes the existence of a unit root, and the alternative hypothesis of the absence of a unit root, which denotes the existence of stationary behavior for the variable under study.

Table 1 displays the log form of all data for the variables of CO2 emissions, energy consumption, GDP, GDP2, and foreign direct investment. Table 1 lists the various outcomes of the stationarity test. The findings demonstrate that all variables are integrated into order 1 (I(1)) stationary in the first difference. In this situation, we can accept the alternative hypothesis and reject the null hypothesis that a unit root exists. We will use the bound test to confirm the existence of cointegration between variables after defining the order of integration.

Table 1.

Unit root test for $\ln CO_2$, $\ln EC$, $\ln GDP$, $\ln GDP^2$ and $\ln FDI$

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)
lnCO 2	−3.090 **	−4.056***	-3.071	−3.958 ***	-1.667	−3.865 ***	-2.005	−3.727 **
lnEC 2	−3.549 **	−6.464 ***	-1.347	−7.578 ***	−3.700 **	−6.481 ***	-1.294	−8.110***
ln *GDP*	-1.079	−4.929 ***	-2.055	−4.967****	-1.863	−4.775****	-1.624	−4.839 ***
ln GDP^2	-1.011	−4.913***	-2.145	−4.933****	-1.668	−4.751****	-1.677	−4.782 ***
ln *FDI*	−3.304 **	−4.780 ***	-2.771	−6.057****	−2.933 *	−7.503 ***	-2.730	−10.932 ***

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

In order to choose the model lags, 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. We concentrate on the Akaike Information Criterion (AIC) and the Schwarz Bayesian Criterion (SBC) to choose the best lag order for the model. We use an order that is high enough to prevent going over the ideal one. We ultimately decided on the sequence previously chosen since, as Table 2 demonstrates, the optimal lag order is (2, 0, 0, 1, 0) according to the AIC and is the same as the lag according to SBC.

Table 2.

Optimum lag order for model selection

Order for ARDL model selection	AIC	SBC
$CO_2 = f(EC, GDP, GDP^2, FDI)$	(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
$\ln CO_2(-1)$	1.135^{****}	10.047
$\ln CO_2(-2)$	$-0.324^{***}*$	-2.456
$\ln EC^2$	0.258	1.473
lnGDP	-4.911	-1.015
$\ln GDP^2$	0.270	1.216
$\ln GDP^2(-1)$	-0.039 ***	-3.544
$\ln FDI$	-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

The best lag order is identified once the time series' characteristics have been examined. We must determine whether the ARDL model contains a cointegrating link (long-run nexus) and estimate the long-run coefficients. Consequently, a boundaries test is performed. According to Table 3, the computed F-statistics (4,42) equal to 5.031 show that at a 1% level, there is cointegration between lnCO2, lnEC, lnGDP, lnGDP2, and lnFDI. It implies that these variables have long-term associations with one another. Table 3 also shows the estimated ARDL model, which has passed various diagnostic tests that show no serial correlation and heteroscedasticity when taking into account from LM test equal to 0.672 and HT equal to 1.441, respectively.

Table 4.

Long run estimates of the ARDL model

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

The ARDL cointegration test is the F-bounds test. Narayan (2005) is used to determine the critical values for the lower I(0) and higher I(1) constraints. The Lagrange multiplier (LM) test for serial correlation with a two-degree-of-freedom y2 distribution is used. With a y2 distribution, the heteroskedasticity test (HT) is used.

Table 5:

Error correction representation for the selected model

Variable	Coefficient	t-statistic	P-value
$\Delta \ln CO_2(-1)$	0.324	3.358	0.001
$\Delta \ln GDP^2$	0.270	6.307	0.000
$ECT(-1)$	-0.189	-5.884	0.000

Energy use has a beneficial impact on CO2 emissions, but FDI has a negative impact. This can be understood as follows: A 1% rise in FDI would result in a 0.112% decrease in CO2 emissions, whereas a 1% increase in energy consumption would cause a 1.367% increase. Additionally, it is clear from the prior long-run relationship that the association between GDP and CO2 emission, including GDP2 and CO2 emission, was negligible.

Statistics

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

A short-run relationship is probable when it comes to the relationship between the independent and dependent variables in a long-run relationship. According to Table 5, there is a considerable correlation between GDP2 and CO2 emissions, with a coefficient of 0.270 at the 1% level. This can be understood as follows: CO2 emissions would rise by 0.270% for every 1% increase in GDP2. The ECT (1) coefficient values are also statistically significant and negative. This outcome shows that the variables identified by the ARDL Bounds testing process have a cointegration connection. The amount by which each short-run period corrects the long-run disequilibrium in the dependent variable is indicated by the coefficient of the ECT term. The coefficients of the ECT components are identical to 0.189, which means that the annual correction for CO2 emission variation from the long-run route is 18.90%.

Conclusion.

The Environmental Kuznets Curve for the United States from 1979 to 2021 is examined in this study using data from the World Bank index to determine the causal relationship between CO2 emission, energy consumption, GDP, GDP squared, and foreign direct investment. Bound tests are used to confirm the existence of cointegration, the autoregressive distributed lag (ARDL) model is used to examine the short- and long-term effects of the dependent variables on the independent variable, and finally, the vector error correction (VECM) method is used to identify the causal relationships between the variables.

We verified that the relationship between the independent and dependent variables was long-run after taking the F-bound test into account. The coefficients for energy consumption and foreign direct investments were significant at the 10% level, according to our research. GDP and GDP2 were shown to be unimportant variables. Energy use has a beneficial impact on CO2 emissions, but FDI has a negative impact. Additionally, it is clear from the prior long-run relationship that the association between GDP and CO2 emission, including GDP2 and CO2 emission, was negligible.

Therefore, it was discovered that energy consumption, economic growth, and foreign direct investment have an impact on rising carbon emissions from both short-run and long-run analyses of the association of variables in the EKC model. Therefore, in terms of policy, the United States' power industry should be rapidly decarbonizing, with major increases in the deployment of renewable energy sources.

Additionally, the combined generation of coal and natural gas should decrease as well, highlighting the crucial significance of renewable energy.The significant amount of new zero-emission capacity (primarily renewables) that will need to be deployed each year to enable an increasing large share of clean electricity generation, especially solar and wind capacity additions, is one of the challenges to achieving the 2050 net-zero goal (as well as the 2035 100% clean electricity goal). In order to promote major renewable deployment, the federal government should also quicken investment programs, tax credits, regulatory actions, state policies, research and development, and market trends.

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