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Energy Consumption, Renewable Energy Transition, and Industrial Production as Determinants of Economic Growth in Kazakhstan: An ARDL Analysis

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ABSTRACT

This study examines the dynamic interrelationships between energy consumption, renewable energy transition, and industrial production as key drivers of Kazakhstan's economic growth over the period 2000-2024. Drawing on annual data and econometric analysis, the research investigates both short- and long-term linkages among these variables. The findings indicate that energy consumption and industrial output exert strong positive effects on GDP, emphasizing their central role in supporting Kazakhstan's sustained economic expansion. In contrast, renewable energy consumption shows a weak and statistically insignificant effect, which reflects its relatively small share in the national energy mix but also signals untapped potential for future development. The results of diagnostic and stability tests confirm the robustness of the model, suggesting that while Kazakhstan's growth has been primarily supported by industrial activity and traditional energy sources, greater diversification toward renewables could strengthen long-term resilience and sustainability. Overall, the study highlights the need for continued industrial modernization, enhanced energy efficiency, and strategic investment in clean energy technologies to promote balanced, inclusive, and environmentally sustainable economic growth.

Keywords: Energy Consumption, Renewable Energy, Industrial Production, Economic Growth, Autoregressive Distributed Lag, Kazakhstan
JEL Classifications: C32, O13, Q43, Q47

1. INTRODUCTION

Over the last two decades, Kazakhstan has experienced steady economic expansion supported by industrial modernization, growing energy consumption, and deeper integration into international markets. As one of the largest energy producers in Central Asia, the country's growth model remains heavily influenced by the balance between energy use, industrial performance, and the gradual shift toward renewable energy. These elements are tightly interlinked: Energy fuels industrial output, industry drives economic growth, and the transition to cleaner energy determines whether such growth can be sustained over the long term (Baisholanova et al., 2025).

Industrial production continues to play a vital role in Kazakhstan's economic structure. The growth of manufacturing, metallurgy, and extractive industries has strengthened employment, export revenues, and technological capacity. Yet, this progress has also increased dependence on fossil energy, leaving the industrial sector vulnerable to fluctuations in global energy markets and external shocks (Talimova et al., 2025). The challenge for Kazakhstan lies in sustaining industrial competitiveness while advancing decarbonization - a balance that defines the future of its industrial and environmental policies.

Energy consumption reflects both the success and the fragility of this growth path. Rising energy demand is a sign of economic dynamism, but it also underscores inefficiencies and continued reliance on carbon-intensive sources. Many economies that have successfully diversified their energy mix have demonstrated greater resilience and more stable growth over time (Aidarova et al., 2024). In Kazakhstan, renewable energy still plays a limited role, but investments in solar, wind, and hydropower suggest a slow and promising transition toward a more sustainable energy system.

The global energy transition further emphasizes the importance of this shift. As the world economy accelerates its move toward low-carbon production, energy exporters like Kazakhstan must adapt to new competitive realities. Experiences from emerging economies such as Brazil and China show that renewable energy adoption not only improves energy security but also stimulates industrial innovation and reduces environmental stress (Sadorsky, 2012). For Kazakhstan, a similar transition could strengthen both economic resilience and environmental integrity.

The connection between energy consumption, industrial development, and economic growth has long been central in empirical research. Studies indicate that both renewable and conventional energy sources contribute to growth, but their effects differ depending on industrial efficiency and technological development (Omri and Nguyen, 2014). Moreover, the way energy is utilized - efficiently or wastefully - shapes whether economic progress translates into sustainable outcomes (Tiba and Omri, 2017). In Kazakhstan's case, understanding these linkages is key to navigating the transformation from a resource-dependent economy toward one driven by innovation and cleaner production.

In essence, Kazakhstan's long-term development will depend on how effectively it balances industrial growth, energy efficiency, and the transition to renewables. Exploring these relationships is crucial for identifying policies that can sustain growth while supporting the broader goal of an environmentally responsible and resilient national economy.

2. LITERATURE REVIEW

Existing research provides comprehensive insights into the interconnections between energy consumption, renewable energy transition, and industrial development as fundamental drivers of sustainable economic growth. Together, these dimensions shape the trajectory of structural transformation, energy security, and long-term macroeconomic resilience. This section reviews the most relevant contemporary studies that directly align with the objectives of this research.

Lin and Moubarak (2014) explored how renewable energy consumption influences China's economic growth using long-term time series data. Their results revealed a two way causal relationship between renewable energy use and GDP, showing that economic expansion and renewable investment reinforce each other. The authors emphasized that sustained growth in renewable energy infrastructure enhances both national energy security and environmental sustainability.

Kahia et al. (2017) examined how renewable and non-renewable energy sources contribute to GDP growth in MENA net oil-importing economies. Their findings showed that both energy types drive economic performance, but renewable energy provides a more stable and sustainable growth path. They concluded that diversifying energy portfolios is key to achieving balanced economic resilience and reducing vulnerability to external energy shocks.

Asongu et al. (2020) analyzed the interaction between urbanization, energy consumption, and economic growth across African economies. The study found that heavy reliance on fossil fuels and rapid urban expansion threaten environmental stability. However, integrating renewable energy into urban and industrial systems was shown to mitigate these effects, promoting more sustainable and inclusive economic development.

Ulucak and Khan (2020) investigated the role of renewable energy, natural resources, and urbanization in shaping environmental sustainability in developing economies. Their results indicated that renewable energy use significantly reduces ecological degradation without constraining economic output. The authors highlighted that prioritizing clean energy policies enables countries to align growth objectives with environmental protection.

Raihan and Tuspekova (2022) focused on Kazakhstan, assessing how economic growth, energy use, and agricultural productivity influence carbon emissions. Their findings demonstrated that GDP and energy consumption increase emissions, while agricultural productivity moderates this effect. They concluded that advancing Kazakhstan's renewable energy capacity is crucial for maintaining growth while minimizing environmental harm.

Yadav and Mahalik (2024) explored whether renewable energy expansion reduces import dependence in emerging economies using CS-ARDL and causality tests. Their analysis showed that greater renewable penetration lowers import bills, strengthens external balances, and supports macroeconomic stability. They emphasized that renewable energy adoption contributes to sustainable growth by improving national energy independence.

Eid et al. (2024) evaluated the role of energy R&D in promoting green growth within OECD countries. Their results demonstrated that investments in renewable energy innovation have stronger long-term benefits for productivity and environmental performance compared to conventional energy R&D. The authors argued that fostering technological advancement is critical to accelerating global clean energy transitions.

Wang and Debel (2025) investigated the interconnection between renewable energy use, industrial output, and sustainable growth in Ethiopia. They found that renewable energy investments enhance industrial competitiveness and productivity, contributing to inclusive economic progress. The study concluded that clean energy development supports structural transformation and long-term industrial modernization.

Sohail et al. (2025) examined how energy-related indicators influence sustainable growth across emerging economies by combining ARDL and machine learning methods. Their findings showed that renewable energy use and efficiency improvements are major long-term drivers of GDP growth, while fossil fuel reliance limits sustainability. The study underscored that integrating AI-based models can improve energy policy precision and forecasting reliability.

3. METHODS

The autoregressive distributed lag (ARDL) model, developed by Pesaran and Shin (1995) and later refined by Pesaran et al. (2001), is applied in this study to explore both the short-run dynamics and long-run equilibrium relationships among economic growth, energy consumption, industrial production, and renewable energy use in Kazakhstan. Unlike conventional cointegration methods such as Engle and Granger (1987) or Johansen (1988), the ARDL framework provides greater flexibility by allowing variables integrated of order zero, I(0), and order one, I(1), to be analyzed together, as long as none are integrated of order two, I(2). This feature makes it particularly suitable for macroeconomic research, where variables often exhibit mixed integration levels. Moreover, the ARDL approach performs effectively with small samples, which makes it appropriate for studies using annual data (Narayan and Narayan, 2005).

The general ARDL(p, q_1, q_2,…, q_k) model can be represented as:

$$Y_t = \alpha_0 + \alpha_1 t + \sum_{i=1}^{p} \phi_i Y_{t-i} + \sum_{j=1}^{k} \sum_{l=0}^{q_j} \beta_{jl} X_{j,t-l} + \varepsilon_t \quad (1)$$

Where Y_t denotes the dependent variable, $X_{j,t}$ represents the explanatory variables, p and q_j are the selected lag orders, ϕ_i and β_{jl} are the estimated parameters, and ε_t is a random disturbance term. This formulation captures both immediate and lagged effects of the explanatory variables, enabling the simultaneous estimation of short-run adjustments and long-run relationships within one unified model.

The estimation procedure involves two major steps. First, the bounds testing approach proposed by Pesaran et al. (2001) is used to determine whether a long-run relationship exists among the variables. The computed F-statistic is compared to critical bounds: If it exceeds the upper bound (I[1]), cointegration is confirmed; if it falls below the lower bound (I[0]), no cointegration exists; and if it lies between the bounds, the result remains inconclusive. Once the existence of cointegration is established, the model proceeds to estimate both short-run dynamics and long-run coefficients using an associated error correction mechanism (ECM), which explains how quickly deviations from equilibrium are corrected over time.

Before estimating the ARDL model, unit root tests such as the augmented dickey-fuller (ADF) and Phillips-Perron (PP) are employed to ensure that none of the variables are integrated of order two or higher. After confirming this, the optimal lag structure is selected using model selection criteria such as the akaike ınformation criterion (AIC), schwarz bayesian criterion (SBC), and Hannan-Quinn Criterion (HQ), ensuring statistical efficiency and model reliability (Narayan and Smyth, 2006).

Finally, several diagnostic and stability tests are conducted to assess the robustness of the ARDL results. The Breusch-Godfrey LM test is used to detect serial correlation, while the Breusch-Pagan-Godfrey and White tests examine heteroskedasticity. The Ramsey RESET test checks for model specification errors, and the CUSUM and CUSUMSQ tests of Brown et al. (1975) assess the stability of model parameters over time. Successful diagnostic outcomes confirm that the ARDL model is statistically sound, stable, and appropriate for capturing Kazakhstan's energy growth dynamics across both short - and long-run horizons.

4. FINDINGS

This study focuses on understanding how Kazakhstan's economic growth, industrial development, and energy transition interact over time. Gross domestic product (GDP) is used as the main indicator of economic performance, reflecting overall national output. Energy consumption (EC), measured in kilograms of oil equivalent per capita, illustrates the scale of domestic energy demand and productive capacity. Renewable energy consumption (REC), expressed as a share of total final energy use, highlights the progress toward cleaner and more sustainable energy sources. The ındustrial production ındex (IPI), benchmarked to 2021 = 100, represents trends in industrial activity and real-sector performance.

A detailed overview of these variables and their data sources is provided in Table 1. The analysis employs annual data spanning 2000-2024. The research data were acquired from the websites https://data.worldbank.org, https://www.macrotrends.net, and https://w3.unece.org (Date of access: September 17, 2025).

Descriptive statistics of the variables are summarized in Table 2. Over the period, the average logarithmic values of GDP, energy consumption, industrial production, and renewable energy consumption were 25.46, 8.15, 4.39, and 1.86, respectively. The relatively small standard deviations suggest that the data series remain stable over time, with no extreme fluctuations. Moreover, the Jarque-Bera test indicates that all variables are approximately normally distributed, confirming their reliability for further econometric analysis within the ARDL framework.

Table 1: Research variables, their short descriptions and data sources

Variable	Short description	Source
GDP	Gross domestic product	https://www.macrotrends.net
EC	Energy consumption (kg of oil equivalent per capita)	https://data.worldbank.org
IPI	Industrial production index, 2021=100	https://w3.unece.org
REC	Renewable energy consumption (% of total final energy consumption)	https://data.worldbank.org

GDP: Gross domestic product, EC: Energy consumption, IPI: Industrial production ındex, REC: Renewable energy consumption

Graph 1: Time series plots of variables

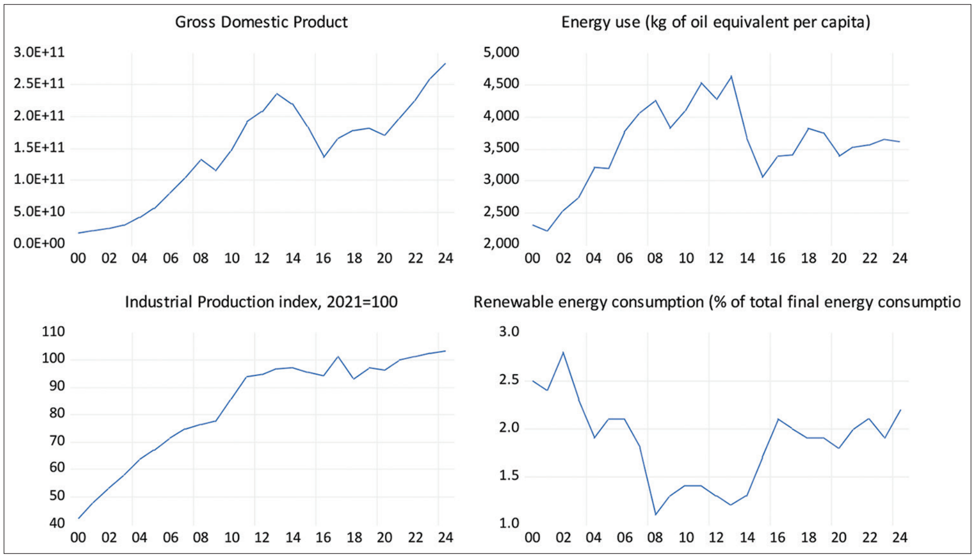

Table 2: Descriptive statistics findings of variables

Statistics	GDP	EC	IPI	REC
Mean	25.45573	8.154698	4.394985	1.860000
Median	25.84010	8.191115	4.544358	1.900000
Maximum	26.37920	8.443715	4.638605	2.800000
Minimum	23.62973	7.704171	3.744787	1.100000
Standard deviation	0.832535	0.192332	0.258638	0.436845
Skewness	−1.040867	−0.839137	−1.114399	−0.008570
Kurtosis	2.723162	3.196775	3.119405	2.392069
Jarque-bera	4.594016	2.974292	5.189371	0.385285
Probability	0.100559	0.226017	0.074669	0.824777

GDP: Gross domestic product, EC: Energy consumption, IPI: Industrial production ındex, REC: Renewable energy consumption

Graph 1 depicts the time evolution of the key variables for Kazakhstan from 2000 to 2024. GDP shows a clear upward trajectory, rising from about 50 billion USD in 2000 to nearly 300 billion USD by 2024, reflecting steady and sustained economic expansion. Energy consumption per capita follows a similar path, increasing from roughly 2,500-4,500 kg of oil equivalent by 2013 before stabilizing around 3,600 kg, which suggests gradual improvements in efficiency and shifts in industrial energy use. The ındustrial production ındex (IPI) also grows steadily - from around 40 to above 100 - indicating ongoing industrial development and modernization. Renewable energy consumption (REC), however, remains relatively modest, dropping to about 1.1% in the late 2000s and recovering to around 2-2.5% after 2015, showing slow but notable progress toward renewable energy adoption. Overall, Graph 1 reflects Kazakhstan's sustained economic and industrial growth accompanied by evolving energy consumption patterns, highlighting the relevance of ARDL analysis for capturing both short - and long-term linkages among these variables.

The Augmented Dickey-Fuller (ADF) test results for all variables are reported in Table 3. The analysis shows that GDP and energy consumption (EC) are non-stationary in their level forms, as their t-statistics (−2.77 and −2.37, respectively) do not exceed the 5% critical threshold, implying the presence of a unit root. In contrast, the ındustrial production ındex (IPI) is stationary at level, with a

Table 3: Augmented Dickey-Fuller unit root test findings of variables

Variable	Level		1st diference	
	t-statistics	P-value	t-statistics	P-value
GDP	−2.770452	0.0775	−3.038061	0.0461
EC	−2.374618	0.1589	−4.482451	0.0019
IPI	−5.373098	0.0002	−3.742002	0.0102
REC	−1.880682	0.3351	−4.320027	0.0028
Test critical values:				
1% level	−3.737853		−3.752946	
5% level	−2.991878		−2.998064	
10% level	−2.635542		−2.638752	

GDP: Gross domestic product, EC: Energy consumption, IPI: Industrial production ındex, REC: Renewable energy consumption

t-statistic of −5.37 significant at the 1% level, confirming its I(0) nature. Renewable energy consumption (REC) is non-stationary at level but becomes stationary after differencing. At the first difference, all variables achieve stationarity, with P-values below 0.05. These findings suggest that the series are integrated of mixed order - I(0) and I(1) - which meets the requirements for applying the ARDL model. This combination allows for a more flexible analysis of both short - and long-term relationships between GDP, energy consumption, industrial output, and renewable energy consumption in Kazakhstan.

The results of the lag length selection for the ARDL models are presented in Table 4. A comparison of the LogL, AIC, BIC, and HQ criteria shows that the ARDL(1,0,1,1) model offers the best overall performance, combining the lowest AIC value (−1.72) with the highest adjusted R^2 (0.9856). This balance indicates that the chosen model effectively captures the relationships among the variables without unnecessary complexity. Therefore, ARDL(1,0,1,1) is identified as the most appropriate specification for analyzing the short - and long-run dynamics between GDP, energy consumption, industrial production, and renewable energy consumption in Kazakhstan.

The results of the ARDL bounds test are summarized in Table 5. The calculated F-statistic of 3.9171 is higher than the upper critical

Graph 2: 95% confidence interval for CUSUM and CUSUMSQ test

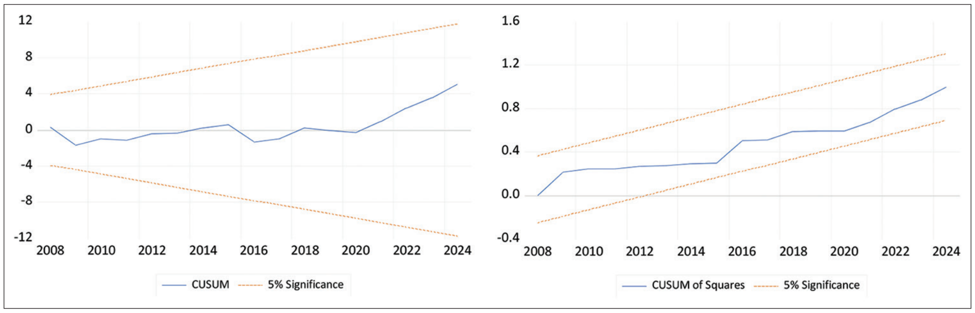

Table 4: Selection of optimal lag

Model	LogL	AIC: Akaike information criterion	BIC: Bayesian information criterion	HQ: Hannan-Quinn information criterion	Adjusted R^2	Specification
5	27.641545	−1.720129	−1.376530	−1.628972	0.985568	ARDL (1, 0, 1, 1)
1	28.547677	−1.712306	−1.319622	−1.608127	0.985781	ARDL (1, 1, 1, 1)
7	26.000691	−1.666724	−1.372211	−1.588590	0.984373	ARDL (1, 0, 0, 1)
3	26.997737	−1.666478	−1.322879	−1.575321	0.984773	ARDL (1, 1, 0, 1)
8	24.620062	−1.635005	−1.389577	−1.569893	0.983390	ARDL (1, 0, 0, 0)
4	25.240830	−1.603403	−1.308889	−1.525268	0.983351	ARDL (1, 1, 0, 0)
6	25.200769	−1.600064	−1.305551	−1.521930	0.983295	ARDL (1, 0, 1, 0)
2	25.713831	−1.559486	−1.215887	−1.468329	0.983053	ARDL (1, 1, 1, 0)

Table 5: Bounds test findings

Test statistic	Value	Signif. (%)	I (0)	I (1)
F-statistic	3.917057	10	2.37	3.2
k	3	5	2.79	3.67
-	-	2.5	3.15	4.08
-	-	1	3.65	4.66

bound value of 3.67 at the 5% significance level, which allows the rejection of the null hypothesis of no long-run relationship. This finding indicates a significant long-term equilibrium among GDP, energy consumption, industrial production, and renewable energy consumption in Kazakhstan. In other words, the variables move together over time, and any short-term fluctuations tend to adjust toward a stable long-run path, supporting the validity of further ARDL long- and short-run estimations.

Table 6 shows the estimated results of the ARDL(1,0,1,1) model, with GDP as the dependent variable. The analysis shows that both energy consumption and industrial production positively and significantly influence economic growth, with coefficients of 0.6624 ($P = 0.0076$) and 1.7332 ($P = 0.0127$), respectively. This suggests that Kazakhstan's economic expansion is largely driven by higher energy use and industrial activity. The lagged GDP term (0.7178, $P = 0.0003$) indicates that growth momentum has remained consistent over time. In contrast, renewable energy consumption shows a negative but statistically insignificant effect ($P = 0.5544$), which is expected given that Kazakhstan is still developing its renewable energy sector and its share in total consumption remains modest. As the sector grows, its impact on economic performance is likely to strengthen. The model's high explanatory power (Adjusted $R^2 = 0.9856$) and strong overall significance ($P < 0.01$) confirm the robustness of the findings and highlight the continued importance of industrial output and traditional energy sources in sustaining Kazakhstan's growth.

The diagnostic test results assessing the reliability of the ARDL model are presented in Table 7. The Breusch-Godfrey LM test ($P = 0.4045$) and the Breusch-Pagan-Godfrey test ($P = 0.5699$) indicate no issues of serial correlation or heteroskedasticity. The Ramsey RESET test ($P = 0.4463$) confirms that the model is correctly specified, with no omitted variable bias. Additionally, the Jarque-Bera test ($P = 0.0874$) shows that the residuals are approximately normally distributed. Taken together, these outcomes verify that the ARDL model meets key econometric assumptions and provides statistically reliable results.

The outcomes of the CUSUM and CUSUMSQ stability tests for the estimated ARDL model are illustrated in Graph 2. Throughout the 2000-2024 period, both lines remain within the 5% significance boundaries, demonstrating that the model parameters are stable over time. This suggests that there are no major structural changes or specification issues affecting the model's consistency. The stability of the coefficients ensures that the ARDL results are reliable for interpreting both short - and long-run dynamics. Overall, the graphs confirm that the model maintains structural stability, supporting the validity of its econometric findings for Kazakhstan's energy-growth relationship.

The observed, fitted, and residual values from the ARDL model are shown in Graph 3. The fitted values align closely with the actual GDP trend, reflecting a strong match across most of the study period, especially between 2006-2013 and 2018-2024. Small deviations observed around 2014-2016 likely result from temporary economic adjustments or external factors. Overall, the residuals remain centered around zero without any visible systematic pattern, suggesting that the model is well-specified and free from major biases. These results demonstrate that the ARDL model successfully captures the key movements in Kazakhstan's economic growth and provides a stable basis for both short - and long-run interpretation.

Table 6: The results of the autoregressive distributed lag regression model

Variable	Coefficient	Standard error	t-statistic	Probability
L_GDP(−1)	0.717808	0.156919	4.574374	0.0003
L_EC	0.662444	0.215291	3.076970	0.0068
L_IPI	1.733271	0.622170	2.785848	0.0127
L_IPI(−1)	−1.054619	0.668208	−1.578280	0.1329
REC	−0.059270	0.098285	−0.603037	0.5544
REC(−1)	0.179192	0.091509	1.958193	0.0668
C	−1.388753	2.845836	−0.487995	0.6318
R-squared	0.989333	Mean dependent var		25.53181
Adjusted R-squared	0.985568	S.D. dependent var		0.756467
S.E. of regression	0.090877	Akaike info criterion		−1.720129
Sum squared resid	0.140396	Schwarz criterion		−1.376530
Log likelihood	27.64154	Hannan-Quinn criterion		−1.628972
F-statistic	262.7796	Durbin-Watson stat		1.833985
Prob (F-statistic)	0.000000			

Table 7: ARDL diagnostic test findings

Test	Statistics	Probability
Breusch-godfrey serial correlation LM test	F-statistic: 0.961849	Prob. F (2,15): 0.4045
Heteroskedasticity test: Breusch-Pagan-Godfrey	F-statistic: 0.819515	Prob. F (6,17): 0.5699
Ramsey RESET test	F-statistic: 0.609703	Prob. F (1,16): 0.4463
Test of normality	Jarque-Bera: 4.874758	Prob.: 0.087390

ARDL: Autoregressive distributed lag

Table 8: ECM results

Variable	Coefficient	Standard error	t-statistic	Probability
D (L_IPI)	1.733271	0.302951	5.721282	0.0000
D (REC)	−0.059270	0.074101	−0.799854	0.4348
CointEq(−1)*	−0.282192	0.057371	−4.918698	0.0001
R-squared	0.779704	Mean dependent var		0.114561
Adjusted R-squared	0.758723	S.D. dependent var		0.166460
S.E. of regression	0.081765	Akaike info criterion		−2.053462
Sum squared resid	0.140396	Schwarz criterion		−1.906205
Log likelihood	27.64154	Hannan-Quinn criterion		−2.014395
Durbin-Watson stat	1.833985			

Graph 3: Line graph for observed, estimated, and residual values

The short-run estimates of the ARDL error correction model are reported in Table 8. The results show that industrial production has a strong and significant positive impact on economic growth (1.7333, P = 0.0000), confirming its central role in supporting short-term GDP expansion in Kazakhstan. In contrast, renewable energy consumption shows a negative but statistically insignificant effect (P = 0.4348), reflecting that Kazakhstan is still in the early stages of renewable energy development and its contribution to growth remains limited. The error correction term (CointEq(−1)) is negative and highly significant (−0.2822, P = 0.0001), indicating that about 28% of short-term imbalances are corrected each year, pointing to a gradual return to long-run equilibrium. The model's high explanatory power (Adjusted R^2 = 0.7587) and satisfactory Durbin-Watson statistic (1.83) confirm its reliability, reinforcing that the ARDL framework effectively captures the interaction between industrial activity, renewable energy, and economic growth in Kazakhstan.

5. CONCLUSION AND RECOMMENDATIONS

This study examined the dynamic relationships between economic growth, industrial development, and energy transition in Kazakhstan from 2000 to 2024 using the ARDL framework. The results confirm a long-run equilibrium among GDP, energy consumption, industrial production, and renewable energy use. Both energy consumption and industrial activity were found to have significant positive effects on economic growth, emphasizing their central role in driving Kazakhstan's economic expansion. Conversely, renewable energy consumption showed a weak and insignificant impact, reflecting the country's early stage of renewable energy development.

The diagnostic and stability tests verified that the estimated ARDL and ECM models are statistically robust and free from major econometric issues, confirming the validity of the results. The significant and negative error correction term indicates a gradual adjustment toward long-run equilibrium, suggesting structural stability in the economy.

Based on these findings, it is recommended that Kazakhstan continues promoting industrial modernization and energy efficiency while strengthening investment in renewable energy technologies. Expanding the share of renewables through targeted fiscal incentives, technological innovation, and green financing could enhance energy diversification and reduce dependence on fossil fuels. In the long run, integrating sustainable energy development with industrial growth policies will be crucial for achieving balanced, inclusive, and environmentally resilient economic progress.

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