

The impact of energy consumption, FDI, and economic growth on CO₂ emissions in Central Asia. Empirical evidence from panel ARDL

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Abstract. Utilizing Panel ARDL and a panel Granger causality test, this paper examines the influence of GDP, energy usage, FDI, and trade openness on carbon dioxide (CO₂) emissions in three specific Central Asian countries: Kazakhstan, Kyrgyz Republic, and Uzbekistan, from 1997 to 2021. PMG approach findings indicate that energy usage, FDI, and trade have a statistically significant positive impact on CO₂ emissions, but GDP has a negative and statistically significant effect on CO₂ emissions. In the short-run, only FDI and energy consumption have statistically significant impact on CO₂ emissions, negative and positive, respectively. Granger non-causality test also verifies that each variables have a granger cause on CO₂ emissions in Central Asian countries.

1 Introduction

Many countries throughout the globe have centred their economic policies on the goal of achieving growth in their economies that is both stable and sustainable. Nevertheless, economic expansion may influence climate change and global warming, which are the most important challenges and worries on a global scale. Increasing Carbon dioxide (CO₂) concentration and additional heat-trapping gases (GHG) are a by-product of industrialization and urbanization [1]. Regarding the relationship that exists between CO₂ emissions, energy use, and GDP expansion, most of the research that has been done has arrived at the same general conclusion. According to this point of view, energy is one of the key resource input variables in the production process, alongside other components such as land, labour, money, and entrepreneurial spirit. This perspective suggests that energy is an indispensable and valuable input factor for resources. Therefore, economic production is affected by the usage of energy [2]. According to this point of view, the amount of CO₂ emissions, which is the primary contributor to GHG emissions, is determined by both the expansion of the economy and the use of energy [3].

It is also widely accepted that rising energy demands and developing economies are intricately linked. The growth hypothesis, the conservation hypothesis, the objectivity

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hypothesis, and the feedback hypothesis all serve as foundations for studies of the connection between economic development and energy. Consumption of energy is assumed to be an instrumental antecedent of economic expansion in the growth hypothesis, along with other antecedents like capital and labour. This indicates that measures adopted to reduce energy use would have a negative impact on GDP increase. Because of this, the path of causation flows from the use of energy to the expansion of the economy.

Huge amounts of research have been done to try to pin down the nature of this connection, but the results are still vague. Numerous explanations for the correlation between rising energy use and a flourishing economy have been presented, and they may be categorized into three broad camps: growth, conservation, and neutral [4-8].

Having achieved economic development is now seen as one of the most essential components to a country's economic progress. Growth is a topic that has been, and will continue to be, the focus of a great deal of research. Numerous economic investigations have agreed that energy is a significant success determinant [9]. To effectively execute energy policy, it is crucial to comprehend the connection between economic development and energy use. The member nations of the Commonwealth of Independent States (CIS) have varying degrees of development, energy consumption, and control of natural resources. Furthermore, in order to boost their economic development rates, emerging and transition countries engage in energy-intensive industries [10].

Throughout the course of the previous few decades, a considerable number of empirical studies have been carried out to study the link that exists between expanding economies and rising levels of carbon dioxide emissions. Despite this, the link continues to be the subject of debate among academics and policymakers. Considering above-mentioned, this research tries to make several empirical contributions with its findings. Firstly, this study examines the correlation between CO₂ emissions, energy use and economic development by expanding time span. Secondly, the current investigation is an innovative piece of research that focuses on the relationship between energy use, CO₂ emissions and the expansion of the economy in selected countries, specifically for Kazakhstan, Kyrgyz Republic, and Uzbekistan to analyse both short- and long-term relationships between the variables under study by applying Panel ARDL model. This article analyses how economic growth and energy influence CO₂ emissions in selected countries. It is anticipated that the empirical results of this research will facilitate management authorities in establishing effective public policies to improve energy supply, making this study essential. Furthermore, it will contribute to the existing literature on how energy use affects economic development in two emerging Central Asian countries.

This paper use panel data analysis to investigate whether CO₂ emissions, FDI, trade openness, energy consumption, and economic growth are related in three distinct Central Asian countries: Kazakhstan, Kyrgyz Republic, and Uzbekistan from 1997 to 2021.

The paper consists of five sections: Section two provides an overview of the relationships between CO₂ emissions, trade openness, FDI, energy consumption and economic growth in the countries under the investigation. Empirical research on the connection between FDI, economic growth, renewable energy consumption and energy use are presented in chapter three. After providing an explanation of the data and technique used, the empirical findings are then examined in the following chapter. In the concluding section, several assessments are carried out considering the results gained via the use of empirical research.

2 Literature review

The existing literature indicates that there has been extensive research on the relationships between CO₂, FDI, energy use and economic development. However, there is a lack of data from empirical research that investigates the link between CO₂, FDI, energy use and economic development in Kazakhstan, Kyrgyz Republic, and Uzbekistan.

A panel of 68 nations was analyzed by Muhammad [11] to determine the relationship between CO₂ emissions, economic growth, and energy consumption using dynamic regression model and seemingly unrelated regression (SUR) based on the system generalized method (SGM) and the generalized method of moments (GMM). According to the findings of the study in the countries, energy consumption can lead to increased CO₂ emissions and economic expansion.

By analyzing quarterly data from 1996 Q1 to 2016 Q4 for the period of 1996 Q1 to 2016 Q4 using an auto-regressive distributed lag (ARDL) model, Mehmood [12] provide three developing nation-specific analyses, Bangladesh, India, and Pakistan to assess interdependence between economic development and institutional quality, in addition to extra control variables, including renewable energy and FDI on CO₂ emissions. The findings of the paper confirm that institutional quality and GDP reduce CO₂ emissions.

Depending on aspects like economic structure and rate of economic development, the effect of energy consumption on economic growth might be quite different from one region to another. As a result, opinions vary as to which direction energy consumption really causes GDP growth. There are four competing ideas in the literature that attempt to account for the correlation between economic expansion and technological advancement: the growth theory, the protective theory, the objective theory, and the feedback theory [13, 14]. Concisely, the growth hypothesis predicts that a rising economy would lead to more energy consumption, hence it follows that a growing economy will need more energy to sustain its development. In this situation, energy conservation regulations might slow down the economy. However, it demonstrates that, in the case of single-direction causation (the conventional hypothesis) between energy consumption and economic development, there is little or no effect of energy conservation on economic development. Energy use and GDP growth may be connected in a bidirectional manner, according to the feedback hypothesis. Furthermore, it shows that energy use and economic growth are not associated, which is consistent with the neutrality hypothesis, suggesting that the advantages of energy efficiency measures are overstated [15].

Using panel cointegration tests and Panel Dynamic OLS, Umurzakov et al. [16] analyzes short-term and long-term link between variables in an effort to explore the integration of economic growth and energy output in post-communist nations between 1995 and 2014. The empirical analysis revealed that the two variables, energy consumption and economic expansion, are cointegrated.

Hydroelectricity use and economic progress of seven Latin American nations is analyzed by Solarin and Ozturk [17] using VAR, GLS, DF, Granger, and Johansen cointegration. The study examines the period from 1970 to 2012. According to the results of the regression studies, the usage of hydroelectricity has a favorable effect on the economies of the Latin American nations being studied.

Utilizing several panel data approaches Inglesi-Lotz [18] was able to evaluate the effect that the adoption of renewable energy influences the OECD countries' economic well-being between the years 1990 and 2010. It appears that renewable energy sources and GDP expansion are associated in a positive and statistically significant way.

Using the GMM framework over the period of 1990 to 2012, Abdouli and Hammami [19] conducted a study of the interaction between GDP growth, foreign direct investment, and energy consumption for 17 countries, including several Middle Eastern and North African countries. This analysis is performed for a total of 17 countries. The findings indicate a bidirectional causal link between economic development and FDI, along with an association between energy consumption and economic growth.

Based on static and GMM econometric models, Muhammad and Khan [20] estimate the impact of FDI, equity capital (EC), capital, and CO₂ on economic development in Asia for 115 origin and 34 destination countries. It has been established empirically that factors such

as FDI inflows and outflows, energy consumption, CO₂ emissions, and capital are crucial to the economic development of Asian countries.

An analysis of urbanization, foreign direct investment, energy consumption and CO₂ emissions in seven emerging economies (E7) from 1991 to 2014 was conducted by Li et al. [21]. He conducted this by using contemporary econometric approaches that are resistant to the problems of intersectional dependency and the occurrence of heterogeneous slopes to produce accurate and trustworthy results. According to the findings, both energy consumption and urbanization had a profound effect on the amount of CO₂ effusions in the nations. Nevertheless, the inflow of FDI helped to reduce the emission of CO₂ in the countries. Moreover, rises in GDP and energy consumption contributed to an increase in E7 nations' CO₂ emissions, resulting in the E7 becoming less ecologically friendly.

By using a model that makes use of dynamic ARDL simulations, Islam et al. [22] examine the impact that energy consumption, urbanization, innovation, trade, FDI, globalization and economic growth had on Bangladesh's CO₂ emissions from 1972 to 2016. According to the findings of the study, globalization, innovation and FDI all have negative effects on CO₂ emissions, which results in an improvement in the quality of the environment; on the other hand, urbanization, energy consumption, trade, and economic growth all have positive effects on CO₂ emissions, which results in an acceleration of environmental deterioration both in the short and long term.

A vector error correction model is applied to the Granger causality test by Ansari et al. [23] using yearly data from 1971 to 2013 to investigate the influence of energy consumption, international commerce, and economic development on global carbon dioxide (CO₂) emissions for the top CO₂ emitters. Based on the results, CO₂ emissions and their drivers are found to be long-term relationships.

3 Data and Methodology

The database maintained by the World Bank serves as the source for the necessary data for the study. The dataset includes yearly observations beginning in 1997 and ending in 2021. We take CO₂ emissions as a dependent variable, and economic growth, energy consumption, trade openness, foreign direct investments are taken as independent variables. Below, we construct a basic model for our empirical analysis:

$$\ln CO_{2,it} = \beta_1 \ln GDP_{it} + \beta_2 \ln ENERGY_{it} + \beta_3 \ln TRADE_{it} + \beta_4 \ln FDI_{it} + \varepsilon_{it} \quad (1)$$

Where, $\ln CO_{2,it}$ - CO₂ emissions, $\ln GDP_{it}$ -logarithm of GDP (constant 2015 US\$), which is taken as a proxy for economic growth, $\ln ENERGY_{it}$ - energy consumption, $\ln TRADE_{it}$ - trade openness, $\ln FDI_{it}$ - Foreign direct investment, net inflows (BoP, current US\$), and ε_{it} - error term.

To estimate the ARDL model, first the unit root test and then the cointegration test must be carried out. It is possible to correctly use the ARDL model for short sample periods and to distinguish between short-run and long-run coefficients. Furthermore, it is useful for analyzing data across a wider time span. There is a high degree of consistency in the long-run parameters, but the short-run parameters are \sqrt{T} reliable, according to Pesaran and Shin [24]. Consequently, equation (1) is converted into a panel ARDL (p, q_1, q_2, q_3, q_4) equation, the lag of the dependent variable is represented by p , whereas the lags of independent variables are represented by q . The equation for the panel's ARDL may be expressed as follows:

$$\ln CO_{2,it} = \alpha_i + \sum_{j=1}^p a_{1,ij} \ln CO_{2,i,t-j} + \sum_{j=0}^{q_1} a_{2,ij} \ln GDP_{i,t-j} + \sum_{j=0}^{q_2} a_{3,ij} \ln ENERGY_{i,t-j} + \sum_{j=0}^{q_3} a_{4,ij} \ln TRADE_{i,t-j} + \sum_{j=0}^{q_4} a_{5,ij} \ln FDI_{i,t-j} + \varepsilon_{it} \quad (2)$$

Where, $i = 1,2,3,...N$ and $t = 1,2,3,...T$. Fixed effects are represented by α_i , a_1-a_5 are the coefficients of the independent variables and regressors that have been correlated with each other over the time period in question, and ε_{it} is the error term, depending on the time and place, it is said to be caused by white noise.

This is the panel error correction (ECM) representation of equation (2):

$$\begin{aligned} \ln CO_{2,it} = & \alpha_i + \sum_{j=1}^p a_{1,ij} \ln CO_{2,i,t-j} + \sum_{j=0}^{q_1} a_{2,ij} \ln GDP_{i,t-j} + \\ & \sum_{j=0}^{q_2} a_{3,ij} \ln ENERGY_{i,t-j} + \sum_{j=0}^{q_3} a_{4,ij} \ln TRADE_{i,t-j} + \sum_{j=0}^{q_4} a_{5,ij} \ln FDI_{i,t-j} + \\ & \beta_{1,ij} \ln CO_{2,i,t-1} + \beta_{2,ij} \ln GDP_{i,t-1} + \beta_{3,ij} \ln ENERGY_{i,t-1} + \beta_{4,ij} \ln TRADE_{i,t-1} + \\ & \beta_{5,ij} \ln FDI_{i,t-1} + \varepsilon_{it} \end{aligned} \tag{3}$$

Where, Δ is the first difference of variables. The short-run coefficients are denoted by a_1-a_5 . While, the long-term indices of CO_2 , economic growth, energy consumption, trade openness and FDI are $\beta_1-\beta_5$, respectively. Long-term associations between the dependent variables and the regressors have been established in the panel ECM model equation (3):

$$\begin{aligned} \ln \Delta CO_{2,it} = & \alpha_i + \sum_{j=1}^p a_{1,ij} \ln \Delta CO_{2,i,t-j} + \sum_{j=0}^{q_1} a_{2,ij} \ln \Delta GDP_{i,t-j} + \\ & \sum_{j=0}^{q_2} a_{3,ij} \ln \Delta ENERGY_{i,t-j} + \sum_{j=0}^{q_3} a_{4,ij} \ln \Delta TRADE_{i,t-j} + \sum_{j=0}^{q_4} a_{5,ij} \ln \Delta FDI_{i,t-j} + \\ & \theta_i ECM_{i,t-1} + \varepsilon_{it} \end{aligned} \tag{4}$$

Where, θ_i is the ECM coefficient that indicates how quickly the long-run equilibrium is adjusted each year. Given the low number of yearly data, a maximum lag length of three is selected as the ideal choice for the ECM model’s optimal lag length, which is obtained by using Akaike’s lag criteria for selection. The pooled mean group methodology, often known as the PMG technique, is utilized in the estimation of the panel ARDL regression. This is an estimating method which was developed by Pesaran et al. [25] involves coefficient averaging and pooling of the coefficients in the estimation process. The above panel technique provides flexibility group differences in the intercepts, short-run coefficients, and error variances. The likelihood-based PMG estimator, additionally, forces all group long-run coefficients to be equal. Consequently, when homogeneity limitation is fulfilled, reliable estimates are obtained. Moreover, this study demonstrated that the PMG estimate is less vulnerable to outliers when small cross-sectional samples (N) are used, and that serial autocorrelation may also be resolved at the same time since small cross-sectional samples are used. This likelihood-based estimate also takes into account the problem of endogenous variables by identifying the appropriate lag structures with regard to both dependent and independent elements.

Before estimating the basic model using a panel dataset, it is important to confirm the stationarity of the sample. The IPS and Fisher type tests are used to determine if a unit root exists in a group of panel series. There are two sets of tests that were developed by Im, Pesaran, and Shin [26] and Maddala and Wu [27]. Each of these tests follows the same basic format, which may be described as an ADF regression for panel dataset in the following format:

$$\Delta y_{it} = \alpha_i \gamma_i y_{it-1} + \sum_{j=1}^p \varphi_j \Delta y_{i,t-1} + \varepsilon_{it} \tag{5}$$

where, $\gamma_i = \rho_i - 1$

The null hypothesis of unit root is tested using both techniques: $\gamma_i = 0$ ($\rho_i = 1$) as contrast to the option of remaining static, $H1: \gamma_i < 0$ ($\rho_i < 1$).

The empirically relevant variables that were included in our model are outlined in Table 1, which provides a summary of those variables. In total, there are a maximum of 75

observations because of data limitation, and there are 5 variables, with only one of them being dependent on the others.

Table 1. Descriptive Statistics

Variable	Obs	Mean	Std. dev.	Min	Max
lnCO ₂	68	1.366584	.9236011	-.2196311	2.730512
lnGDP	75	24.22159	1.431896	21.87145	26.09241
lnFDI	72	20.41342	1.85864	15.35495	23.56956
lnTRADE	75	4.325496	.3630004	3.373905	4.984333
lnENERGY	63	.4851469	.7653352	-.8303974	1.589235

Source: Computed by using Stata 17.0

Displaying correlations between model’s independent variables, Table 2 shows the model’s multicollinearity. A correlation value of 1.000 indicates that the two variables are completely associated with one another, while 0.000 indicates that there is absolutely no association between the two variables. In general, correlation values between 0.3 and 0.5 indicate a poor correlation, and correlation scores between 0.5 and 0.7 suggest a moderate connection between two variables. Those with values more than 0.7 to 1 have a strong link; the same is true for those with negative values, which have the opposite effect and have a negative correlation [28, 29].

Table 2. Correlation Matrix

	lnCO ₂	lnGDP	lnFDI	lnTRADE	lnENERGY
lnCO ₂	1.0000				
lnGDP	0.9365	1.0000			
lnFDI	0.7636	0.7691	1.0000		
lnTRADE	-0.3628	-0.5690	-0.1207	1.0000	
lnENERGY	0.9853	0.9633	0.7789	-0.4320	1.0000

Source: Computed by using Stata 17.0

Table 3 presents the results of a test for the variance inflation factor, which was done to confirm that the assumption of trivial multicollinearity was met. Seeing as how the VIF for any of the independent variables is less than 5, the assumption is supported and the condition for identifying multicollinearity is fulfilled. VIF > 10 or 1/VIF 0.10 is a warning sign, according to the literature.

Table 3. Variance Inflation Factor test results

Variable	VIF	1/VIF
lnGDP	1.73	0.578032
lnFDI	1.68	0.596466
lnTRADE	1.13	0.883118
lnENERGY	1.25	0.865125
Mean VIF	1.51	

Source: Computed by Stata 17.0

4 Results and Discussion

Before using panel data models, namely the panel ARDL model, to investigate the connection between our interest variables, we have carefully tested for unit root and cointegration. It is

shown in Table 4 that results of the stationarity tests were conducted by utilizing a variety of techniques, namely Phillips-Perron (PP), Im-Pesaran-Shin (IPS) tests, and the augmented dickey fuller (ADF). Evidence is shown by the results that two different series, such as energy consumption and FDI, are stationary in level according to the results of IPS test. In the first difference, all variables in the study, namely CO₂ emissions, GDP, FDI, trade openness, and energy consumption are stationary. At either their level or at the first level, our results show that the variables are stationary. Our analysis can therefore be conducted using the panel ARDL model.

Table 4. Panel Stationarity Test Results

	Fisher-type tests		Im-Pesaran-Shin test	
	Fisher-PP statistics			
	I(0)	I(1)	I(0)	I(1)
lnCO ₂	2.0808	55.2125***	-1.1070	-4.1359***
lnGDP	3.3077	36.1328***	0.6109	-3.5487***
lnFDI	8.6460**	96.1235***	-2.5237***	-4.7223***
lnTRADE	4.5300	45.0643***	-0.7913	-3.7483***
lnENERGY	5.0640	71.9163***	-1.7815**	-3.7701***

Note: In parentheses, the standard errors are as follows: ** p<0.05, * p<0.1, *** p<0.01. Results of the IPS test are presented using t-bar test statistics. Statistical information about the Fisher-type test is presented as inverse chi-squared test statistics.

Table 5 displays the results from the cointegration test. As the majority of the p-values are less than 0.05, we may conclude that the variables are cointegrated.

Table 5. Pedroni Test for Cointegration

	Statistic	p-value
Within		
Modified variance ratio	0.4158	0.3388
Modified Phillips–Perron t	-0.6690	0.2517
Phillips–Perron t	-2.4578	0.0070
Augmented Dickey–Fuller t	-2.4193	0.0078
Between		
Modified Phillips–Perron t	-0.3468	0.3644
Phillips–Perron t	-2.5846	0.0049
Augmented Dickey–Fuller t	-2.2321	0.0128

Standard errors in parentheses: *** p<0.01, ** p<0.05, * p<0.1

Using the Panel ARDL model, we examine the long- and short-run connection between CO₂ emissions, GDP, FDI, trade openness, and energy consumption in Kazakhstan, Kyrgyz Republic, and Uzbekistan after confirming stationarity and cointegration across variables. Table 6 displays the results of the empirical analysis.

Table 6. Panel ARDL Analysis

VARIABLES	PMG	PMG	MG	MG	DFE	DFE
__ec		-0.432		-1.689**		-0.711***
		(0.354)		(0.734)		(0.155)
D.lnGDP		-0.451		-0.626		-0.374
		(0.499)		(0.676)		(0.342)

D.lnFDI		-0.0110*		-0.0329		0.0123
		(0.0302)		(0.0406)		(0.0141)
D.lnTRADE		-0.0470		-0.323		-0.137**
		(0.0667)		(0.266)		(0.0674)
D.lnENERGY		0.307**		-1.057		0.132
		(0.707)		(0.736)		(0.208)
lnGDP	-0.401***		-0.284*		-0.199***	
	(0.0690)		(0.147)		(0.0706)	
lnFDI	0.0790***		0.0800**		0.00463	
	(0.0250)		(0.0334)		(0.0218)	
lnTRADE	0.181***		0.0133		0.255***	
	(0.0555)		(0.0854)		(0.0636)	
lnENERGY	1.194***		0.967***		1.226***	
	(0.0718)		(0.137)		(0.0878)	
Constant		3.755		6.375**		3.183**
		(2.912)		(2.809)		(1.400)
Observations	53	53	53	53	53	53
		PMG or MG		DFE or MG		DFE or PMG
Hausman chi2		40.38		22.48		23.28
Prob>chi2		0.660		0.0002		0.0001

Standard errors in parentheses: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Firstly, before interpreting the results, we run a Hausman test to choose the right model to interpret whether PMG, MG or DFE model are appropriate. The findings of the Hausman test show that PMG model is more appropriate in this scenario because p-value of Hausman test is 0.660 which cannot reject null hypothesis. That is why we proceed to interpret the result of PMG model chosen according to the result of Hausman test.

According to the PMG model's results, all factors, namely energy consumption, FDI, trade openness, and GDP, have a statistically significant influence on CO₂ emissions at the 1% level in the long run, but none have a significant impact on CO₂ emissions in the short run. Based on the results, economic development has a negative and statistically significant influence on environmental deterioration in the study's selected nations at the 1% level. When there is a 1 percent rise in economic development, there can be 0.401 % decrease in the amount of CO₂ emissions generated. The results are supported by the works done by Saidmamatov et al. [30].

Overall, the findings of the sample indicate that foreign direct investment has a positive impact on CO₂ emissions and is statistically significant at the 1% level. This finding indicates that a rise of 1 percent in FDI corresponds to a rise of 0.0790 percent in CO₂ emissions, which indicates that FDI inflows in the countries under study have a statistically favorable influence on CO₂ emissions.

As per the findings, 1 % increase in trade openness contributes to 0.181 % acceleration of CO₂ emissions in selected Central Asian countries in the long run but not in the short run.

The next variable, energy use has significantly positive impact on CO₂ emissions in the countries under the study. According to the results, if there is one percent increase in energy usage, there will be 1.194 percent rise in CO₂ emissions of the countries.

Table 7 displays the results of a panel Granger causality test performed by Dumitrescu and Hurlin [31]. In the first step of this process, we assess the hypothesis that Granger causation does not explain the relationship between economic growth and energy use. The p-

value for the Granger non-causality test [32] results indicate that all the variables have granger cause on CO₂ emissions in Kazakhstan, Kyrgyz Republic, and Uzbekistan [33-55].

Table 7. Juodis, Karavias [31] Granger non-causality test results:

Null Hypothesis	Statistics
GDP does not granger-cause CO ₂ emissions	104.63166***
FDI does not granger-cause CO ₂ emissions	21.255775***
Trade does not granger-cause CO ₂ emissions	5538.0595***
Energy use does not granger-cause CO ₂ emissions	166.07241***

***, ** and * indicate significance at 1%, 5% and 10% levels, respectively.

5 Conclusion

Researchers have recently shown an interest in examining the connection between rising GDP and CO₂ emissions, as well as rising energy use. Nevertheless, investigations based on energy consumption are few for Central Asian nations, and there are no general consensuses among the diverse studies.

Therefore, the primary objective of this study is to investigate the nexus between CO₂ emissions, economic growth, and energy consumption on a panel of selected Central Asian countries (Kazakhstan, Kyrgyz Republic, and Uzbekistan) from 1997 to 2021 by applying a panel ARDL model to see the long-run and short-run relationships between the variables under the study, and additionally, Granger Causality test is performed. According to the findings of this study, energy consumption, foreign direct investment, and trade openness increase CO₂ emissions by 1% in selected regions over the long term, while economic growth has a negative and statistically significant impact on CO₂ emissions at a significance level of 1%. In the short-run, only FDI and energy consumption have statistically significant negative and positive influence on CO₂ emissions, respectively. According to the results of Granger non-causality test, all the variables have granger cause on CO₂ emissions in Central Asian countries.

To maintain environmental quality and encourage increasing energy consumption, it is necessary to take efforts to lessen the consequences of trade and investments via extensive outreach and public awareness. In addition, transportation, manufacturing, and electricity providers must adhere to strict energy saving standards. Further, these regulations should encourage and facilitate the widespread use of alternative fuels.

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