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Investigating the Relationship between Energy Consumption and Economic Growth Using Toda-Yamamoto Causality Test: The Case of Kazakhstan and Azerbaijan

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ABSTRACT

This study examines the relationship between energy consumption and economic growth in Kazakhstan and Azerbaijan using the Toda-Yamamoto causality test. Following their independence, both countries implemented significant structural reforms to transition to a market economy, recognizing the efficient use of energy resources as a strategic component for economic growth. Kazakhstan benefited from its abundant oil and natural gas reserves, resulting in an increased economic growth rate. In contrast, Azerbaijan fostered its economic development through a growth model centered on energy exports. The research analyzes the impact of oil and renewable energy consumption on economic growth through various models. The findings indicate a significant causal relationship between energy consumption and economic growth in Kazakhstan, while this relationship is not statistically significant in Azerbaijan. Consequently, the study concludes that energy consumption is a crucial factor for economic growth in Kazakhstan. Furthermore, the research explores how structural differences between energy consumption and economic growth influence the time needed to reach equilibrium. Results show that Kazakhstan achieves equilibrium in a shorter timeframe compared to Azerbaijan. This study aims to enhance the understanding of growth dynamics, particularly in energy-rich countries, by highlighting the effects of energy consumption on economic growth and the implications of different energy policies on this relationship.

Keywords: Toda-Yamamoto Causality Test, Energy Consumption, Economic Growth, Gross Domestic Product, Kazakhstan, Azerbaijan
JEL Classifications: C13, C20, C22

1. INTRODUCTION

Following the collapse of the USSR, Kazakhstan declared its independence on December 16, 1991, and undertook significant structural reforms during its transition to a free market economy (Taibek et al., 2023; Bekzhanova et al., 2023). These reforms were crucial for boosting Kazakhstan's economic growth rate and accelerating its development process. With its abundant natural resources, Kazakhstan experienced this challenging transition more smoothly than many other countries that gained independence after the Soviet Union. Kazakhstan holds approximately 3% of the world's oil reserves, 1.1% of its natural gas reserves, and 3.3% of its coal reserves. Additionally, it ranks second globally in uranium reserves (Mudarissov and Lee, 2014; Xiong et al., 2015; Bolganbayev et al., 2021; Kelesbayev et al., 2022a; Mashirova et al., 2023; Niyetalina et al., 2023). These rich energy resources have provided a significant advantage in Kazakhstan's economic growth and transition to a free market economy. By becoming an attractive destination for foreign direct investment, Kazakhstan has accelerated its economic development through the structural reforms and energy sector-focused investments implemented after independence (Sabenova et al., 2023; Mukhtarov et al., 2020; Kelesbayev et al., 2022b; Sultanova et al., 2024). Kazakhstan has risen to second place, after Russia, in terms of gross domestic product (GDP) among the commonwealth of ındependent states (CIS) countries. This economic growth has led to significant improvements in the country's living standards. The energy resources of Kazakhstan play a strategic role in sustaining economic growth and enhancing regional development. Energy consumption is a key driver of Kazakhstan's economic growth, contributing positively to the country's development through the efficient use of energy resources. Therefore, the impact of energy consumption on economic growth is a significant area of study in energy-rich countries like Kazakhstan (Mudarissov and Lee, 2014; Xiong et al., 2015; Bolganbayev et al., 2021; Kelesbayev et al., 2022a; Mashirova et al., 2023; Sabenova et al., 2024).

After the collapse of the USSR, Azerbaijan declared its independence on October 18, 1991, and has since implemented significant structural reforms to transition to a free market economy, just like Kazakhstan. However, the occupation of its lands in Nagorno-Karabakh by Armenia has led to serious social and economic challenges for Azerbaijan. Despite the difficulties associated with these reforms, the country's abundant energy resources have played a crucial role in its economic development. Azerbaijan holds the largest oil and natural gas reserves among the Turkic Republics, second only to Kazakhstan, with approximately 7 billion barrels of oil and 2.5 trillion cubic meters of natural gas. These reserves account for about 0.6% of the world's oil supply (Suleymanov and Hasanov, 2014; Şahin and Konak, 2019). The energy sector is a major driver of Azerbaijan's economic growth, serving as the primary source of the country's commercial income. Energy production and consumption support the nation's economic progress, and revenues from energy exports significantly contribute to the economy. The energy sector not only directly boosts economic performance but also indirectly raises living standards. In this context, understanding the impact of energy consumption on economic growth has become a critical research area for energy-rich countries like Azerbaijan. The Azerbaijani example illustrates that energy resources play a strategic role in sustaining economic growth and accelerating development, going beyond merely serving as a source of income (Suleymanov and Hasanov, 2014; Şahin and Konak, 2019; Yesbolova et al., 2024).

Economic growth refers to the annual increase of a country's production factors due to efficient use. These factors include labor, natural resources, domestic capital accumulation, foreign trade policies, banking and financial structures, energy production and consumption, and foreign direct investments (Neelankavil et al., 2012). In general, economic growth is a process that enhances the production capacity and welfare levels of a country. The most common indicator used to measure this process is gross domestic product (GDP) (Dyussembekova et al., 2023). GDP represents the total value of final goods and services produced by an economy within a specific period. When calculated at the prices of the year in which production occurs, it is referred to as Nominal GDP. The acceleration of globalization, advances in information technologies, and easier access to financial markets have made economic growth a more significant issue today. Economic growth not only reflects the economic performance of a country during a specific period but also allows for comparisons with other countries that have similar economic structures. Because of these characteristics, economic growth is critical for the analysis of both policymakers and academics (Sartbayeva et al., 2023; Issayeva et al., 2023; Abdibekov et al., 2024; Ibyzhanova et al., 2024). These elements demonstrate that economic growth is not merely a numerical increase; it is also a key factor influencing the overall welfare level of a country and its competitiveness in the global arena.

Energy consumption is a fundamental indicator of economic growth and development. The Industrial Revolution marked a significant turning point, as the acceleration of mechanization made energy consumption a key driving force behind production processes, thus supporting economic growth. Since the 18^{th} century, rising energy consumption has become critical for maintaining continuous production, with any declines typically leading to slower economic growth rates (Siddiqui, 2004). Consequently, the relationship between energy consumption and economic growth has been extensively explored in academic literature. Recent years have seen a rapid increase in global energy consumption due to developing technologies and rising energy demands (Alshehry and Belloumi, 2015; Abidin et al., 2015; Matei, 2017). However, this surge, particularly from the extensive use of fossil fuels, has resulted in significant environmental challenges. The reliance on fossil energy sources contributes to greenhouse gas emissions and exacerbates global warming, while their finite nature raises long-term sustainability issues (Apergis and Danuletiu, 2014). As a result, there is growing interest in renewable energy sources. Alternatives such as wind, solar, geothermal, biofuel, and tidal energy are now gaining prominence. Although the initial investment costs for renewable energy can be high, advancements in technology are helping to lower these costs and expedite the transition. In fact, the increasing global investment in renewable energy suggests that these sources will eventually replace fossil fuels in energy production (Apergis and Danuletin, 2014).

This study aims to examine the relationship between energy consumption and economic growth in the economies of Kazakhstan and Azerbaijan, utilizing the Toda-Yamamoto structural break test. The primary research problems are how energy consumption influences economic growth and how these effects vary under different energy policies.

2. LITERATURE REVIEW

Numerous studies in academic literature explore the relationship between energy consumption and economic growth using various analytical methods. These studies, conducted across different countries, assess the effects of energy consumption on economic growth from multiple perspectives. One frequently used method in this field is the Toda-Yamamoto structural break test, which analyzes the relationship between energy consumption and economic growth. We will only refer to certain studies.

Allou et al. (2020) examined the impact of China's foreign direct investment (FDI) on social and economic welfare in Ivory Coast. Utilizing 3-month data from 2003 to 2017, the researchers applied the vector autoregressive (VAR) model in conjunction with the Toda and Yamamoto (1995) causality test. Their results indicated that Chinese FDI creates a unidirectional causality towards social welfare, as measured by the Human Development Index, but it had no significant impact on economic welfare, represented by real GDP per capita.

Aimer and Dilek (2021) analyzed the causal relationship between energy consumption and economic growth in 16 countries within the Middle East and North Africa region, using data from 1985 to 2016. Their approach differed from traditional methods, as they employed the ARDL bounds test and the Toda and Yamamoto (1995) causality analysis, which do not require the time series data to be integrated at the same level. Their findings revealed a long-term relationship between economic growth and final energy consumption. Additionally, they identified a unidirectional causality from economic growth to energy consumption, suggesting that energy-saving policies would not negatively impact economic growth.

Dritsaki (2017) investigated the relationship between inflation and nominal interest rates in Germany, Great Britain, and Switzerland, using data from 1995 to 2015. To assess the long-term equilibrium relationship, he utilized the ARDL cointegration technique developed by Pesaran et al. (2001) along with the Toda and Yamamoto (1995) Granger causality approach. The ARDL bounds test results indicated the presence of a cointegrated vector for all three countries, confirming the Fisher assumption. Furthermore, the Toda-Yamamoto analysis revealed that nominal interest rates had a positive effect on inflation, while inflation influenced interest rates only in Germany.

Abinaya et al. (2016) investigated the Granger causality relationship between stock prices and trading volumes of Nifty 50 companies listed on the National Stock Exchange of India. The study utilized minute-by-minute data (converted from instantaneous data) covering the period from July 2014 to June 2015 and employed the Toda-Yamamoto method, as the time series data were not uniformly integrated. The results indicated that 29 companies exhibited a bidirectional causality relationship between price and volume, while 15 companies showed unidirectional causality. Additionally, no causality was found among six companies. These findings suggest that the Efficient Market Hypothesis does not hold for the 29 companies.

Maduka et al. (2016) examined the relationship between government health expenditures, health outcomes (such as life expectancy and mortality), and economic growth in Nigeria from 1970 to 2013, using the Toda-Yamamoto causality test. The study assessed the degree of integration of the variables with the ADF and KPSS tests and revealed a long-term equilibrium relationship among the variables, confirmed by the Johansen cointegration test. The results of the TY causality analysis showed that government health expenditures do not directly impact economic growth but do so indirectly through health outcomes like mortality rates and life expectancy.

Simionescu et al. (2022) explored dynamic interactions among the economies of France, Spain, and Germany, discussing the green transformation regarding nuclear and renewable energy sources among European Union member states. A comprehensive methodology, including time series analysis and causality tests (Granger and Toda-Yamamoto), was applied using data from 1983 to 2019. The empirical results showed no statistical causality between renewable energy usage and economic growth in France and Spain, while renewable energy had a slight positive effect on growth in Germany. Additionally, economic growth in Spain was found to significantly increase nuclear energy consumption. The country-specific findings provide recommendations for developing low-carbon sectors and strategies for nuclear energy.

Gershon and Emekalam (2021) examined the determinants of renewable energy consumption in Nigeria using the Toda-Yamamoto method, analyzing 24 years of data. The study revealed a long-term relationship between renewable energy consumption and its determinants. The most significant factors influencing the demand for petroleum product imports were found to be real income (GDP) and CO_2 emissions, while trade openness was deemed ineffective. Furthermore, a unidirectional causality was identified from CO_2 emissions to GDP, indicating that fossil fuels play a vital role in driving economic growth in Nigeria. The study underscores that concerns for the environment are secondary to real income.

Miamo and Achuo (2021) investigated the causal relationship between crude oil prices and real GDP growth in Cameroon, using data from 1980 to 2018. They employed the ARDL modeling framework, along with the Bounds and Toda-Yamamoto cointegration and causality tests. The ARDL estimates indicated that crude oil prices have a positive and significant impact on real GDP growth, both in the short and long term. The Toda-Yamamoto test further revealed a unidirectional causality from real GDP to crude oil prices. Based on these findings, the authors recommend that the government increase investments in the oil sector and effectively manage oil revenues.

Sankaran et al. (2019) explored the effects of electricity consumption, per capita income, real exchange rates, and both imports and exports on industrial production in ten late-industrialized countries, utilizing annual data from 1980 to 2016. They employed the ARDL bounds test method to analyze the long-term relationships between the variables and used the error correction model to examine short-term dynamics. The Toda-Yamamoto test was applied to assess the causality relationship.

The results indicated the presence of both short-term and long-term relationships, supporting various hypotheses, such as growth, conservation, feedback, and neutrality, for different countries. The study emphasizes that the efficient use of energy consumption can significantly bolster economic development in late-industrialized nations.

Demirgil and Birol (2020) examined the impact of renewable energy consumption on economic growth in Turkey from 1980 to 2018. Initially, a unit root test was conducted on the variables, revealing that they contained a unit root at their level values. The researchers assessed the cointegration relationship using the bounded ARDL test, which indicated a long-term relationship between the variables. The findings reveal that a 1% increase in renewable energy consumption leads to a 0.91% increase in economic growth. Following the cointegration analysis, the Toda-Yamamoto causality test was performed, demonstrating a one-way causal relationship from renewable energy consumption to economic growth. These results suggest that renewable energy consumption significantly contributes to fostering economic growth in Turkey.

Bilgin (2023) analyzed the inflation phenomenon in Turkey by examining its connection to factors such as energy prices, exchange rates, and the current account deficit. The empirical research investigated the causal relationships between the producer price index (PPI), oil prices, gold prices, and the US dollar. Unit root tests were applied, and the Toda-Yamamoto causality analysis was conducted using a VAR (vector autoregression) model. The results indicate that oil prices and the US dollar have a one-way causal effect on the PPI. This finding highlights the significant influence of energy prices on production costs.

3. METHODS

In time series analysis, the first step is to assess the stationarity of the series. A review of the relevant literature reveals that the most recommended tests for analyzing stationarity are the Augmented Dickey-Fuller (ADF) test, the Phillips–Perron (PP) test, and the Kwiatkowski-Phillips-Schmidt-Shin (KPSS) test. This study utilizes the ADF test to examine the stationarity of the series. The test statistics are given by Equation (1).

$$\Delta Y_t = \beta_0 + \beta_1 t + \delta Y_{t-1} + \alpha_i \sum_{i=1}^{m} \Delta Y_{t-i} + \varepsilon_t \tag{1}$$

In the ADF test, if the null hypothesis is rejected for values, then the series is stationary at the relevant significance level (Dickey and Fuller, 1979).

This study investigated the long-term relationship between the series using the Autoregressive Distributed Lag (ARDL) method. A significant advantage of the ARDL bounds test is that it does not require all variables in the model to be stationary at the same level. The ARDL method allows for the inclusion of variables that are stationary at level I(0) or I(1) in their first differences. Another benefit of this method is its applicability to small sample sizes (Narayan and Narayan, 2005). The mathematical structure of the ARDL model with two independent variables is as follows:

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

The first step of the ARDL method is to test for a long-term relationship between the variables. If a long-term relationship is confirmed, both short-term and long-term coefficients are estimated and tested (Narayan and Smyth, 2006). Conversely, if no long-term relationship is identified, only the ARDL regression coefficients are estimated. To determine the presence of a long-term relationship, the F-statistic based bounds test is conducted according to the following criteria:

- If the F-statistic is <I(0), there is no cointegration relationship.
- If the F-statistic is >I(1), a cointegration relationship exists.
- If the F-statistic falls between the I(0) and I(1) limits, the presence of a cointegration relationship cannot be determined (Pesaran et al., 2001).

As a preliminary step in ARDL analysis, the stationarity of the series is checked. Following this, the appropriate lag length is determined using various commonly employed criteria, including the Akaike Information Criterion (AIC), Schwartz Information Criterion (SIC), Log-Likelihood (LogL), Bayesian Information Criterion (BIC), and the Hannan-Quinn Information Criterion (HQ).

Once the model is established, it is crucial to test its compatibility and goodness-of-fit. The Breusch-Godfrey LM test is applied to check for autocorrelation, while the White Test and Breusch-Pagan-Godfrey test are used to identify heteroscedasticity. Additionally, the Ramsey RESET test is conducted to assess the suitability of the functional structure.

In Granger causality analysis, a variable X is said to Granger-cause another variable Y if the estimation error of Y's current value decreases based on its past values and those of X (Jain and Ghosh, 2013). A common issue with traditional Granger causality tests is that they can produce spurious causal relationships when dealing with non-stationary time series. Moreover, analyzing differenced series can lead to information loss. To address these concerns, Toda and Yamamoto (1995) proposed a testing method that relies on a Vector Autoregression (VAR) model, which is independent of the cointegration and stationarity levels of the series. The causality relationship in this method is examined using the WALD test (Toda and Yamamoto, 1995). The steps of the method are summarized below (Yuan et al., 2014):

1. Determine the optimal lag length (k) by establishing the VAR model.
2. Estimate the VAR model using a lag length of (k + dmax). During this step, diagnostic tests are conducted to assess the suitability of the VAR model.
3. Examine the significance of the first k lags of each variable using the Wald test. The test results are compared to the Chi-square table value. If the results are significant, the null hypothesis - stating that no causality exists - is rejected.

The Toda-Yamamoto model, based on the VAR (k + dmax) framework for variables X and Y, can be expressed as follows.

$$Y_t = \omega + \sum_{i=1}^{k} \alpha_{1i} X_{t-i} + \sum_{i=1}^{k} \beta_{1i} Y_{t-i} + \sum_{i=k+1}^{d\max} \delta_{1i} X_{t-i} + \sum_{i=k+1}^{d\max} \theta_{1i} Y_{t-i} + \varepsilon_{1t} \quad (3)$$

$$X_t = \varphi + \sum_{i=1}^{k} \alpha_{2i} X_{t-i} + \sum_{i=1}^{k} \beta_{2i} Y_{t-i} + \sum_{i=k+1}^{d\max} \delta_{2i} X_{t-i} + \sum_{i=k+1}^{d\max} \theta_{2i} Y_{t-i} + \varepsilon_{2t} \quad (4)$$

4. DATA AND FINDINGS

The examination of the relationship between energy consumption and economic growth has been an important research topic, contributing to both theoretical literature and our understanding of macroeconomic developments. This study specifically investigates the relationship between energy consumption from petroleum and renewable sources and economic growth using Toda-Yamamoto causality analysis. The decision to categorize energy consumption into two components—oil-based energy consumption and renewable energy consumption—stems from the need to closely examine the effects of different energy sources, particularly for the economies of Kazakhstan and Azerbaijan, which are the focus of this research. Economic growth is represented in the models as the annual change in GDP.

In the research, energy consumption (from petroleum and renewable resources) is measured in terawatt-hours (TWh), while economic growth is measured as the annual growth rate. Table 1 provides concise definitions of the research variables along with their data sources. The data was collected from the sources listed in the table as of September 15, 2024. The analysis period covers the years 1991-2023. Models containing the same variables were analyzed for both Kazakhstan (Model 1) and Azerbaijan (Model 2), allowing for a comparison of the economic growth dynamics of the two countries.

Table 2 presents the descriptive statistics and distribution metrics for the research variables. The average renewable energy consumption during the research period was 24.88 for Kazakhstan and 5.64 for Azerbaijan. In terms of oil consumption, Kazakhstan had a rate of 138.01, while Azerbaijan's rate was 60.21. Additionally, the average annual GDP growth for Kazakhstan was 3.66, compared to Azerbaijan's 4.92. The results of the Jarque-Bera test also indicated that all research variables followed a normal distribution.

Graph 1 illustrates the time path of GDP for Kazakhstan and Azerbaijan. Upon examining the graph, it is evident that Kazakhstan's GDP shows no extreme fluctuations. In contrast, Azerbaijan experienced a negative extreme value in 1993 and a positive extreme value in 2007. Over the past decade, both countries have exhibited stable and steady positive economic growth.

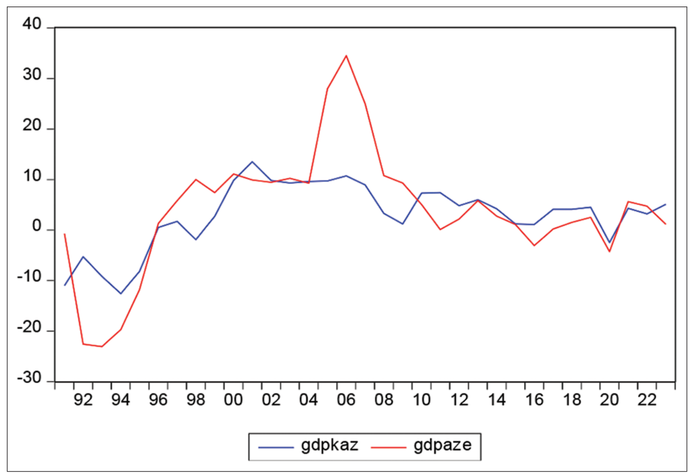
Graph 2 depicts the time path of energy consumption derived from oil resources in Kazakhstan and Azerbaijan. In Kazakhstan, oil-based energy consumption was approximately 250 TWh in 1991, which steadily declined to around 100 TWh by 1999. After that point, consumption gradually increased and reached levels

Table 1: Variable definitions and sources

Variable	Definition	Source
OILAZE	AZE Oil consumption	https://ourworldindata.org
OILKAZ	KAZ Oil consumption	https://ourworldindata.org
RNVAZE	AZE renewables	https://ourworldindata.org
RNVKAZ	KAZ renewables	https://ourworldindata.org
GDPAZE	AZE GDP growth (annual %)	https://data.worldbank.org
GDPKAZ	KAZ GDP growth (annual %)	https://data.worldbank.org

GDP: Gross domestic product

Graph 1: Time path Graph of gross domestic product parameter for Kazakhstan and Azerbaijan



Graph 2: Time path graph of oil-based energy consumption in Kazakhstan and Azerbaijan

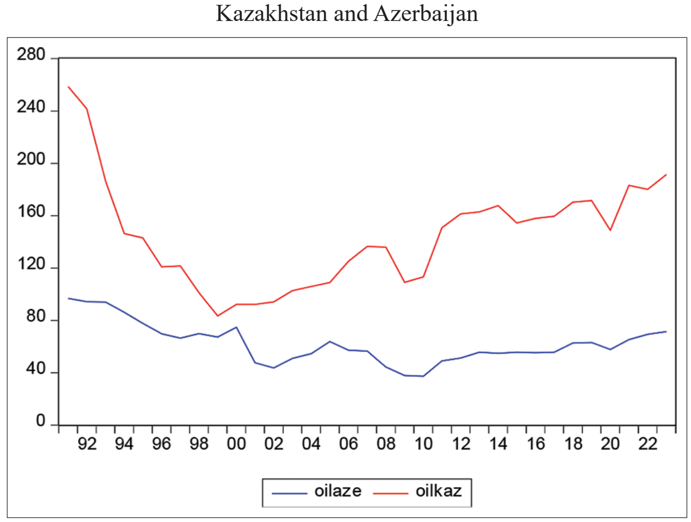


Table 2: Descriptive statistics findings for the variables

Statistics	RNVKAZ (TWh)	RNVAZE (TWh)	OILKAZ (TWh)	OILAZE (TWh)	GDPKAZ	GDPAZE
Mean	24.87228	5.640612	138.0097	60.20618	3.664516	4.920697
Median	23.10564	5.259206	143.0072	57.11258	4.200000	5.048945
Maximum	37.43088	9.566865	191.3780	94.05540	13.50000	34.50000
Minimum	18.13226	3.504816	83.37866	37.24386	−12.6000	−23.1000
Standard deviation	5.020994	1.481682	31.88581	12.97045	5.954637	11.49526
Skewness	0.845279	0.837559	−0.0615	0.493780	−0.9571	0.088297
Kurtosis	2.819830	3.089751	1.770073	3.252426	3.813474	4.519465
Jarque-Bera	3.733491	3.634851	1.973473	1.342031	5.587593	3.022446
Probability	0.154626	0.162443	0.372791	0.511189	0.061188	0.220640

between 190 and 200 TWh by 2023. In comparison, Azerbaijan demonstrated a more stable trend. Consumption was about 100 TWh in 1991 and has remained at around 80-90 TWh in 2023.

Graph 3 illustrates the time path of energy consumption produced from renewable sources in Kazakhstan and Azerbaijan. In Kazakhstan, oil-based energy consumption was approximately 20 TWh in 1991. This value increased steadily, reaching between 35 and 40 TWh by 2023. In contrast, Azerbaijan's energy consumption demonstrated more stability over the same period. It remained constant at around 5 TWh from 1991 to 2023. The graph clearly indicates that Kazakhstan consistently exhibited higher values in renewable energy consumption throughout the entire period.

Table 3 presents the findings from the ADF unit root test for the variables. The results show that all variables are stationary at the first difference at the 5% significance level. As explained in the methods section, it is sufficient for the variables to be stationary in the ARDL model, and there is no need to express them in terms of their differences at the same level. Consequently, the first differences of the research variables were utilized in the analysis phase.

An important step in the ARDL model process is determining the number of lags in the equation. Table 4 provides the criteria values for four models that offer the best fit according to LogL, AIC, BIC, and HQ criteria for both Kazakhstan and Azerbaijan. Based on the AIC criterion, the ARDL(4, 4, 0) model was chosen for Kazakhstan, while the ARDL(1, 4, 0) model was selected for Azerbaijan.

The findings from the ARDL bounds test are presented in Table 5 to assess the existence of a long-term relationship for Kazakhstan and Azerbaijan according to the ARDL model. It was concluded that a long-term relationship exists between the variables, as the calculated F value for both models exceeded the critical value from (Table 1) proposed in the study by Pesaran et al. (2001) at the 5% significance level. Based on these findings, the ARDL long-term form and error correction regression model will be employed.

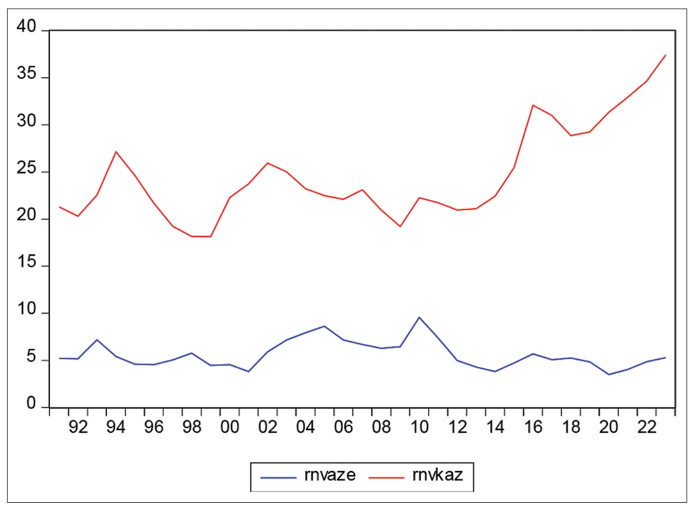
One of the criteria for assessing the compatibility of the ARDL regression model is the diagnostic test values. The data in Table 6 for Kazakhstan and Azerbaijan indicates that there are no autocorrelation issues according to the Breusch-Godfrey test, no heteroscedasticity problems as per the Breusch-Pagan-Godfrey test, the residuals are normally distributed according to the Jarque-Bera test (Jarque and Bera, 1987), and there is no model identification error (functional form error) based on the Ramsey RESET test (Ramsey, 1969).

Table 3: ADF unit root test findings for the variables

Variable code	Level		1st difference	
	t-statistics	P*	t-statistics	P*
RNVKAZ	−0.08435	0.9429	−4.09834	0.0034
RNVAZE	−2.53225	0.1176	−5.26409	0.0002
OILKAZ	−2.85576	0.0619	−4.00768	0.0042
OILAZE	−2.41422	0.1459	−5.07724	0.0003
GDPKAZ	−2.52999	0.1181	−5.61424	0.0001
GDPAZE	−1.76024	0.3926	−5.28936	0.0001
Test critical values				
1% level	−3.65373		−3.66166	
5% level	−2.95711		−2.96041	
10% level	−2.61743		−2.61916	

ADF: Augmented Dickey-Fuller

Graph 3: Time path graph for energy consumption from renewable



Sources in Kazakhstan and Azerbaijan

Table 7 presents the ARDL model findings and long-term prediction values for Kazakhstan. The model predictions indicate that the lagged values of GDP and energy consumption from petroleum resources are significant at a 5% level, while the effect of energy consumption from renewable resources is statistically insignificant. Consistent with the short-term effects, the impact of energy consumption from petroleum resources on GDP remains significant in the long term, whereas the effect of energy consumption from renewable resources is found to be statistically insignificant. However, the coefficient estimates show that the

Table 4: Autoregressive distributed lag model selection criteria values

Model specification	LogL	AIC	BIC	HQ	Adjusted R^2
Model 1 kazakhstan					
ARDL (4, 4, 0)	−56.7959	4.842566	5.365932	5.002564	0.614137
ARDL (4, 3, 4)	−54.1183	4.865595	5.531697	5.069229	0.613017
ARDL (4, 4, 4)	−53.1843	4.870309	5.583990	5.088488	0.610145
ARDL (4, 4, 1)	−56.7769	4.912639	5.483584	5.087182	0.590576
Model 2 Azerbaijan					
ARDL (1, 4, 0)	−84.5312	6.609370	6.990000	6.725733	0.211875
ARDL (2, 4, 0)	−83.9438	6.638841	7.067049	6.769748	0.204483
ARDL (1, 4, 1)	−84.3614	6.668674	7.096882	6.799581	0.180393
ARDL (1, 0, 0)	−89.7582	6.697015	6.887330	6.755196	0.045971

AIC: Akaike information criterion, BIC: Bayesian information criterion, HQ: Hannan-Quinn, ARDL: Autoregressive distributed lag

Table 5: Autoregressive distributed lag bounds test findings

Test statistic	Value	Significant (%)	I (0)	I (1)
Model 1 Kazakhstan				
F-statistic	5.206813	10	2.63	3.35
k	2	5	3.1	3.87
-		2.5	3.55	4.38
-		1	4.13	5
Model 2 Azerbaijan				
F-statistic	5.096405	10	2.63	3.35
k	2	5	3.1	3.87
-		2.5	3.55	4.38
-		1	4.13	5

Table 6: Autoregressive distributed lag diagnostic test findings

Variables/tests	Statistics	P
Model 1 Kazakhstan		
Breusch-Godfrey serial correlation LM test	F-statistic: 2.149932	Prob. F (2.15): 0.1510
Heteroskedasticity test: Breusch-Pagan-Godfrey	F-statistic: 0.314457	Prob. F (10.17): 0.9664
Ramsey reset test	F-statistic: 0.242713	Prob. F (1.16): 0.6289
Test of normality	Jarque-bera: 0.173187	Prob. 0.917050
Model 2 Azerbaijan		
Breusch-Godfrey serial correlation LM test	F-statistic: 1.385459	Prob. F (2.18): 0.2756
Heteroskedasticity test: Breusch-Pagan-Godfrey	F-statistic: 0.645977	Prob. F (7.20): 0.7134
Ramsey reset test	F-statistic: 1.282236	Prob. F (1.19): 0.2716
Test of normality	Jarque-Bera: 0.651147	Prob. 0.722113

effect of energy consumption from petroleum resources is negative, while the effect from renewable resources is positive.

After confirming the existence of cointegration through the bounds test and long-term estimation findings, Table 8 provides the results of the ARDL error correction model. The findings reveal that the effect of the error correction term is statistically significant. The error correction term, which takes a value between −2 and −1 (−1.78477), suggests that it converges toward the long-term equilibrium value in a series of decreasing waves (Alam and Quazi, 2003). The model estimates that the GDP variable will reach equilibrium in approximately 0.56 years (<1 year) following a short-term shock. The adjusted R-squared value of the model

Table 7: Autoregressive distributed lag model and long-term prediction findings for Model 1 Kazakistan

Variable	Coefficient	SE	T-statistic	P
Prediction findings for the model (model 1 Kazakhstan)				
C	−0.05153	0.51491	−0.10007	0.92150
DGDPKAZ(−1)*	−1.78477	0.42256	−4.22373	0.00060
DOILKAZ(−1)	−0.21086	0.06055	−3.48272	0.00280
DRNVKAZ**	0.33523	0.25162	1.33228	0.20040
D (DGDPKAZ[−1])	0.30822	0.30308	1.01698	0.32340
D (DGDPKAZ[−2)	−0.06596	0.20910	−0.31546	0.75630
D (DGDPKAZ[−3])	−0.30719	0.15324	−2.00459	0.06120
D (DOILKAZ)	0.07784	0.03351	2.32291	0.03280
D (DOILKAZ[−1])	0.24601	0.06314	3.89612	0.00120
D (DOILKAZ[−2])	0.18144	0.05177	3.50465	0.00270
D (DOILKAZ[−3])	0.07751	0.04255	1.82142	0.08620
Long-term prediction findings				
DOILKAZ	−0.11815	0.03185	−3.70917	0.00170
DRNVKAZ	0.18783	0.13518	1.38948	0.18260
C	−0.02887	0.28916	−0.09984	0.92160

EC=DGDPKAZ- (−0.1181*DOILKAZ+0.1878*DRNVKAZ−0.0289) SE: Standard error

Table 8: Autoregressive distributed lag error correction regression model findings for model 1 Kazakistan

Variable	Coefficient	SE	T-statistic	P-value
D (DGDPKAZ[−1])	0.30822	0.25468	1.21022	0.24280
D (DGDPKAZ[−2])	−0.06596	0.18169	−0.36305	0.72100
D (DGDPKAZ[−3])	−0.30719	0.13187	−2.32942	0.03240
D (DOILKAZ)	0.07784	0.02800	2.77957	0.01280
D (DOILKAZ[−1])	0.24601	0.05478	4.49093	0.00030
D (DOILKAZ[−2])	0.18144	0.04415	4.10922	0.00070
D (DOILKAZ[−3])	0.07751	0.03694	2.09792	0.05120
CointEq(−1)*	−1.78477	0.36056	−4.95002	0.00010
R^2	0.87580	Mean dependent variable		−0.08929
Adjusted R^2	0.83233	SD dependent variable		5.31534
SE of regression	2.17651	Akaike info criterion		4.62828
Sum squared resid	94.74403	Schwarz criterion		5.00891
Log likelihood	−56.796	Hannan-Quinn criterion		4.74464
Durbin-Watson stat	2.39475			

SE: Standard error, SD: Standard deviation

is calculated at 0.83, indicating that 83.3% of the variability in GDP is explained by the energy consumption variables included in the model.

Table 9 presents the findings of the Autoregressive Distributed Lag (ARDL) model and long-term prediction values for Azerbaijan.

Table 9: Autoregressive distributed lag model and long-term prediction findings for model 2 Azerbaijan

Variable	Coefficient	SE	T-statistic	P-value
Prediction findings for the model (model 2 Azerbaijan)				
C	−0.33422	1.170608	−0.285509	0.7782
DGDAZE(−1)*	−0.762947	0.176284	−4.327939	0.0003
DOILAZE(−1)	−0.399277	0.39035	−1.022868	0.3186
DRNVAZE**	0.576004	1.158947	0.497007	0.6246
D (DOILAZE)	0.14887	0.159089	0.935767	0.3606
D (DOILAZE[−1])	0.438245	0.258953	1.692376	0.1061
D (DOILAZE[−2])	0.502716	0.217912	2.306971	0.0319
D (DOILAZE[−3])	0.46090	0.15527	2.96847	0.00760
Long-Term prediction findings				
DOILAZE	−0.52334	0.52640	−0.99418	0.33200
DRNVAZE	0.75497	1.51749	0.49751	0.62430
C	−0.43806	1.55122	−0.28240	0.78050

EC=DGDAZE - (−0.5233*DOILAZE+0.7550*DRNVAZE−0.4381) SE: Standard error

The model estimates indicate that the lagged values of GDP and energy consumption derived from oil resources are statistically significant at a 5% level. However, the impact of energy consumption from renewable resources is found to be statistically insignificant. In terms of long-term effects, both variables show statistically insignificant effects, which differs from the findings for Kazakhstan. Notably, like the Kazakhstan model, the effect of energy consumption from oil resources is negative, while the effect from renewable resources is positive.

After determining the existence of cointegration through the bounds test and long-term predictions, the findings of the ARDL error correction model are displayed in Table 10. The results show that the effect of the error correction term is statistically significant. The error correction term, which takes a value between −1 and 0, indicates that there is a convergence towards equilibrium (Alam and Quazi, 2003). The calculated error correction term of −0.76295 suggests that 76.3% of the shocks occurring in the short term can be eliminated within 1 year. This implies that it will take approximately 1.31 years (or about 1 year and 4 months) to return to equilibrium following a short-term shock. The adjusted R-squared value of the model is 0.559, indicating that 55.9% of the variation in GDP is explained by the energy consumption variables in the model.

The findings from the Toda-Yamamoto Causality Test for Model 1 (Kazakhstan) are summarized in Table 11. The lag length for the Toda-Yamamoto test was determined to be 3 based on the VAR model. The results reveal significant causal effects of both variables (oil-based energy consumption and renewable energy consumption) on GDP. Specifically, the 1-period and 3-period lagged values of oil-based energy consumption exhibit negative effects, while the 2-period lagged values show a positive effect. Conversely, the 1-period and 3-period lagged values of renewable energy consumption have a positive effect, whereas the 2-period lagged values have a negative effect.

The results of the Toda-Yamamoto Causality Test for model 2 (Azerbaijan) are presented in Table 12. The lag length for the Toda-Yamamoto test was calculated as 2 based on the VAR model. The findings indicate that the causal effects of both variables (oil-based energy consumption and renewable energy consumption) on GDP were not significant.

Table 10: Autoregressive distributed lag error correction regression model findings for Model 2 Azerbaijan

Variable	Coefficient	SE	T-statistic	P-value
D (DOILAZE)	0.14887	0.12336	1.20677	0.24160
D (DOILAZE[−1])	0.43825	0.14366	3.05054	0.00630
D (DOILAZE[−2])	0.50272	0.13848	3.63026	0.00170
D (DOILAZE[−3])	0.46090	0.12208	3.77557	0.00120
CointEq(−1)*	−0.76295	0.15757	−4.84185	0.00010
R^2	0.62402	Mean dependent variable		−0.41039
Adjusted R^2	0.55864	SD dependent variable		8.22624
SE of regression	5.46513	Akaike info criterion		6.39509
Sum squared resid	686.95520	Schwarz criterion		6.63298
Log likelihood	−84.531	Hannan-Quinn criterion		6.46781
Durbin-Watson stat	2.06824			

SE: Standard error, SD: Standard deviation

Table 11: Toda-Yamamoto causality test for model 1 Kazakhstan

Hypothesis	Lag (k+dmax)	Chi-square	df	P-value
OIL GDP	3	38.99724	2	0.0000
Coefficient				
OILKAZ(−1)		−0.04709	0.032327	
OILKAZ(−2)		0.036588	0.042997	
OILKAZ(−3)		−0.12947	0.039629	
RNV GDP	3	10.16476	2	0.0062
Coefficient				
RNVKAZ(−1)		0.514575	0.210262	
RNVKAZ(−2)		−0.2753	0.305400	
RNVKAZ(−3)		0.021265	0.200257	

Table 12: Toda-Yamamoto causality test for model 2 Azerbaijan

Hypothesis	Lag (k+dmax)	Chi-square	df	P-value
OIL GDP	2	0.627389	1	0.4285
RNV GDP	2	2.175173	1	0.1403

5. CONCLUSION AND RECOMMENDATIONS

The analysis of the descriptive information in this study reveals that Azerbaijan exhibits a more variable structure regarding economic growth. Whereas Kazakhstan has consistently been a leader in the use of renewable resources over the past 30 years, which is crucial for environmental sustainability. The study employed the Autoregressive Distributed Lag (ARDL) method to examine long-term effects and the Toda-Yamamoto method to investigate causality. When considering the long-term effects, both countries showed a notable negative impact. This finding serves as a motivational tool for countries to invest in renewable energy sources. Additionally, the absence of a causal effect for Azerbaijan, contrasted with the presence of a causal relationship for Kazakhstan, highlights the differences in the economic structures of the two nations. From Kazakhstan's perspective, energy consumption plays a pivotal role in driving economic growth. The structural differences in the relationship between energy consumption and economic growth in both countries are also evident in the time it takes for each to reach an equilibrium. According to the model's findings, Kazakhstan is expected to reach this balance point much more quickly than Azerbaijan.

Future research could delve deeper into the relationship between economic growth and energy consumption, particularly in Kazakhstan, by incorporating structural break analyses. This would not only contribute to existing literature but also help clarify the dynamics of Kazakhstan's economy. The comparison of the two countries demonstrated that their relationships between energy consumption and economic growth vary. There is also an opportunity for further research by expanding the study to include additional countries for a clearer understanding of this effect across a broader panel.

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