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Article

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International Journal of Energy Economics and Policy

Provided in Cooperation with:
International Journal of Energy Economics and Policy (IJEEP)

Reference: Issayeva, Gulmira/Zhussipova, Elmira Y. et. al. (2024). Examining the environmental Kuznets curve hypothesis in energy, agriculture, and industry sectors : the case of Kazakhstan. In: International Journal of Energy Economics and Policy 14 (4), S. 1 - 11.
https://www.econjournals.com/index.php/ijeep/article/download/16005/7963/37829.
doi:10.32479/ijeep.16005.

International Journal of Energy Economics and Policy

ISSN: 2146-4553

available at http: www.econjournals.com

International Journal of Energy Economics and Policy, 2024, 14(4), 1-11.

Examining the Environmental Kuznets Curve Hypothesis in Energy, Agriculture, and Industry Sectors: The Case of Kazakhstan

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Received: 25 January 2024 **Accepted:** 10 May 2024 **DOI:** https://doi.org/10.32479/ijeep.16005

ABSTRACT

This study analyzed Kazakhstan's Environmental Kuznets Curve hypothesis using the ARDL Boundary Value Approach method. The study focused on economic growth, energy production, agriculture, and industrial production variables in 2000-2022. The per capita national income variable represented economic growth, while CO_2 emissions represented environmental quality. Energy consumption and production should be considered as they are interconnected in examining environmental quality and economic development. Therefore this study used the Kuznets hypothesis in a broader perspective by taking into account various factors such as agricultural and industrial production, as well as energy consumption. The results indicate that the square term of GDP in all four models is negative, which supports the Kuznets hypothesis for Kazakhstan. Furthermore, it is noteworthy that the inclusion of macro variables such as agricultural production, industrial production, and renewable energy consumption, in addition to GDP, does not alter the support for the Kuznets hypothesis. Models 2, 3, and 4 have shown that agricultural production does not have any impact on CO_2 emissions. However, the same is not true for industrial production and renewable energy production, as they do have an impact. The study aimed to test the Kuznets hypothesis and reveal the impact of macro indicators on CO_2 emissions. By doing so, the study not only provides useful information to country managers but also contributes to the literature by highlighting the relationships between environmental quality and macro variables.

Keywords: Kazakhstan, Kuznets Curve, Auto Regressive Distributed Lag Boundary Value Approach, Energy, Agriculture, Industry
JEL Classifications: C13, C20, C22

1. INTRODUCTION

Kazakhstan declared its independence on December 16, 1991, following the collapse of the Soviet Union. To overcome the economic difficulties faced after gaining independence, Kazakhstan transitioned to a free market economy and implemented important structural reforms (Taibek et al., 2023; Bekzhanova et al., 2023; Yesbolova et al., 2024). Although these radical changes initially presented challenges, the country's economy experienced rapid growth in the early 2000s. During this period, Kazakhstan introduced its national currency, the Tenge, implemented monetary and financial reform policies, controlled inflation, encouraged free entrepreneurship, and established the Kazakhstan Stock Exchange (KASE). These successful reforms helped Kazakhstan to emerge as a significant economic power among the post-Soviet countries. The country's economic growth has been remarkable, as noted by several studies (Kasım, 2022; Sultanova et al., 2024; Xiong et al., 2015; Myrzabekkyzy et al., 2022; and Dyussembekova et al., 2023). Kazakhstan's rich fossil energy resources have played a vital role in its recovery from the economic difficulties it faced after gaining independence. The country holds about 3.3% of the world's total coal reserves, approximately 3% of oil reserves, and approximately 1.1% of natural gas reserves (Mudarissov and Lee, 2014; Xiong et al., 2015; Bolganbayev et al., 2022; Mashirova et al., 2023; Issayeva et al., 2023).

The energy demand has increased due to industrialization as energy production, lighting, transportation, heating, and many other processes require energy. This demand has increased over time. Kazakhstan is the largest energy producer in the region, with 102 power plants (Koç and Saidmurodov, 2018). Apart from fossil energy resources, Kazakhstan also has abundant renewable energy resources like geothermal energy, wind energy, hydroelectricity, biofuel, and solar energy. Its wide and rich geography provides ample opportunities for harnessing these resources (Xiong et al., 2015; Ongarova, 2018; Sartbayeva et al., 2023; Sabenova et al., 2023; Niyetalina et al., 2023). Despite its huge potential for renewable energy resources, Kazakhstan currently produces 75% of its energy in coal-based power plants. This has made Kazakhstan one of the leading countries in greenhouse gas emissions worldwide (Syzdykova, 2020). However, the government of Kazakhstan has recognized the importance of renewable energy resources for environmental sustainability and has developed policies to encourage their use. Significant investments were made in renewable energy sources such as wind, hydroelectric power, biogas, and solar. In the first quarter of 2021, the electrical energy produced from renewable sources increased to 2005.5 million kWh from 1470 million kWh in the first quarter of 2020 (Smagulova et al., 2023).

Kazakhstan is ranked 9th in the world in terms of its wide geography. Therefore the country has great potential in agriculture and livestock (Timor et al., 2018 and Liang et al., 2020). However, the share of the agriculture and livestock sector in the country's GDP has decreased over the years, as investments were focused on the energy sector after independence. Despite this, the agriculture and livestock sector is still the third largest export sector in Kazakhstan, after the energy and mining sector (Timor et al., 2018; Sartbayeva et al., 2023).

According to Kuznets (1973), economic growth refers to a country's ability to provide its population with an increasingly diverse range of economic products over the long term. In general, economic growth is measured by an increase in a country's production levels and real national income per capita, commonly known as the GDP (Nafziger, 2006). GDP figures are considered more reliable indicators of economic growth as they reflect more realistic results. Factors such as political stability, government policies, human capital development, foreign trade policy, foreign direct investment, domestic capital structure, banking and financial infrastructure, energy production and consumption, industrial production, and agriculture and livestock production are key determinants of economic growth (Neelankavil et al., 2012; Sandalcilar, 2012).

In Kuznets 1955, Kuznets analyzed the impact of increasing or decreasing economic growth on income distribution inequality. His article, titled "Economic Growth and Income Equality," revealed that as per capita income (which represents economic growth) increases, income inequality also increases. However, after a certain income level, inequality begins to decrease. The relationship between income distribution inequality and per capita income is represented graphically in the form of an inverted U, known as the Kuznets Curve, named after Kuznets himself (Dinda, 2004).

The damage inflicted on the environment by the rapidly growing civilian and military industries in the bipolar world following World War II was first recognized in the 1960s. This issue was brought up in international meetings during the 1970s and 1980s. In the early 1990s, environmental degradation became a pressing concern, as issues such as global warming and climate change came to the forefront. This led to further examination of the relationship between economic growth and environmental pollution. In 1991, Grossman and Kruger adapted the Kuznets Curve model to the relationship between per capita income and environmental pollution. Their hypothesis, known as the environmental kuznets curve (EKC) hypothesis, states that environmental pollution will initially increase with economic growth, but will eventually decrease while growth continues to increase (Dinda, 2004). This theory has been the subject of many studies in the literature, but its validity is still under observation. Researchers have not reached a consensus on this issue due to various factors such as different data collection sources, research techniques, conditions of the examined period, and different structures of the country's economies (Van Alstine and Neumayer, 2008).

This study analyzes the Environmental Kuznets Curve hypothesis using the ARDL Boundary Value Approach method. The study focuses on examining the correlation between economic growth, energy production, agriculture, and industrial production in Kazakhstan between 2000 and 2022.

2. LITERATURE REVIEW

Numerous studies in the literature have explored various aspects of the Kazakhstan economy and the Environmental Kuznets Curve hypothesis. In this paper, the main studies related to these topics will be presented.

Pesaran et al. (2001) conducted a study analyzing the dynamic cointegration and causality relationships between the Global Mean Sea Level (GMSL) and its determinants. They empirically examined the short- and long-term effects of climate change, energy consumption, carbon dioxide emissions, urbanization, and trade openness on the global mean sea level using 1970-2019 time series data. According to the research findings, all variables were integrated to the first order, that is, I(1), as determined from the results of the Augmented Dickey-Fuller (ADF), Phillips-Perron (PP), and Kwiatkowski-Phillips-Schmidt-Shin (KPSS) tests. Their research findings revealed that, from the bounds test approach, only a cointegration relationship emerged when GMSL (global mean sea level) was the dependent variable. Additionally, the Granger causality test results of the VEC model indicated that short-term unidirectional causalities run from carbon dioxide emissions and energy consumption to GMSL, from energy consumption and trade openness to carbon dioxide emissions, and from trade openness to GMSL. They also found that the temperature, carbon dioxide emissions, and urbanization variables have significant positive effects in the short run, while energy consumption and trade openness have significant negative effects on GMSL at any level of significance. They discovered that increasing temperature and carbon dioxide over time will rapidly increase GMSL.

Yandle et al. (2004) conducted a comprehensive analysis of scientific research published on the Environmental Kuznets Curve (EKC) up to that time. They identified 14 key findings and methodologies.

Van Alstine and Neumayer (2008) critically analyzed the theoretical and empirical literature on EKC. Their research found that recent advancements in empirical methods addressed past criticisms and added robustness to EKC results for specific environmental pollutants. As a result, they suggested that economic growth and liberalization should not be considered as solutions to environmental problems, especially in developing countries. They also emphasized that recent studies reveal unpleasant consequences for many underdeveloped countries (UDCs) entering the phase of economic development in which emissions levels will increase rapidly.

In their study, Yurttagüler and Kutlu (2017) tested the relationship between income and CO_2 emissions in Turkey using time-series analysis. They analyzed the validity of the Environmental Kuznets Curve (EKC) with the Johansen Cointegration test using data from 1960 to 2011. They discovered a cointegrated relationship between income and CO_2 emissions. Moreover, they observed an N-shaped relationship between these variables. Thus, they concluded that the data set in question did not support the EKC hypothesis.

Liu et al. (2020) conducted a study to examine the link between globalization and CO_2 emissions for G7 countries from 1970 to 2015. They used the panel fixed effects model and the semi-parametric panel fixed effects model for their analysis. The findings of their research indicate that the relationship between globalization and CO_2 emissions takes the shape of an inverted U. This finding strongly supports the Environmental Kuznets Curve hypothesis. The study also found that an increase in economic output leads to a statistically significant rise in CO_2 emissions. However, an increase in the consumption of renewable energy reduces CO_2 emissions.

Pao and Tsai (2011) conducted a study on the impact of economic growth and financial development on environmental degradation in BRIC countries (excluding Russia between 1992 and 2007), using the panel cointegration method. Their findings supported the Environmental Kuznets Curve (EKC) hypothesis. They also observed a strong bidirectional causality between emissions and foreign direct investments and a strong unidirectional causality from production to foreign direct investments. Furthermore, they found a strong bidirectional causality between output emissions and output-energy consumption and a strong unidirectional causality from energy consumption to emissions.

Moutinho and Robaina (2016) analyzed the relationship between Carbon Dioxide emissions in electricity production, GDP, and the share of renewable energy sources (RES) in 20 European countries from 1991 to 2010. The study evaluated the short- and long-term causality of the share of renewable energy sources through cointegration analysis, FMOLS, and DOLS for long-term forecasting. They also used VECM, generalized forecast variance decomposition approach, and impulse-response analyses to examine the relationship between GDP and the share of renewable energy in electricity production. The research findings supported the EKC hypothesis for the period under examination. Additionally, a positive Granger causality relationship was discovered from GDP to renewable energy, and a negative Granger causality relationship was found from renewable energy to GDP between 2001 and 2010. The variance decomposition analysis also confirmed these results. Furthermore, the impact-response analysis revealed that CO_2 reacts negatively to shocks to GDP but positively to shocks to the share of renewable energy in electricity production and the square of GDP.

Ibyzhanova et al. (2024) conducted a study on the relationship between energy production, foreign trade, and economic growth in the Turkish Republic. They used the Panel Data method to analyze data from 2000 to 2020. According to their findings, energy production has a positive impact on economic growth in the Turkish Republic. On the other hand, they found that the volume of foreign trade does not have a statistically significant effect on economic growth when both exports and imports are considered together. The researchers interpreted this result as an indication of the importance of energy production for increasing economic growth. They emphasized that countries should prioritize energy production as a means of boosting their economies.

In a study conducted by Niyetalina et al. (2023), the relationship between energy production from fossil fuels, low-carbon resources, and renewable resources and inflation in Kazakhstan was analyzed between 2000 and 2021. The study employed the VAR method within the framework of the Taylor rule. The findings revealed that interest affects inflation, which aligns with the Taylor rule. The study also found a significant statistical relationship between energy production and inflation in Kazakhstan. Specifically, energy production from fossil resources has an increasing effect on inflation, whereas energy production from other sources, such as renewable and low-carbon sources, reduces inflation. The study highlighted the crucial role of energy production from renewable and low-carbon sources in Kazakhstan to combat inflation.

Balcı (2020) conducted a study on the relationship between economic growth and environmental pollution in Turkey. This study used the ARDL bounds test approach with data covering the period of 1980-2014. It found that economic growth has a positive impact on environmental pollution. Additionally, there is a linear causality from growth to carbon emissions. Balcı interpreted these findings as proof that Turkey is in the early stages of economic growth and that environmentally friendly investments should be prioritized.

Kalfa (2022) also examined the relationship between Turkey's GDP, Exports, Manufacturing Added Value, and electrical energy consumption. The study used data from 1995 to 2020 and the ARDL bounds test approach. The findings indicate a strong and positive relationship between electrical energy consumption and exports. Furthermore, there is a causality relationship from electrical energy consumption to exports and from GDP to

Table 1: Research variables and their short descriptions

Variable	Short description	Source
CO_2E (Y01)	Carbon dioxide emissions	https://ourworldindata.org
CRP (X01)	Agricultural production index	https://data.worldbank.org
ENRR (X02)	The proportion of energy produced from renewable sources in energy consumption	https://ourworldindata.org
INPE (X03)	Industrial production index	https://w3.unece.org
GDPLOG (X04, X05*)	Economic growth (Logarithm)	https://data.worldbank.org

*: X05=X04×X04

exports, manufacturing value added to exports, and from GDP to manufacturing value added.

3. METHODS

This study aims to test the Environmental Kuznets Curve hypothesis using the ARDL approach. The Kuznets model is a theoretical model that examines the relationship between economic growth and environmental quality. The analysis can be done by using economic growth and the square of economic growth as independent variables, while environmental quality can be considered as the dependent variable. Additionally, various variables that can affect environmental quality can be included in the model (Tutulmaz, 2012). This study uses per capita national income as a proxy for economic growth and CO_2 emissions as a proxy for environmental quality.

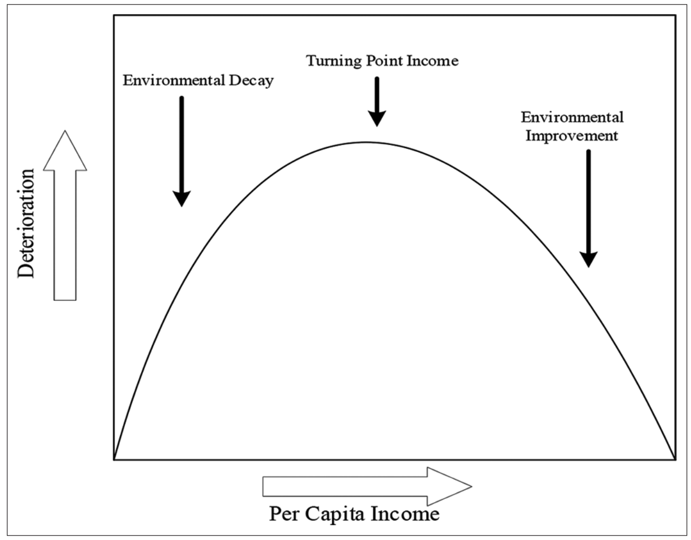
The auto regressive distributed lag (ARDL) limit testing method has certain advantages over the Engle-Granger and Johansen methods. Firstly, the variables included in the model do not need to be stationary at the same level. It is enough for the series to be stationary at either I(0) or I(1). This study has used the ADF unit root test to examine the stationarity of the series. Secondly, the ARDL method provides more reliable prediction values than the other two methods when the number of observations is small (Narayan and Smyth, 2005; Balcı, 2020). The mathematical structure of the model consists of the lagged values of the dependent variable, as well as the current and lagged values of the independent variables. Therefore, an ARDL model with two independent variables can be expressed as follows.

$$\Delta Y_t = a_0 + \sum_{i=0}^{m} a_{1i}\Delta Y_{t-i} + \sum_{i=0}^{m} a_{2i}\Delta M_{t-i} + \sum_{i=0}^{m} a_{3i} EY_{t-i} + a_{4i}\Delta Y_{t-1} + a_{5i}\Delta M_{t-1} + a_{6i}\Delta E_{t-1} + u_t$$

The first step in analyzing the model is to determine whether there is a long-term relationship between the variables. If there is a long-term relationship, then the next step is to estimate and test the short and long-term coefficients (Narayan and Smyth, 2005). The decision rules based on the F value calculated at this stage are as follows:

- If the F statistics <I(0) Limit, then there is no cointegration relationship.
- If the F statistics >I(1) Limit, then there is a cointegration relationship.
- If the F statistics falls between the I(0) and I(1) Limits, then it is not possible to evaluate the cointegration relationship (Kalfa, 2022).

Graph 1: A typical environmental kuznets curve diagram



Source: Yandle et al. (2004)

The second step in preparing for modeling is to decide on the delay length. Commonly used criteria for delay length are the akaike ınformation criterion (AIC), schwartz ınformation criterion (SIC), log-maximum likelihood (LogL), Bayesian information criterion (BIC), and the Hannan-Quinn information criterion (HQ).

After obtaining the model, it is important to test for compatibility and model goodness. In this context, the Breusch-Godfrey-LM test is applied to determine autocorrelation, the White test and breusch-Pagan-Godfrey test to detect heteroscedasticity, and the Ramsey Reset test, which is a functional form test (Ak, 2021). The CUSUM and CUSUMSQ tests developed by Brown et al. (1975) are used to examine whether there is a structural break in the estimated model, and the results are presented graphically.

4. DATA AND FINDINGS

The environmental kuznets curve (EKC) hypothesis is an important topic of discussion as it tests the relationship between economic growth and environmental quality. However, there are conflicting studies that both support and oppose this hypothesis, motivating further research. In the literature, CO_2 emissions represent environmental quality, while national income per capita represents the economy. To further evaluate this hypothesis in the context of Kazakhstan, the study also examined the variables of energy consumption, agricultural production, and industrial production, which are important factors for the country's economy. The research used data from Table 1, covering the analysis period of 2000-2022.

Graph 2: Time path graph for variables

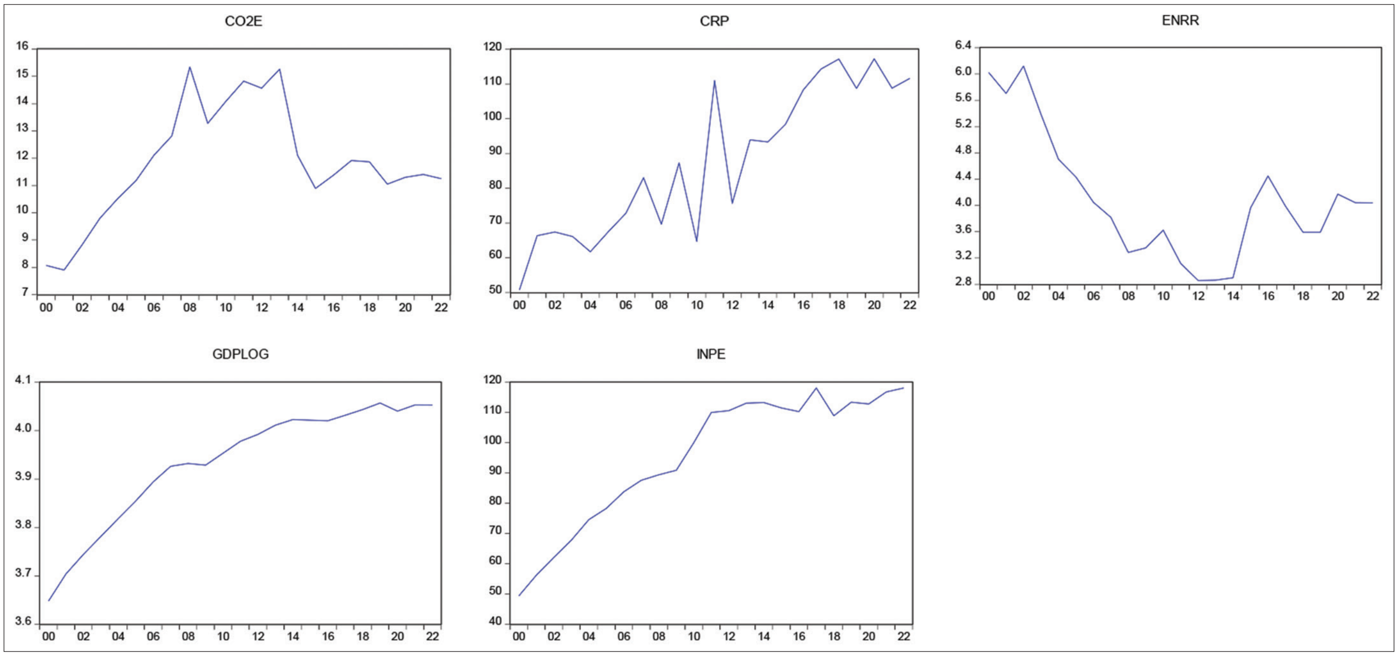


Table 2: Descriptive statistics findings of variables

Statistics	CRP	ENRR	CO_2E	GDPLOG	INPE
Mean	87.62435	4.090082	11.81385	3.935210	95.52174
Median	87.30000	3.990229	11.40539	3.978031	108.9000
Maximum	117.2400	6.120414	15.34125	4.057010	118.1000
Minimum	50.70000	2.857217	7.904210	3.648014	49.40000
Standard deviation	21.42353	0.957038	2.090309	0.121787	21.71874
Skewness	−0.0018	0.777187	−0.01222	−0.97327	−0.74135
Kurtosis	1.529726	2.778713	2.483920	2.798633	2.223426
Jarque-Bera	2.071647	2.362335	0.255814	3.669971	2.684731
Probability	0.354934	0.306920	0.879935	0.159616	0.261227

Table 3: ADF unit root test findings of variables

Variable	Level		First diference	
	t-statistics	P-value	t-statistics	P-value
CO_2E	−1.55571	0.7774	−5.09569	0.0028
CRP	−7.37856	0.0000	−12.8235	0.0000
ENRR	−1.38053	0.8380	−4.78183	0.0057
GDPLOG	−2.58949	0.2876	−3.90527	0.0305
INPE	−1.45419	0.8144	−5.81462	0.0006
Test critical values				
1% level	−4.44074		−4.49831	
5% level	−3.6329		−3.65845	
10% level	−3.25467		−3.26897	

ADF: Augmented Dickey-Fuller

The Environmental Kuznets hypothesis suggests an inverted-U relationship between economic growth and environmental quality, as shown in Graph 1. To test this hypothesis, four separate models were used. The first model used only economic growth as the independent variable and was applied to the example of Kazakhstan. In the other three models, the contribution of agricultural production, industrial production, and energy consumption to this hypothesis was investigated respectively.

The four models are as follows:

- Model 1: Per capita income only
- Model 2: Agricultural production index with per capita national income
- Model 3: Industrial production index with national income per capita
- Model 4: Energy consumption with per capita income.

Table 2 presents the descriptive statistics findings of the analyzed variables. The agricultural production index varied between 50.7 and 117.2 during the analyzed period, with an average of 87.6. The industrial production index, on the other hand, had an average of 95.5, which was higher than the average of the agricultural production index. The analysis also showed that energy consumption from renewable sources ranged from 2.86% to 6.12%, with an average of 4.09% for the entire period. Finally, CO_2 emissions, which are an indicator of environmental quality, ranged from 7.9 to 15.3.

A detailed analysis of the variables is presented in the time path graph, Graph 2. The graph shows that CO_2 emissions steadily increased until 2007, remained at a relatively high level between 2007 and 2013, and then stabilized. On the other hand, GDP demonstrated a clear upward trend in all periods. A comparison of these two graphs suggests that there is a visual structure that supports the Kuznets hypothesis for Kazakhstan.

Table 4: ARDL model selection criterion values

Model	Specification	LogL	AIC	BIC	HQ	Adj, R-sq
Model 1	ARDL (1, 0, 0)	−17.516	2.264842	2.463672	2.298492	0.164257
Model 2	ARDL (1, 0, 0, 0)	−17.5116	2.369646	2.618182	2.411708	0.104973
Model 3	ARDL (1, 0, 2, 2)	−11.9016	2.200166	2.647532	2.275878	0.305777
Model 4	ARDL (1, 2, 0, 1)	−6.42749	1.518683	1.916341	1.585982	0.645303

ARDL: Auto regressive distributed lag

Table 3 shows the results of the ADF unit root test for the variables. The test reveals that the CRP variable is stationary at the 5% significance level, whereas the other variables are stationary at the first difference. Thus, the models used the first differences of the variables that were stationary at the first level and the current value of the CRP variable.

In the ARDL model, one of the crucial steps is to determine the number of lags in the equation. Table 4 displays the criterion values that offer the best fit for each model in terms of LogL, AIC, BIC, and HQ criteria. As per the table:

- For Model 1, the optimal fit is achieved by lagging the dependent variable by one and using the level values of two independent variables - GDP and GDP squared
- For Model 2, the optimal fit is obtained by lagging the dependent variable by one and using the level values of three independent variables - GDP, GDP squared, and CRP
- For Model 3, the optimal fit is achieved by using the 1-lagged model of the dependent variable, the level value of GDP, the square of GDP, and the 2-lagged values of the INPE variables
- For Model 4, the optimal fit is obtained by using the 1-lagged value of the dependent variable, the 2-lagged value of GDP, the level value of the square of GDP, and the 2-lagged values of the ENRR variables.

Table 5 presents Model 1 for the ARDL regression model analysis. The F test result shows a significant difference according to the model. The corrected R-square value is 0.23, indicating that the model tool and the historical values of CO_2 emissions and GDP (and the square of GDP) variable explain 23% of the variability in CO_2 emissions. The coefficients of the variables are positive and significant, and it is noteworthy that the effect of the square of GDP is permanent but negative, supporting the Kurnets hypothesis.

The ARDL regression model analysis findings for Model 2 are presented in Table 6. The model was not found to be significant according to the F test, however, it was observed that the effect of GDP is positive and significant at $P < 0.10$ level. The square of GDP did not show any statistical significance, but it was found to be negative, which is an important finding for the Kurnets hypothesis. The effect of the agricultural production index variable, which is the other independent variable in the model, was found to be statistically insignificant. Moreover, the corrected R-square value reveals that 18.8% of the variability in CO_2 emissions can be explained by the past period values of CO_2 emissions, GDP, GDP squared, and agricultural production index variables through the model.

Table 5: ARDL regression findings for model 1

Variable	Coefficient	Std, error	t-statistic	Prob,
DY01(−1)	−0.18254	0.217956	−0.83750	0.4139
DX04	28.77878	9.895788	2.90819	0.0098
DX05	−137.658	348.1735	−0.39537	0.6975
C	−0.22016	0.209064	−1.05306	0.3071
R-squared	0.349715	Mean dependent var		0.235577
Adjusted R-squared	0.234959	S,D, dependent var		0.749099
S,E, of regression	0.655211	Akaike info criterion		2.161926
Sum squared resid	7.298133	Schwarz criterion		2.360882
Log likelihood	−18.7002	Hannan-Quinn criter,		2.205104
F-statistic	3.247464	Durbin-Watson stat		2.264488
Prob(F-statistic)	0.047818			

ARDL: Auto regressive distributed lag

Table 6: ARDL regression findings for model 2

Variable	Coefficient	Std, error	t-statistic	Prob,
DY01(−1)	−0.18173	0.224696	−0.80877	0.4305
DX04	27.85084	13.17818	2.113406	0.0506
DX05	−126.924	371.5202	−0.34163	0.7371
X01	−0.00116	0.010465	−0.11115	0.9129
C	−0.0982	1.118214	−0.08782	0.9311
R-squared	0.350217	Mean dependent var		0.235577
Adjusted R-squared	0.187771	S,D, dependent var		0.749099
S,E, of regression	0.675116	Akaike info criterion		2.256392
Sum squared resid	7.292502	Schwarz criterion		2.505088
Log likelihood	−18.6921	Hannan-Quinn criter,		2.310365
F-statistic	2.155901	Durbin-Watson stat		2.265136
Prob(F-statistic)	0.120817			

ARDL: Auto regressive distributed lag

The analysis findings for Model 3 of the ARDL regression model are presented in Table 7. The F test suggests that the model is not significant. However, the impact of GDP is positive and significant. Although the effect of the square of GDP is not statistically significant, it is negative, which is considered an important finding in terms of the Kurnets hypothesis. Furthermore, it is observed that the industrial production index variable's two-period lagged value, which is the other independent variable in the model, is significant at the $P < 0.10$ significance level. The adjusted R-square value indicates that the historical CO_2 emission values, GDP, GDP squared, and industrial production index variables account for 30.6% of the variability in CO_2 emissions through the model.

The analysis findings for Model 4 of the ARDL regression model are presented in Table 8. According to the F test, the model is significant. The corrected R-square value of the model is 0.645, indicating that 64.52% of the variability in CO_2 emissions is explained by the historical CO_2 emission values, GDP, GDP squared, and energy consumption variables through the model. The coefficients of the variables show that renewable energy consumption has a negative and statistically significant effect.

Table 7: ARDL regression findings for model 3

Variable	Coefficient	Std, error	t-statistic	Prob,
DY01(−1)	−0.52805	0.278258	−1.8977	0.0870
DX04	62.3224	24.44382	2.549618	0.0289
DX05	−718.178	624.4135	−1.15016	0.2768
DX05(−1)	−1365.28	776.2305	−1.75886	0.1091
DX05(−2)	701.9832	517.2059	1.357261	0.2045
DX03	0.071848	0.042697	1.68273	0.1233
DX03(−1)	0.041756	0.043051	0.969917	0.3550
DX03(−2)	−0.13191	0.067771	−1.94644	0.0802
C	−0.5849	0.261633	−2.23557	0.0494
R-squared	0.61432	Mean dependent var		0.160477
Adjusted R-squared	0.305777	S,D, dependent var		0.748913
S,E, of regression	0.623995	Akaike info criterion		2.200166
Sum squared resid	3.893699	Schwarz criterion		2.647532
Log likelihood	−11.9016	Hannan-Quinn criter,		2.275878
F-statistic	1.991032	Durbin-Watson stat		2.384626
Prob(F-statistic)	0.152298			

ARDL: Auto regressive distributed lag

Table 8: ARDL regression findings for model 4

Variable	Coefficient	Std, error	t-statistic	Prob,
DY01(−1)	−0.91279	0.219215	−4.16391	0.0016
DX04	−16.8249	17.11921	−0.98281	0.3468
DX04(−1)	17.32478	15.10891	1.14666	0.2759
DX05	−612.56	600.543	−1.02001	0.3296
DX05(−1)	66.96734	336.1812	0.1992	0.8457
DX02	−2.562	0.618022	−4.14549	0.0016
DX02(−1)	0.342661	0.38602	0.887677	0.3937
DX02(−2)	−0.53836	0.366624	−1.46844	0.1700
C	0.100945	0.254708	0.396316	0.6995
R-squared	0.794956	Mean dependent var		0.221528
Adjusted R-squared	0.645833	S,D, dependent var		0.995292
S,E, of regression	0.592317	Akaike info criterion		2.092614
Sum squared resid	3.859235	Schwarz criterion		2.540693
Log likelihood	−11.92610	Hannan-Quinn criter,		2.180084
F-statistic	5.33088	Durbin-Watson stat		1.915013
Prob(F-statistic)	0.00642			

ARDL: Auto regressive distributed lag

Unlike the other three models, the effect of GDP is negative in Model 4. It is noted that the square of GDP is negative, similar to other models.

Table 9 provides additional information about the compatibility of the ARDL regression model for Models 1 and 4, both of which were found to be statistically significant. The table shows that there is no autocorrelation problem based on the Breusch-Godfrey test for both models. In addition, there is no heteroscedasticity problem based on the Breusch-Pagan-Godfrey test. The residuals are normally distributed based on the Jarque-Bera test (Konak, 2020), and model identification is confirmed by the Ramsey RESET test. Therefore, it was concluded that there was no error in the functional form (Güriş et al., 2017).

Table 10 presents the ARDL bounds test results for Models 1 and 4. The results revealed a long-term relationship between the variables since the calculated F value for the model was less than the recommended I(1) table value (Pesaran et al., 2001 at a 5% significance level.

The findings for Model 1 using the ARDL model error correction form are presented in Table 11. The prediction values for the error correction term were statistically significant. A value between −2 and −1 indicates that the error correction term is approaching the long-term equilibrium value in the form of decreasing waves. (Alam and Quazi, 2003). This implies that it takes about 0.85 years (approximately 10 months) to restore equilibrium after a short-term shock.

The findings for Model 4 using the ARDL model error correction form are presented in Table 12. The prediction values for the error correction term were found to be statistically significant. A value between −2 and −1 indicates that the error correction term is converging towards the long-term equilibrium value in the form of waves of decreasing size (Alam and Quazi, 2003). This means that it takes approximately 0.71 years (about 9 months) to regain equilibrium after a short-term shock.

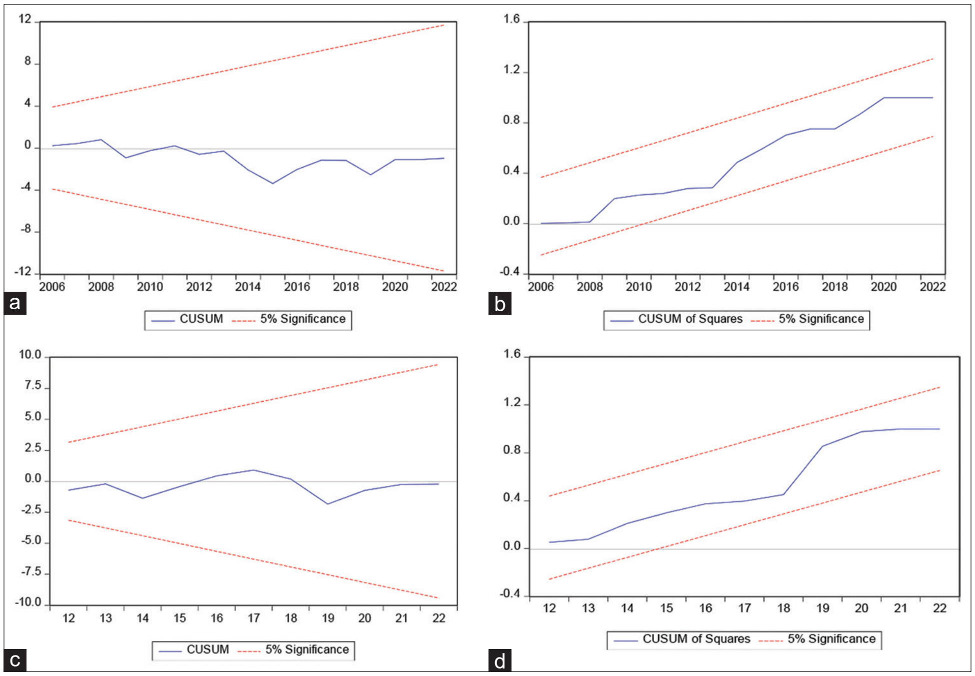
Table 13 presents the findings for Model 1 using the ARDL method long-term effect coefficient. The findings show that the effect of the lagged value of CO_2 emissions and the value of GDP is significant for the short term, while the effect of GDP is statistically significant for the long-term effect.

The findings of the ARDL method long-term effect coefficient for Model 4 are presented in Table 14. The results indicate that the

Table 9: Diagnostic test findings for model 1 and model 4

Test	Statistics	Prob.
Model 1		
Breusch-Godfrey serial correlation LM test	F-statistic: 0.937252	Prob. F(2,15): 0.4135
Heteroskedasticity test: Breusch-Pagan-Godfrey	F-statistic: 0.977560	Prob. F(15,3): 0.4265
Ramsey RESET test	F-statistic: 0.053724	Prob. F(1,16): 0.8196
Test of normality	Jarque-Bera: 0.702653	Prob.: 0.703754
Model 4		
Breusch-Godfrey serial correlation LM test	F-statistic: 2.282441	Prob. F(2,9): 0.1578
Heteroskedasticity test: Breusch-Pagan-Godfrey	F-statistic: 0.507726	Prob. F(8,11): 0.8273
Ramsey RESET test	F-statistic: 0.775242	Prob. F(1,10): 0.3992
Test of normality	Jarque-Bera: 0.953498	Prob.: 0.620798

Graph 3: 95% confidence interval for CUSUM-CUSUMSQ test for models 1 (a and b) and 4 (c and d)



Graph 4: Time path graph for observation values and prediction and error values according to the auto regressive distributed lag model (a: Model 1, b: Model 4)

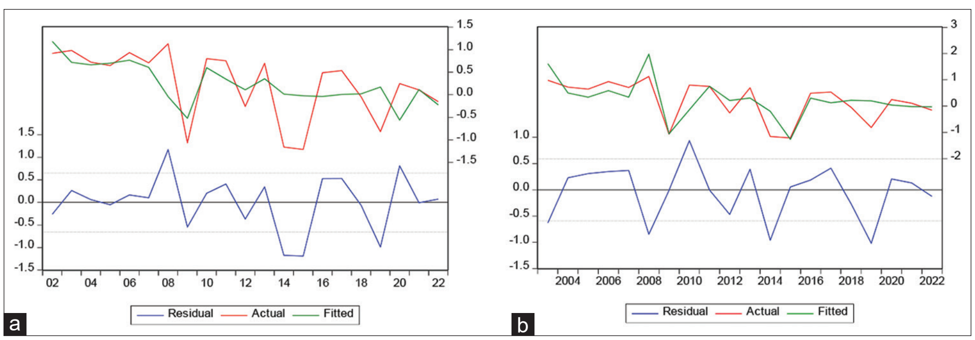


Table 10: Bounds test findings for model 1 and model 4

Test statistic	Value	Signif, (%)	I(0)	I(1)
Model 1				
F-statistic	7.569411	10	2.63	3.35
k	2	5	3.10	3.87
		2.5	3.55	4.38
		1	4.13	5.00
Model 4				
F-statistic	8.814509	10	2.37	3.20
k	3	5	2.79	3.67
		2.5	3.15	4.08
		1	3.65	4.66

impact of CO_2 emissions and renewable energy consumption is significant in the short term, but in the long term, only the influence of renewable energy consumption is statistically significant, similar to its short-term effect.

Moreover, the ARDL model's diagnostic test values were examined, and the CUSUM and CUSUMSQ tests were used to determine whether Models 1 and 4 have structural breaks (Brown et al., 1975). The results were presented in Graph 3, and it was

Table 11: Error correction regression model findings for model 1

Variable	Coefficient	Std, error	t-statistic	Prob,
CointEq(−1)*	−1.18254	0.198136	−5.96831	0.0000
R-squared	0.640422	Mean dependent var		0.00069
Adjusted R-squared	0.640422	S,D, dependent var		1.007382
S,E, of regression	0.604075	Akaike info criterion		1.876211
Sum squared resid	7.298133	Schwarz criterion		1.92595
Log likelihood	−18.7002	Hannan-Quinn criter,		1.887006
Durbin-Watson stat	2.264488			

found that both models do not have structural breaks and provide stable results.

Graph 4 shows the time path graph for CO_2 emission observation values, ARDL method prediction values according to Models 1 and 4, and error values of the prediction. The observation values and the predicted values in the graphs are seen

Table 12: Error correction regression model findings for model 4

Variable	Coefficient	Std, error	t-statistic	Prob,
D(DX04)	0.944423	8.418494	0.112184	0.9127
D(DX05)	−574.056	248.0124	−2.31462	0.0410
D(DX02)	−2.54534	0.43758	−5.81685	0.0001
D(DX02[−1])	0.542867	0.206091	2.634113	0.0232
CointEq(−1)*	−1.41149	0.319141	−4.42278	0.0000
R-squared	0.812191	Mean dependent var		−0.05353
Adjusted R-squared	0.762108	S,D, dependent var		1.001619
S,E, of regression	0.488531	Akaike info criterion		1.617492
Sum squared resid	3.579943	Schwarz criterion		1.866425
Log likelihood	−11.1749	Hannan-Quinn criter,		1.666086
Durbin-Watson stat	2.265284			

Table 13: Long-term effect findings for model 1

Variable	Coefficient	Std, error	t-statistic	Prob,
C	−0.22016	0.209064	−1.05306	0.3071
DY01(−1)*	−1.18254	0.217956	−5.42559	0.0000
DX04**	28.77878	9.895788	2.908185	0.0098
DX05**	−137.658	348.1735	−0.39537	0.6975
Levels equation				
Variable	Coefficient	Std, error	t-statistic	Prob,
DX04	24.33643	7.78478	3.126155	0.0061
DX05	−116.409	291.6624	−0.39912	0.6948
C	−0.18617	0.17651	−1.05475	0.3063

Table 14: Long-term effect findings for model 4

Variable	Coefficient	Std, error	t-statistic	Prob,
C	−0.00699	0.214738	−0.03256	0.9746
DY01(−1)*	−2.00423	0.337217	−5.94346	0.0001
DX04(−1)	14.01795	13.49784	1.038533	0.3213
DX05(−1)	123.116	599.7001	0.205296	0.8411
DX02(−1)	−2.23296	0.888068	−2.5144	0.0288
D(DX04)	−0.97712	14.27478	−0.06845	0.9467
D(DX05)	15.00534	527.9013	0.028425	0.9778
D(DX02)	−2.21261	0.6119	−3.61597	0.0041
D(DX02[−1])	0.326429	0.312528	1.044479	0.3187
Levels equation				
Variable	Coefficient	Std, Error	t-Statistic	Prob,
DX04(−1)	0.261329	8.486577	0.030793	0.9760
DX05(−1)	−285.234	358.0994	−0.79652	0.4426
DX02(−1)	−1.44172	0.430137	−3.35176	0.0065
C	0.052774	0.132113	0.399458	0.6972

to be compatible with each other. Additionally, the model error values follow a random trend with zero mean.

5. CONCLUSION AND RECOMMENDATIONS

Economic growth and environmental quality are two crucial macro indicators that significantly impact human lives. It has been long known that the rise in industrial activities and energy consumption leads to environmental pollution, which harms people's lives in various ways. In this study, the relationship between environmental quality and economic growth was analyzed, focusing on the Kuznets hypothesis, using Kazakhstan as an example. However, environmental quality and economic growth cannot be considered independently of energy consumption and production. Therefore, the Kuznets hypothesis was examined in a broader context, which included agricultural and industrial production and energy consumption in the models. The study showed that the square of the GDP term is negative in all four models, indicating that the Kuznets hypothesis holds for Kazakhstan. Additionally, it is worth noting that the inclusion of macro variables such as agricultural production, industrial production, and renewable energy consumption in the models did not affect the support for the Kuznets hypothesis. The study evaluated the Kuznets hypothesis, using three macro indicators to represent three sectors. The study found that agricultural production did not have any effect on CO_2 emissions, while industrial production and renewable energy production were effective in reducing CO_2 emissions. This research provides valuable insights into the relationships between environmental quality and macro variables and can be helpful for country managers.

However, the study did not evaluate the impact of social indicators such as education levels on environmental sensitivity. Investigating the relationship between social indicators and the Kuznets hypothesis could contribute to both the literature and practitioners. Another important research problem is the evaluation of cultural differences, which is a variable that can be examined using social indicators.

6. FUNDING

This research is funded by the Science Committee of the Ministry of Science and Higher Education of the Republic of Kazakhstan (Grant No. AP 19677574 "Development of an economic mechanism for environmental taxation as a financial instrument for environmental regulation of the Republic of Kazakhstan").

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