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Relationship between Energy Consumption, Economic Growth and Population in Kazakhstan

Rimma Parmanova[1], Meruyert Baimoldayeva[2]*, Gulmira Azretbergenova[3], Perizat Beisekova[4]

[1]Caspian Public University, Almaty, Kazakhstan, [2]Kazakh National Agrarian Research University, Almaty, Kazakhstan, [3]Khoja Akhmet Yassawi International Kazakh-Turkish University, Turkestan, Kazakhstan, [4]Astana International University, Astana, Kazakhstan. *Email: meruert.kz.79@mail.ru

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ABSTRACT

This study examines the relationship between energy consumption, economic growth and population in Kazakhstan for the period 1991-2023. In the study, the Johansen cointegration test was applied to determine the long-term relationship between the variables and the results show that the variables are cointegrated. The Granger causality test was used to analyze the causality relationships. The findings reveal that there is a unidirectional causality from energy consumption to gross domestic product (GDP). This situation shows that energy consumption is an important factor driving economic growth in the Kazakh economy. In addition, a unidirectional causality relationship from GDP to the population variable was determined. This result shows that economic growth has an effect on population growth but there is no reverse relationship. The findings reveal that Kazakhstan should develop strategies to increase energy efficiency within the framework of sustainable growth policies. In addition, it is recommended to plan long-term development policies by considering the effect of economic growth on population growth. The study emphasizes that the relationship between energy consumption and economic growth should be examined in more depth.

Keywords: Energy Consumption, Economic Growth, Population Growth, Johansen Cointegration Test, Granger Causality Analysis, Kazakhstan
JEL Classifications: O40, Q43, Q40

1. INTRODUCTION

The relationship between energy consumption, economic growth and population growth stands out as an important area of research in terms of sustainable development and economic stability. This relationship becomes even more critical, especially in countries with abundant energy resources. Kazakhstan is one of the countries that draw attention in this context with its large fossil fuel reserves, growing economy and increasing population. The country's energy consumption dynamics, economic growth strategies and demographic changes create significant effects on both national and global scales.

Kazakhstan, as an energy-rich country, ranks high in world rankings in terms of oil, natural gas and coal reserves. The energy sector is one of the cornerstones of the country's economy and constitutes a significant part of the GDP (Azretbergenova and Syzdykova, 2020). However, the sustainability of economic growth and how energy demand will be shaped by population growth are increasingly gaining importance for academic circles and policy makers. In this context, understanding the relationship between energy consumption, economic growth and population is a critical requirement for determining Kazakhstan's long-term energy policies.

The main purpose of this study is to analyze the dynamic relationship between energy consumption, economic growth and population growth in Kazakhstan. Within the scope of the study, the effect of energy consumption on economic growth and population growth will be examined using econometric methods such as time series analysis and causality tests. In this context, the role of energy supply security, economic growth policies and population changes on energy demand will be discussed in detail.

The existing literature reveals that the relationship between energy consumption and economic growth may not be linear and may produce different results in different countries. However, a detailed examination of this relationship for energy-rich and developing countries such as Kazakhstan will make significant contributions to the literature. In addition, considering the effects of socio-economic variables such as population growth and urbanization on energy demand, suggestions will be made on how a policy framework should be established in terms of sustainable development.

As a result, examining the relationship between Kazakhstan's economic growth, energy consumption and population dynamics will not only provide an academic contribution but also contribute to the development of practical suggestions for shaping the country's energy policies. This study predicts that the findings obtained specifically for Kazakhstan may also be guiding for other energy-rich countries with similar structures.

2. LITERATURE REVIEW

The relationship between energy consumption, economic growth and population is complex and multifaceted as evidenced by various studies in different countries. While both renewable and non-renewable energy consumption plays an important role in economic growth, population dynamics affect both energy demand and economic outcomes. The interaction between these factors varies by region and is influenced by local policies and socio-economic conditions. Some of the empirical studies in the literature are given below.

Michieka (2014) shows that urban population growth significantly affects energy consumption and economic development in Kenya, with a unidirectional causality from urban population to GDP, suggesting that urbanization plays a crucial role in shaping energy use and economic growth.

DeLong and Burger (2015) highlight a strong relationship between energy consumption, economic growth, and population dynamics. They argue that increased energy efficiency has historically supported population growth by mitigating density dependency effects. As energy use scales with population size, it facilitates economic activities and improves social structures. The authors argue that understanding this interaction is crucial for developing sustainable strategies, as fluctuations in energy availability can significantly affect both population growth and the socio-economic system.

Owusu (2018) shows that in the short term, population growth and electricity consumption positively affect economic growth. In the long term, economic growth leads to increased CO_2 emissions, while both population growth and energy use contribute to emissions across time horizons.

Wilson and Mukhopadhyaya (2020) found in their study that as a country develops, energy consumption increases alongside resource consumption and population growth. Economic growth is strongly associated with energy use, suggesting that higher energy consumption is linked to improved socio-economic outcomes and population booms.

Syzdykova et al. (2020) examined the relationship between energy consumption and economic growth in the Commonwealth of Independent States (CIS) countries for the period 1992-2018. The authors found a two-way causality relationship between energy consumption and economic growth in the CIS countries.

Leitão and Balsalobre-Lorente (2020) demonstrate a causality between electricity consumption, economic growth, and urban population. They show that energy consumption is significantly associated with economic growth and that increased energy use is associated with urbanization and carbon dioxide emissions in the long run.

Sarkodie et al. (2020) show that energy consumption, economic growth, and population variables are interconnected in Kenya, Senegal, and Eswatini. While CO_2 emissions, population growth, and income levels drive energy demand and use, economic development is influenced by energy use and demographic dynamics. This interrelationship emphasizes the inseparability of income, population growth, energy, and CO_2 emissions in the context of sustainable development, emphasizing the need for collective decision-making to achieve the Sustainable Development Goals.

Wilson and Mukhopadhyaya (2020) establish a strong relationship between energy consumption and economic growth in their study and show that as a country develops, energy use increases alongside resource consumption and population growth. This correlation suggests that higher energy consumption is associated with improved socio-economic outcomes, including increased life expectancy. However, while economic growth typically drives energy use, the authors emphasize that this relationship may not necessarily lead to proportional increases in life satisfaction, suggesting a complex interaction between these factors.

Justice et al. (2023) identified a unidirectional relationship in their study, whereby economic growth in Nigeria is affected by factors such as mortality and fertility rates, as well as energy consumption. However, the vector error correction model shows that energy consumption and population dynamics have a non-significant effect on GDP during the study period from 1989 to 2020. This suggests that while energy consumption is linked to economic growth, its effect together with population dynamics is not significant in driving GDP growth in Nigeria.

Nwamaka and Orhewere (2022) found that there is a negative significant relationship between energy consumption and economic development in the long run in Nigeria and a similar negative significant effect in the short run. Population growth negatively affects economic development but has a positive significant effect on energy consumption. This suggests that although increasing population may increase energy demand, it is not necessarily associated with economic growth, highlighting the complex dynamics between these variables in Nigeria from 1995 to 2019.

Engel-Cox and Chapman (2023) emphasized that energy consumption is intricately linked to economic growth and population dynamics. Since energy inputs are essential for development, increasing energy consumption can drive economic growth. However, this growth can also have negative impacts on natural systems. Policy makers should consider sustainable energy solutions that balance energy efficiency, population needs, quality of life, and ecosystem health, recognizing that different countries have different starting points in achieving sustainable development goals.

Benmoussa (2023) argues that there is a complex relationship between energy consumption, economic growth and population. He argues that population growth drives economic dynamism and increases consumption needs, which in turn affects energy consumption. However, the model emphasizes the importance of sustainability, showing that uncontrolled energy consumption can lead to resource depletion. A balance must be achieved between population growth and the world's carrying capacity to ensure sustainable economic development without compromising environmental integrity.

Sijabat (2024) has shown that there is a long-term relationship between energy consumption (both renewable and non-renewable), population size and economic growth in G20 countries. While renewable energy consumption positively affects GDP growth, non-renewable energy consumption, especially oil, significantly affects GDP. Urban population is defined as a control variable that negatively affects GDP growth. Therefore, both energy consumption and population dynamics play very important roles in shaping economic growth trajectories in these countries.

3. METHODOLOGY AND DATASET

This study aims to examine the relationships between energy consumption (energy), economic growth (GDP) and population variables in Kazakhstan using annual data between 1991 and 2023. Data on GDP and population variables used in the analysis were obtained from the World Bank database and energy consumption (gigajoule per capita) from the Statistical Review of World Energy reports. Natural logarithms of the variables were taken and included in the analysis.

In order to make the right model selection in the study, firstly it was examined whether the variables were stationary or not. Then cointegration tests were conducted to investigate the long-term relationship between the variables. After the cointegration tests, the error correction mechanism was operated for the variables. Granger and Newbold (1974) focused on spurious regression in time series data. Therefore, in studies conducted on time series, there is a possibility of encountering spurious regression problem. Therefore, firstly whether the variables were stationary or not and if they were stationary, at what level they were stationary were investigated with Augmented Dickey and Fuller (1979) and Phillips and Perron (1988) unit root tests. Then, cointegration test, which determines the existence of a long-term relationship between the variables included in the model, was applied. For this purpose, Johansen-Juselius cointegration test was used in the study. In determining the long-term relationship, the stationarity of the error terms is examined by estimating the cointegration equations (1) and (2).

$$Y_t = \alpha_0 + \alpha_1 X_t + u_{1t} \tag{1}$$

$$X_t = \alpha_0 + \alpha_1 Y_t + u_{2t} \tag{2}$$

For the existence of cointegration, the error terms (u_t) obtained from equations (1) and (2) are expected to be stationary. For this, the following equations are estimated.

$$\Delta u_{1t} = \beta_1 u_{1t-1} + \sum_{i=1}^{q} \alpha_i \Delta u_{1t-i} + v_{1t}$$

$$\Delta u_{2t} = \beta_1 u_{2t-1} + \sum_{i=1}^{q} \alpha_i \Delta u_{2t-i} + v_{2t}$$

Here, if $\beta_1 = 0$ it is decided that the error terms are not stationary and there is no cointegration relationship between the variables; in the opposite case, it is decided that there is a cointegration relationship. However, these results do not provide information about whether there is a short-term relationship between the variables. There is uncertainty about whether the long-term relationship between the variables will balance over time. In this case, the VEC model is estimated. In general, a short-term error correction model is suggested together with a long-term balance model in causality tests. These models allow for the integration of both long-term relationships (balance relationships) between the variables and short-term adjustment behavior (imbalance). For example, let's assume that there are two variables defined as Y and E to express the explanation of the error correction equations. Accordingly, if the two variables are stationary and cointegrated, causality tests can be created according to the VEC model. The VEC to be created for the two variables is as follows:

$$y_t = \alpha_1 + \sum_{i=1}^{m} \beta_{1i} \Delta E_{t-i} + \sum_{i=1}^{n} \gamma_{1i} \Delta Y_{t-i} + \sum_{i=1}^{r} \delta_{1i} ECM_{r,t-1} + u_t$$

$$\Delta E_t = \alpha_2 + \sum_{i=1}^{m} \beta_{2i} \Delta E_{t-i} + \sum_{i=1}^{n} \gamma_{2i} \Delta Y_{t-i} + \sum_{i=2}^{r} \delta_{2i} ECM_{r,t-1} + u_t$$

In the VEC model, the lagged error terms $ECM_{r,t-1}$ are expressed as rate adjustment parameters. ECM means that there are two sources of causality for Y, either through the lagged terms of ΔE or the lagged error terms. If one or more of these sources affect Y, that is, if the parameters are statistically different from zero, then the null hypothesis of "E is not the Granger cause of Y" is not accepted. This hypothesis is tested using the t-test for error correction terms and the F test for lagged values of explanatory variables. The rate-adjusting parameter in at least one of the VEC systems must be statistically different from zero. If the rate-adjusting parameters are zero in the entire equation system, there is no long-term equilibrium relationship and the model created does not have the error-correcting feature.

The purpose of the stationarity analysis performed in the study is to make the means and variances of the time series used independent of time. For this purpose, the presence of a unit root in the series was analyzed using the Augmented Dickey Fuller (ADF) test. In the next stage, whether the variables move together in the short and long term was analyzed using the Johansen cointegration test. Finally, whether there is a causal relationship between the variables was tested with Granger causality analysis.

4. ANALYSIS FINDINGS

Tables 1 and 2 show the results of the Augmented Dickey Fuller (ADF) and Phillips-Perron (PP) tests. The results obtained using the Augmented Dickey Fuller (ADF) test show that the variables are stationary at the first difference at a significance level of 5%. In other words, the variables considered are stationary at the same level.

In the test results, the selection criteria Akaike Information Criterion (AIC) and Schwarz Criterion (SC) were taken into consideration. According to the results of the stationarity test, the variables used in the model do not contain a unit root and do not pose a negative effect on the estimates to be made in other sections. Making the variables stationary at the same level allows the examination of the long-term relationship. The selected lag length will be used in the Johansen Cointegration Test, where the short-term and long-term relationship between the variables will be tested. As seen in Table 3, the lag length was considered as 4 according to the suitability of the AIC and SC criteria, which are the most appropriate and reliable selection criteria as a result of the test.

Table 4 shows the results of the Johansen cointegration test. According to the results of the analysis, it was concluded that there was a long-term relationship between the variables at a significance level of 5%. In other words, there was cointegration between the variables.

Table 5 shows the results of the Error Correction Model. The Error Correction Model shows how long it will take for imbalances occurring within a period to reach balance. According to the results of the model, the error correction mechanism works because the error correction term takes a value between −1 and 0 and is statistically significant. The value of 1/|−0.60| is 1.66. This means that imbalances occurring within approximately two periods (years) will return to balance in the long term.

While the Johansen cointegration test provides information about the existence of a cointegration relationship between the variables used in the model, it does not provide information about the direction of the relationship between the variables. The Granger causality test was used to determine the direction of the relationship between the variables. According to the Granger causality test results in Table 6, a one-way causality relationship was found between energy consumption and GDP, from energy consumption to GDP. In addition, a one-way causality relationship was found from GDP to the population variable. The results were evaluated according to a 95% confidence level. According to the causality test result, energy consumption in Kazakhstan contributes to economic growth. The resulting economic growth effect helps to increase the standard of living of the people of the country.

Table 1: ADF unit root test results

Variables	Level			Variables	1st difference		
	Lag\	t-statistic	P-value		Lag	t-statistic	P-value
GDP	1	−2.045010	0.5548	*ΔGDP*	0	−3.403618	0.0185**
POP	4	−2.774441	0.3833	*ΔPOP*	1	−4.498198	0.0065***
ENC	3	−3.935127	0.0255**	*ΔENC*	0	−5.077768	0.0014***

The ADF regression equation includes both the constant term and the trend from the deterministic components. Δ: First order difference operator

Table 2: PP unit root test results

Variables r	Level			Variables	1st difference		
	Lag	t-statistic	P-value		Lag	t-statistic	P-value
GDP	3	−1.827547	0.6676	*ΔGDP*	3	−3.431020	0.0171**
POP	3	−1.671554	0.7405	*ΔPOP*	3	−4.284580	0.0072***
ENC	3	−2.669901	0.2547	*ΔENC*	3	−5.128541	0.0013

PP regression equation includes both constant term and trend from deterministic components. Δ: First order difference operator.

Table 3: Determination of lag length

Lag	LR	FPE	AIC	SC	HQ
0	NA	1.29e+53	140.8079	130.8518	130.8601
1	276.2365	1.53e+38	119.4644	120.0402	119.6430
2	56.14670	1.87e+37	117.4246	118.3315	117.6240
3	40.25128	3.68e+36	115.6242	117.0640	116.0610
4	20.15148*	1.97e+36*	114.8515*	116.7233*	115.4176*

*Indicates the appropriate lag length

Table 4: Johansen cointegration test results

Trace test	0.05 Critical value	Probability value	Cointegration number
47.93854	29.79707	0.0002	None*
22.56222	15.49471	0.0036	At most one*
0.776613	3.841466	0.3782	At most two
Max-eigen test	**0.05 critical value**	**Probability value**	**Cointegration number**
25.37632	21.13162	0.0119	None*
21.78561	14.25460	0.0027	At most one*
0.776613	3.841466	0.3782	At most two

Table 5: Error correction model

Variables	Coefficient	Standard error	Probability value
D (GDP)	1.14e-13	3.59e-14	0.0027
D (POP)	−0.004763	0.008176	0.5076
ECM (−1)	−0.608761	0.190082	0.0073
C	6420.677	7682.304	0.4023

Table 6: Granger causality analysis

Hypothesis	Chi-square	Probability value	Decision
$GDP \nrightarrow ENC$	5.512410	0.2076	H_0 accepted
$POP \nrightarrow ENC$	1.514403	0.7963	H_0 accepted
$ENC \nrightarrow GDP$	21.40642	0.0003	H_0 accepted
$POP \nrightarrow GDP$	4.028120	0.3472	H_0 accepted
$ENC \nrightarrow POP$	2.692305	0.5978	H_0 accepted
$GDP \nrightarrow POP$	8.556457	0.0209	H_0 accepted

5.CONCLUSION

This study examines the relationship between energy consumption, economic growth (GDP) and population in Kazakhstan between 1991 and 2023. The Johansen cointegration test results showed that there is a long-term balance relationship between these variables. In addition, the Granger causality test results revealed that energy consumption in the Kazakh economy affects GDP unidirectionally and GDP shapes population growth unidirectionally.

These findings emphasize that Kazakhstan's economic development is dependent on energy consumption and that energy resources should be managed sustainably. The fact that economic activities are largely based on energy use requires energy policies to be determined with great care. In addition, the causality relationship between GDP and population shows that economic development contributes to population growth. This situation reveals that a balance should be established between economic development and social policies in the long term.

In this context, it is recommended that Kazakhstan strengthen its energy efficiency policies in line with its sustainable development goals. Increasing investments in renewable energy sources can reduce the economy's dependence on energy and support long-term economic stability. In addition, adopting energy-saving policies and using more efficient technologies in the industrial sector are critical to reducing the dependence between energy consumption and economic development. Finally, energy policies in Kazakhstan should not only be addressed in terms of economic development, but also take into account factors such as population growth, environmental sustainability, and social well-being. In this context, it is vital for policymakers to adopt a long-term and comprehensive energy strategy for Kazakhstan's economic and social development.

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