

The Relationship Between Central Asia's CO2 Emissions, Unemployment Rate, And Economic Development ARDL- PANEL APPROACH

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Article History:

Received: 28-11-2024

Revised: 7-1-2025

Accepted: 16-1-2025

Abstract: This paper studies the effect of unemployment rate and GDP per capita on carbon dioxide emissions in Central Asia was determined using the "Panel ARDL - PMG" model. In the study, the unemployment rate and GDP per capita in Central Asia have long-term positive effect on the annual CO2 emissions, and a short-term positive effect was observed only in the countries' economic development factor. According to the results, unemployment rate in two countries in Central Asia has a negative effect on annual CO2 emissions in the short term, and in three countries it has a positive effect. Also, GDP per capita has a positive effect on annual CO2 emissions in the short term in one country in four countries. It was estimated that the secret was statistically insignificant. These results have important implications for policymakers, emphasizing the potential role of unemployment mitigation strategies in promoting environmental sustainability in Central Asia.

Keywords: correlation-regression analyses, CO2, CA, unemployment

Introduction

In recent years, the interconnection between economic indicators and environmental sustainability has garnered increasing attention worldwide. Central Asian countries, nestled between Europe and Asia, have been particularly affected by the complex interplay between economic dynamics and environmental challenges. In order to shed light on the complex relationship between the region's economic conditions and environmental impact, this study will investigate the correlation-regression analysis between unemployment rates and carbon dioxide (CO2) emissions in Central Asian countries. Following its independence from the Soviet Union, Central Asia—which is made up of Kazakhstan, Kyrgyzstan, Tajikistan, Turkmenistan, and Uzbekistan—has experienced substantial economic changes.

While the region boasts abundant natural resources and strategic geographic positioning, it also grapples with socio-economic challenges, including unemployment, poverty, and

underemployment. Economic activities in Central Asian countries, ranging from extractive industries to agriculture and manufacturing, have profound implications for carbon emissions and environmental sustainability.

Unemployment rates serve as a key barometer of economic health, reflecting the availability of job opportunities, labor market dynamics, and overall economic performance in a given country. High unemployment rates can lead to social unrest, economic instability, and adverse consequences for individuals and communities. However, the relationship between unemployment and environmental outcomes, particularly CO₂ emissions, remains a topic of debate and empirical inquiry. Existing literature on the correlation between unemployment and CO₂ emissions offers mixed findings, reflecting the diverse socio-economic contexts and methodological approaches employed in different studies. Some scholars argue that high unemployment rates are associated with lower CO₂ emissions due to reduced economic activity and energy consumption. Others contend that unemployment may lead to increased energy use in households and reduced investments in clean technologies, resulting in higher carbon emissions. In light of this, the purpose of this research is to investigate empirically the connection between Central Asian nations' CO₂ emissions and unemployment rates.

Literature Review

The following scientists have conducted research on topics related to correlation of unemployment and CO₂. Global CO₂ emissions peaked at 31,983.6 million tons in 2020 and have grown at an average annual rate of 1.4% over the last ten years, according to the Statistical Review of World Energy 2021. This impact is extremely dangerous to human survival and causes significant economic damage because it typically lingers in the atmosphere and oceans for many generations. Given the wide range of links that exist between many nations and areas in the age of globalization, no nation can be left alone. Consequently, it is now essential to take concrete action to lower carbon emissions globally. (Xu et al. 2021; Wang et al. 2019)

Mrabet & Jarbouli have examined the effects of institutional determinants on the GDP and CO₂ emissions efficiency in Gulf and Maghreb nations between 1995 and 2013. They demonstrated that labor and other inputs had a favorable impact on the CO₂ emission efficiency of Arabic nations. The capital of Maghreb countries influences the GDP efficiency. The Gulf countries' massive investments result in the creation of jobs and, consequently, lower unemployment (Mrabet et al. 2017). In the Asia-Pacific area and the United States, unemployment has a major indirect effect on CO₂ emissions (Nestor et al. 2022). Between 1980 and 2011, Wang, Li, and Fang examined the connections among 170 nations' energy consumption, CO₂ emissions, urbanization, and economic growth. The findings showed that there was a statistically significant positive association between the variables over the long term and that there was a co-integration relationship between the variables in all of the nations that were analyzed (Wang et al. 2021).

Researchers from the Viet Nam National University of Agriculture Anh Tru NGUYEN found that whereas per capita CO₂ emissions have a negative impact on per capita GDP in Central Asia, per capita energy consumption has a positive link with per capita GDP. Furthermore, the region's per capita energy consumption is negatively impacted by per capita GDP. The findings show that energy consumption continues to be a major factor in the economic development of Central Asian nations. Nonetheless, as CO₂ emissions have been identified as a factor contributing to a decline in economic growth, there is a need to lower them in this area (2021).

Emphasizing the risks associated with using fossil fuels for energy is crucial to reducing the rate of ecological disturbance. Nowadays, with so many environmental issues facing the world, it is critical to look for environmentally acceptable energy solutions for both residential energy needs and product production. Consequently, numerous research works have emphasized the significance of renewable energy in enhancing economic expansion and guaranteeing environmental sustainability (Kuziboev et al., 2024). When total energy and non-renewable energy consumption are equated for ecological conditions, it is discovered that renewable energy sources are most effective at promoting environmental sustainability. In the G7, the use of renewable energy contributes positively to both environmental conservation and economic prosperity (Carfora et al. 2019).

Energy use and CO₂ emissions have a significant impact on global health indicators. Domen looked into the average CO₂ emissions from cities as well as the emissions per person in such cities. 14% of emissions were attributed to agricultural activities, while 19% were attributed to the industrial sector (2009). These days, people are exposed to small concentrations of dangerous gases like carbon monoxide and carbon dioxide on a daily basis, which can have serious negative effects. This is due to the rapidly developing technological media, the quickly expanding industry, the hundreds of cars that drive through major cities every day, and the use of pesticides and other poisonous substances for the inflated production of products. The goal of the examined regions' environmental policies should be to control CO₂ emissions in order to slow down global warming. The broad adoption of low-carbon, energy-saving, ecologically friendly, and energy-efficient technologies—including increasing the efficiency of coal energy use—should be the approach taken to lower CO₂ emissions (Volchyn et al. 2018).

Measures promoting energy production and conservation, foreign direct investment, trade openness, and economic growth would be ideal for the entire region. Even if there is a political intent to develop similar goals and objectives, separate policy and strategy designs for participant subgroups should most likely be considered to enhance the environmental protection of the region (Kuziboev et al. 2023)

METHODOLOGY

Data description.

In this research, we used *co2_emissions_per_capita* and *net_migration* panel data for Central Asian countries. This panel covered annual data from 1991 to 2021 for five countries.

Cross-sectional dependence test

To select the proper unit root test, it is significant to test the cross-sectional dependence (CD) test for the given series in the panel datasets (Pesaran 2006). For this, the empirical study applies (Pesaran 2004) CD method. To determine the CD test (Pesaran 2004) purpose the following model:

$$CD = \sqrt{\frac{2T}{N(N-1)}} (\sum_{i=1}^{N-1} \sum_{j=i+1}^N T p_{ij}^2) \quad (1)$$

In Eq. 1, T is the time period dimension and N is the cross-sectional dimension, is p_{ij}^2 the sample estimation for the pairwise residual correlation.

Panel unit root test

The initial phase in the study is to evaluate variables' stationery to prevent false regression and reliability of the predicted outcomes. The panel unit root approach has gained popularity and is most frequently utilized in research articles because of its better power in comparison to unit root tests based on a single time series. The estimation analysis may be biased while the stationary method is applied without considering the cross-sectional dependence. Since the first-generation panel unit root test do not consider the cross-sectional dependence, however, considering the potential of cross-section dependency in our study, we utilize a second generation panel unit root test proposed by (Pesaran 2006) including cross-sectionals Augmented Dickey–Fuller (CADF) and cross-sectional Im, K. S., Pesaran, M.H., Shin, Y (CIPS) unit root tests, both kinds of panel unit root tests are considered to robust to CD test. The CADF model can be presented as fellows in Eq. 2

$$\Delta y_{it} = \alpha_i + \beta_i Y_{it-1} + \varphi \bar{y}_{t-1} + \sum_{j=0}^q \theta_{j+1} \Delta \bar{y}_{t-j} + \sum_{k=1}^q \omega_k \Delta y_{it-k} \quad (2)$$

Here, $\bar{y}_{t-1}$ is the average of lagged levels at time t of all N observations and $\bar{y}_t$ is the first difference of the individual series of the model. After estimating the CADF regression for each cross-section, the CIPS (Cross-sectional augmented IPS) statistics can be calculated by averaging the t -statistics of the coefficient β in the CADF model:

$$CIPS = N^{-1} \sum_{t=1}^N CADF_t \quad (3)$$

Where the $CADF_i$ is the cross-sectional augmented Dickey– Fuller statistics for i^{th} cross-section unit. In the existence of CD, this test gives more consistent and accurate results than the first generation test.

ARDL – PGM approach

In this context, the ARDL modeling proposed by Pesaran et al. (1996, 2001) is considered relevant insofar as it can be specified as an error correction model when the underlying variables are integrated of order one (I(1)), or fractionally integrated (I(0) and I(1)), except that the dependent variable is constrained to be I(1). However, this technique cannot be applied in the case where variables are integrated for order 2. In addition, ARDL modeling provides consistent and efficient estimators because it eliminates endogeneity problems by including lag length in both endogenous and exogenous variables. The ARDL (p, q) model used in this study can be expressed as follows:

$$\text{co2_emissions_per_capita}_{it} = \mu_i + \sum_{j=1}^{p-1} \beta_{1ij} \text{co2_emissions_per_capita}_{it-j} + \sum_{j=0}^{q-1} \beta_{2ij} \text{net_migration}_{it-j} + v_{it} \quad (4)$$

According to Pesaran et al. (1996, 2001), this equation can be reformulated as follows:

$$\Delta \text{co2_emissions_per_capita}_{it} = \mu_i + \gamma_{1i} \text{co2_emissions_per_capita}_{it-1} + \gamma_{2i} \text{net_migration}_{it-1} + \sum_{j=1}^{p-1} \delta_{1ij} \Delta \text{co2_emissions_per_capita}_{it-j} + \sum_{j=0}^{q-1} \delta_{2ij} \Delta \text{net_migration}_{it-j} + \varepsilon_{it} \quad (5)$$

where terms in level reflect long-run dynamics, while terms in first difference reflect short-run effects. ε_{it} denotes the error term and Δ the first difference operator. The choice of lagged variable (p, q) is determined according to the Akaike Information Criterion (AIC) or Schwarz Bayesian criterion (S.B.C). Regarding the estimation of the panel ARDL model, Pesaran and Smith (1995) and Pesaran et al. (1999) introduced two techniques respectively the Mean Group (MG) and the Pooled Mean Group (PMG) estimation. However, these procedures, based on the maximum likelihood method, are considered to be the most consistent since they take into account the specificities of the different regions and make a better interpretation of long-run equilibrium.

DISCUSSION

Table 1 illustrates the results of the cross-sectional dependence test. Based on the results of this method, the null hypothesis is rejected because ($P - \text{values} < 5\%$), which indicates that the existence of cross-sectional dependence at 1% significance level for all series.

Table 1. Results of cross-sectional dependence test.

	<i>LOG(CO₂)</i>	<i>LOG(unem_rate)</i>	<i>LOG(gdp_per_capita)</i>
Pesaran CD	3.621	14.669	16.48
Prob.	0.00	0.000	0.000

The findings of the cross-sectional dependence test represent that any shock or amendment in the variables can effects in any of the panel regions as well. Indeed, the second-generation panel unit root tests are applied in the next step.

At the next stage, a panel unit root test was conducted for 3 variables at their own level (level) and at the 1st order level (first difference) (Table 2).

Table 2. Panel unit root test outcomes.

Variables	Level	First difference
CADF		
<i>LOG(CO₂)</i>	6.52	55.44***
<i>LOG(unem_rate)</i>	72.55***	69.09***
<i>LOG(gdp_per_capita)</i>	1.83	25.28***
CIPS		
<i>LOG(CO₂)</i>	0.36	-6.07***
<i>LOG(unem_rate)</i>	-8.32***	-7.65***
<i>LOG(gdp_per_capita)</i>	2.12	-2.91***

It can be seen from the table that the variables *LOG(CO₂)*, *LOG(gdp_per_capita)* are stationary at the 1st order level according to the CADF and CIPS unit root tests. It can also be observed that the variable *LOG(unem_rate)* is stationary at its level and at the level of order 1 according to CADF, CIPS. Therefore, it is appropriate to use the level of order 1 when integrating these variables into equations.

Based on the above, long-term and short-term effects of unemployment rate and GDP per capita on environmental degradation in Central Asian countries were assessed (Table 3).

Table 3. Estimation ARDL (PMG)

Dependent variable:				
<i>DLOG(CO₂)</i>				
Variable	Coefficient	Std. Error	t-Statistic	Prob.*
Long Run Equation				
<i>LOG(unem_rate)</i>	0.133578	0.044280	3.016641	0.0031
<i>LOG(gdp_per_capita)</i>	0.332340	0.024040	13.82418	0.0000
Short Run Equation				

$ECT(-1)$	-0.250911	0.125376	-2.001277	0.0474
$DLOG(unem_rate)$	-0.039114	0.083670	-0.467485	0.6409
$DLOG(gdp_per_capita)$	0.170144	0.059549	2.857209	0.0050
C	3.645767	1.854825	1.965559	0.0514

The evaluation's findings indicate that, over time, a 1% rise in the Central Asian nations' unemployment rate may cause an increase in yearly CO₂ emissions of 0.13%, whereas a 1% increase in GDP per capita may cause an increase in CO₂ emissions of 0.33%. The impact of the unemployment rate on annual CO₂ emissions is statistically negligible in the near run, whereas GDP per capita has a positive influence with a coefficient of 0.17. Additionally, 25% of the disequilibrium from the previous year is corrected this year, according to the adjustment parameter (0.25) in the equation indicating the short-term effect (speed of adjustment parameter), which is negative and substantial at the 1% level.

In addition, in our research, we evaluated the short-term impact of unemployment rate and GDP per capita on annual CO₂ emissions for each country in Central Asia separately (Table 4).

Table 4. Individual country results

Country	Estimation ARDL (PMG)		
	$ECT(-1)$	$DLOG(unem_rate)$	$DLOG(gdp_per_capita)$
Kazakhstan	-0.148***	-0.054***	0.157**
	(0.003)	(0.001)	(0.005)
Kyrgyzstan	-0.323***	0.031**	0.348***
	(0.007)	(0.008)	(0.036)
Tajikistan	-0.061***	-0.352***	0.241**
	(0.008)	(0.032)	(0.054)
Turkmenistan	-0.705***	0.13 ***	0.104***
	(0.031)	(0.006)	(0.02)
Uzbekistan	-0.015***	0.05***	-0.001
	(0.001)	(0.003)	(0.004)

***Significance of 1%; **significance of 5% and *significance of 10%

According to the evaluation results, it can be seen that in some countries of Central Asia, the level of unemployment in the short term has a negative effect on the volume of annual CO₂ emissions, and in some countries it has a positive effect. Also, GDP per capita has a positive

effect on annual CO₂ emissions in the short term in four countries, and in one country, the effect was statistically insignificant. Specifically, in Kazakhstan, a 1% increase in unemployment causes annual CO₂ emissions to drop by 0.05%, whereas a 1% increase in GDP per capita causes CO₂ emissions to rise by 0.15%. In Kyrgyzstan, annual CO₂ emissions increase by 0.03% for every 1% increase in the unemployment rate and by 0.34% for every 1% increase in GDP per capita. In Tajikistan, annual CO₂ emissions decrease by 0.35% with a 1% increase in the unemployment rate and increase by 0.24% with a 1% increase in GDP per capita. Additionally, there was a 1% rise in the unemployment rate in the Republics of Uzbekistan and Turkmenistan, as well as a yearly rise in CO₂ emissions.

Conclusion And Recommendation

Based on the findings of our research investigating the association among CO₂ emissions, the unemployment rate, and economic development in Central Asia using a panel-ARDL approach, several key conclusions can be drawn. The study reveals a consistent long-term positive relationship between both the unemployment rate and GDP per capita in Central Asia and annual CO₂ emissions. This underscores the significant influence of economic factors on environmental outcomes in the region over extended periods. In the short term, the relationship between economic indicators and CO₂ emissions exhibits more nuanced patterns. While economic development, as measured by GDP per capita, positively impacts CO₂ emissions across most countries in the short term, the effect of the unemployment rate varies. Some countries experience a negative short-term relationship between unemployment and CO₂ emissions, indicating potential environmental benefits during economic downturns. However, in other countries, higher unemployment is associated with increased CO₂ emissions, suggesting complex interactions between economic activity and environmental outcomes.

These findings have significant implications for policymakers in Central Asia. Efforts to address CO₂ emissions must consider the broader socioeconomic context, including the unemployment rate and GDP per capita. While reducing the environmental impact of industrial activity, strategies aiming at encouraging sustainable economic development should place a high priority on investments in clean energy infrastructure, technological innovation, and job creation.

Moreover, policies to alleviate unemployment should be designed with environmental sustainability in mind to ensure that economic growth is not achieved at the expense of environmental degradation. While this study provides valuable insights into the relationship between economic development, unemployment, and CO₂ emissions in Central Asia, further research is needed to explore the underlying mechanisms driving these relationships. Future studies could investigate the role of specific industries, energy sources, and policy interventions in shaping environmental outcomes. Additionally, incorporating a more comprehensive dataset spanning a longer time period and considering the impacts of external factors, such as

international trade and investment, could enhance our understanding of the dynamics of CO₂ emissions in the region. In conclusion, our research highlights the complex interplay between economic factors and environmental outcomes in Central Asia. By elucidating these relationships, policymakers can develop more effective strategies to promote sustainable development and address the pressing challenges of climate change while fostering economic prosperity and social well-being in the region.

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