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The Impact of Economic and Environmental Factors on the Consumption of Renewable Energy: The Case of Kazakhstan

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ABSTRACT

The article examines the impact of economic and environmental factors on the consumption of renewable energy sources (RES) in Kazakhstan. The study is based on a quantitative analysis of data, including adjusted net savings (ANS), the share of renewable electricity output (REO), and carbon dioxide (CO_2) emissions per capita. The dependent variable in this analysis is the share of renewable energy in the total final energy consumption. The results of the regression analysis revealed the following relationships: an increase in the share of electricity production from renewable energy sources (REO) by 1% leads to an increase in their consumption by 0.119% ($p < 0.01$), which is associated with reduced production costs and improved accessibility. Adjusted net savings (ANS) also have a positive effect: their growth by 1% increases renewable energy consumption by 0.055% ($p < 0.05$), confirming the role of economic stability and investment in the development of green energy. At the same time, an increase in CO_2 emissions negatively affects renewable energy consumption, decreasing it by 0.154% for each additional ton of CO_2 per capita ($p < 0.01$), which is explained by the predominance of traditional hydrocarbon energy sources. The study highlights that the sustainable development of renewable energy sources requires a comprehensive approach, including the stimulation of its production, reduction of carbon emissions, and maintenance of economic stability. The results have practical value for the formation of Kazakhstan's state policy aimed at transition to sustainable energy and reducing environmental pressure.

KEYWORDS: Renewable Energy, Energy Consumption, Carbon Emissions, Electricity Output, Sustainable Development, Economic Stability

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1. INTRODUCTION

Since fluctuations in global oil and gas prices significantly impact Kazakhstan's economy, diversifying energy sources through renewable energy use has become a strategic priority. Kazakhstan is a major producer and exporter of fossil fuels, such as oil, natural gas, and coal. The country ranks 9th globally in coal production, 17th in crude oil production, and 24th in natural gas production (IEA, 2020). The country's total oil reserves are estimated at 30 billion barrels, with proven natural gas reserves of 2.3 trillion cubic meters (BP, 2021). As a result, as an oil and gas exporting country, Kazakhstan is vulnerable to global market fluctuations, which could adversely affect national income and economic stability.

The installed capacity of renewable energy sources (RES) has been steadily increasing each year. As of January 1, 2020, the installed capacity of RES facilities was 1050 MW, and by January 1, 2023, it had reached 2388 MW, marking an increase of approximately 2.3 times over three years. By the end of 2023, Kazakhstan's total installed capacity of renewable energy sources amounted to 2.9 thousand MW, which is 20.1% higher compared to the end of 2022. Compared to 2018, the capacity of renewable energy facilities increased significantly by 5.4 times (Energyprom.kz, 2024).

The volume of energy produced by renewable energy sources (RES) has also been increasing annually. In 2020, 2400 million kWh of electricity was produced, and by 2023, this had grown to 5110 million kWh. In the period from January to December 2023, the electricity generation from renewable energy sources amounted to 6675 million kWh, showing a 30.6% increase compared to the same period in 2022. The share of electricity produced by renewable energy facilities in the total volume of electricity production increased from 4.5% to 5.9% (Energyprom.kz, 2024).

The number of people employed in the renewable energy sector is also growing. In 2020, it amounted to 955 people, and in 2023 this figure reached 1660 people. Between 2020 and 2023, Kazakhstan's renewable energy sector has developed rapidly and undergone significant changes. The increase in the number of RES facilities, the substantial growth in their installed capacity, and the rising share of electricity generation from renewable sources highlight the sector's potential. For instance, the theoretical capacity of solar energy in Kazakhstan is about 2,500-3,000 hours of sunlight per year (USAID, 2020), which is one of the highest in the world. The capacity of wind energy is also huge – about 1,820 billion kWh per year (USAID, 2020). Therefore, it is important to study the impact of the integration of renewable energy sources on sustainable economic development. At the same time, there is a need to study in more depth the various aspects that contribute to these trends in order to ensure the efficiency and sustainability of the level of RES consumption.

By increasing the consumption of renewable energy, Kazakhstan not only seeks to diversify its economy but also to reduce dependence on energy imports and stabilize the domestic market. Therefore, studying the factors influencing the level of renewable energy consumption in Kazakhstan has become one of the key issues today.

In general, a broad examination of the indicators affecting renewable energy consumption has become a major topic of interest for researchers and experts at both global and national levels. Numerous studies have explored the relationship between energy consumption and its influencing factors (Şener et al., 2018; Bourcet, 2020). However, it is challenging to claim that all factors influencing renewable energy consumption have been fully studied. Specific models and data for Kazakhstan are particularly scarce. Additionally, it is essential to consider that each aspect (factor) of renewable energy use can have either a positive or negative impact. The interaction of these factors could significantly influence the formation of policies for renewable energy use.

This study will provide a scientific basis for developing the renewable energy sector and achieving environmental sustainability in Kazakhstan, as well as help identify the link between increasing renewable energy production and improving environmental indicators.

The structure of this work is as follows: The second section reviews the literature; the third section explains data sources, model specifications, and methodology; the fourth section presents empirical results along with brief discussions. The final section provides conclusions and recommendations.

2. LITERATURE REVIEW

There are many studies in the literature to determine the factors affecting the demand for renewable energy consumption. Several academic studies have examined the economic, technical, environmental, and political factors that determine renewable energy consumption (Aguirre & Ibikunle, 2014; Papież et al., 2018; Lin et al., 2016; Omri & Nguyen, 2014). Some empirical research has identified a direct link between energy consumption and carbon dioxide (CO_2) emissions (Mukhtarov et al., 2020). Furthermore, researchers indicate that the development of the industrial, agricultural, and service sectors is essential for a country's growth and significantly impacts national income. All three sectors are highly dependent on energy availability, indirectly increasing CO_2 emissions (Nugraha & Osman, 2019). Nevertheless, despite the significant amount of research dedicated to the development of renewable energy sources (RES) and their impact on the economy, both globally and in Kazakhstan, certain gaps need to be explored.

In this section, the studies devoted to the impact of various indicators on the level of renewable energy consumption and the impact of renewable energy integration on economic growth in the case of different countries are reviewed.

Panel data analysis across many countries shows that renewable energy consumption is linked to per capita GDP growth (Al-Darraji & Bakir, 2020; Singh et al., 2019). This effect is observed in both developed and developing countries, with slightly stronger impacts in developed nations (Singh et al., 2019). The relationship between renewable energy and economic growth is either bidirectional or unidirectional, depending on the country (Soava et al., 2018). Beyond economic benefits, adopting renewable energy catalyzes green economic transformations, job creation, and enhanced energy security (Chou et al., 2023). It also positively correlates with industrial productivity and technological innovations, particularly in regions with abundant renewable resources (Chou et al., 2023). These findings support policy decisions to increase renewable energy consumption and highlight its potential as a driver of sustainable economic development (Soava et al., 2018; Chou et al., 2023).

Globally, much attention is focused on the impact of RES on macroeconomic indicators, including gross domestic product (GDP), employment, and sustainable economic growth. Studies in the European Union (Fischer & Newell, 2008) confirm that active adoption of RES leads to long-term economic growth, reduced dependence on hydrocarbon imports, and the creation of new jobs in the «green» energy sector.

For developing countries, studies show mixed results. Some authors, such as Apergis & Danuletiu (2014), note that the transition to RES may be accompanied by temporary economic losses due to the need for significant investments and reduced revenues from traditional energy resources. At the same time, research in China shows that RES can become a powerful catalyst for stimulating long-term economic growth when supported by government policies and incentives for private investment (He & Huang, 2021).

Sadorsky (2009) analyzed the effects of real GDP per capita, CO_2 emissions, and oil prices on renewable energy consumption using various panel cointegration methods with annual data from 1980 to 2005 for the G7 countries. He found that real GDP per capita and CO_2 emissions positively and significantly influence renewable energy consumption, whereas oil prices have a negative impact. Salim & Rafiq (2012) examined how renewable energy consumption relates to real

GDP and oil prices across six emerging economies, applying methods like panel fully modified ordinary least squares (FMOLS), panel dynamic ordinary least squares (DOLS), and the autoregressive distributed lag (ARDL) approach. Their ARDL findings revealed that oil prices negatively and significantly affect renewable energy consumption in China and Indonesia, while having no significant effect in Brazil, India, the Philippines, and Turkey. Additionally, both panel DOLS and FMOLS analyses indicated that the impact of oil prices was statistically insignificant.

Hassoun and Hicham (2020) investigated the relationship between the renewable energy and the sustainable development. The authors employed the endogenous variable the adjusted net savings as the sustainable development factor, the renewable energy consumption as the exogenous variable. Their research is based on a balanced panel model, panel random effect model and a panel ARDL cointegration model. The outcomes showed that the renewable energy consumption has a negative and significant impact on the adjusted net saving in the short-run, but in the long-term the renewable energy consumption has a positive influence on the sustainable development factor.

Behboudi et al. (2017) employed a Bayesian vector autoregressive to study the link among the adjusted net saving, carbon dioxide emissions (CO2), renewable and non-renewable energy for the case of Iran during the period of 1980-2013. They concluded with impulse response that there is a positive influence of renewable and nonrenewable consumption on (ANS), while the adjusted net saving has a positive impact on renewable energy consumption, but a negative effect on non-renewable energy consumption.

You (2011) analyzed the relationship between energy and (ANS) in China during the period of 1980-2004. The authors concluded that the consumption from renewables and non-renewables contribute positively to increase the rate of the adjusted net saving.

A study covering 193 countries from 2011 to 2020 found that renewable electricity generation is positively associated with adjusted net savings and renewable energy consumption, while negatively affecting CO2 emissions. This suggests that increasing renewable energy generation can contribute to the development of an environmentally sustainable economy and improve environmental quality (Laureti et al., 2022). Additionally, the study also used a variety of econometric techniques, including panel data regression and machine learning algorithms, to predict future trends in renewable electricity generation.

Behboudi & Moosavi (2014) analyzed the relationship between sustainable development (measured by adjusted net savings), the human development index, natural resource exports, and the quality of governmental institutions (such as rule of law, political stability, etc.) across 11 MENA countries from 1996 to 2010. Using panel cointegration methods, they found that natural resources have a significant and negative impact on sustainable development.

Mirziyoyeva & Salahodjaev (2022) examined the link between renewable energy and CO2 emissions intensity in the countries with the highest carbon emissions from 2000 to 2015. For these purposes the authors employed panel data methods such as fixed effects regression and the two-step GMM estimator. According to their study, the findings indicate that renewable energy significantly reduces CO2 emissions. Specifically, a 1% increase in renewable energy consumption is associated with a 0.98% reduction in CO2 emissions.

The relationship between renewable energy (RE) consumption and CO2 emissions in a sample of major renewable energy-consuming countries over the period 2000–2015 was studied by Huang et al. (2021). The primary contribution of their study was to address whether a substantial shift toward renewable energy consumption would result in lower CO2 emissions. Using the two-step generalized method of moments (GMM) estimator; authors' empirical findings indicated that RE has a significant negative impact on CO2 emissions: a one percentage point increase in

RE consumption leads to a 0.5% decrease in CO_2 emissions.

In Kazakhstan, research in this area is more limited. Existing works, such as the study by Sansyzbayeva et al. (2020), justify the need for accelerated and active use of renewable energy sources in Kazakhstan based on the analysis of both domestic and international experience. The study identifies the positive and negative aspects of renewable energy development and the factors hindering its progress.

Other studies indicate a positive correlation between renewable energy consumption and economic growth in a country (Sarkhanov & Huseynli, 2022; Abdibekov et al., 2023). While renewable energy shocks have a limited impact on economic growth, their effect on growth variance decomposition is higher for Kazakhstan compared to Turkey (Abdibekov et al., 2023). It is expected that the support of renewable energy by the government of Kazakhstan through national targets, policies, and auction systems will contribute to sustainable economic growth and the development of a green economy (Bespalyy, 2021).

Issayeva et al. (2023) examined the industrial production index, economic growth, and the percentage of energy produced from renewable energy sources in Kazakhstan's energy consumption and CO_2 emissions. The study data were analyzed using the Johansen cointegration test, vector autoregressive (VAR) analysis, Granger causality analysis, and the VECM model. In the study, they examined three key factors that affect CO_2 emissions in Kazakhstan. The results of their study showed that these factors account for 16.1% of the variability in CO_2 emissions, indicating the statistical accuracy of the selected variables.

Raihan & Tuspekova (2022) in their research examine the potential of economic growth, renewable energy use, and technological innovations to achieve environmental sustainability by reducing CO_2 emissions in Kazakhstan. Time series data from 1996 to 2018 were analyzed using the Dynamic Ordinary Least Squares (DOLS) method. The DOLS estimation results indicate that the coefficient for economic growth is positive and significant with respect to CO_2 emissions, suggesting that a 1% increase in economic growth is associated with a 0.34% rise in CO_2 emissions.

These studies collectively emphasize the crucial role of renewable energy in promoting sustainable development across various economic contexts. However, the main drawback of existing studies is that much focus either on the environmental aspects of renewable energy development or energy security issues. Their impact on long-term economic indicators, such as investment, trade balance, and adjusted net savings, has not been sufficiently studied. Kazakhstan, as a resource-dependent economy, requires a specific approach that takes into account not only the transition to renewable energy but also the potential risks associated with reduced hydrocarbon revenues and the costs of implementing new technologies.

One of the important scenarios of factor interaction includes examining the impact of adjusted net savings (as a percentage of GDP), carbon dioxide emissions (per capita, in tons), and the volume of renewable electricity production (as a percentage of total energy produced) on renewable energy consumption (as a share of total energy consumption). However, the interrelationships between renewable energy, CO_2 emissions, adjusted net savings, and renewable energy production have not been comprehensively studied. While previous research has analyzed the general benefits and economic viability of renewable energy use, the direct impact of these factors on consumption levels has not been investigated in Kazakhstan's context. This situation enhances the theoretical and practical significance of the study. Specifically, evaluating and analyzing the interrelationships of the proposed indicators and their capacity to influence the growth in renewable energy consumption could help reduce the environmental burden in the country. Additionally, developing domestic electricity production based on renewable energy sources would allow Kazakhstan to reduce dependency on energy imports and stabilize the domestic energy market, which could, in turn, play a key role in the nation's transition to a «green economy». Therefore, the study aims to identify opportunities for achieving sustainable development in Kazakhstan by analyzing the relationships between renewable energy consumption, CO_2 emissions, and adjusted net savings.

3. METHODOLOGY

The study employed a quantitative research method to examine the impact of sustainable development indicators on the share of renewable energy consumption. This method involves collecting quantitative data and using statistical techniques to test hypotheses about the relationships between variables.

The research design focuses on correlational analysis, as it aims to determine the strength and direction of relationships between dependent and independent variables. Thus, this study investigates the impact of factors such as the volume of renewable electricity production (as a percentage of total electricity), adjusted net savings (ANS), and CO2 emissions (in metric tons per capita) on renewable energy consumption in Kazakhstan. Table 1 provides explanations of the variables used in the study and their data sources.

TABLE 1 - Explanation of variables and their data source

Variable	Explanation	Data source
RES	Renewable energy consumption, share of total final energy consumption, in %	World Bank Data
REO	Output of renewable electricity production, share of total energy production, in %	World Bank Data
ANS	Adjusted net savings, share of gross national income, in %	World Bank Data
CO_2	CO_2 emissions, tons per capita	World Bank Data

Note: compiled by authors

In this study, renewable energy consumption is considered as the share of renewable energy in the country's total final energy consumption, and this indicator is used as the dependent variable. The independent variables include the volume of renewable electricity output (REO), expressed as a percentage of total electricity production, and CO2 emissions measured in tons per capita. The independent variable ANS (Adjusted Net Savings) represents adjusted net national savings, expressed as a percentage of gross national income (% GNI).

It considers profits and costs (depreciation of fixed capital, depletion of natural resources and forests, and pollution-related damages). The study used secondary data from Kazakhstan, spanning from 2001 to 2020. Thus, look at the formula (1):

$$ES = \beta_0 + \beta_1 \cdot REO + \beta_2 \cdot ANS + \beta_3 \cdot CO_2 + \varepsilon \quad (1)$$

where:

RES – consumption of renewable energy sources, % of total energy consumption;
REO – volume of renewable electricity production, % of total electricity production;
ANS – adjusted net savings, % of gross national income;
CO_2 – CO_2 emissions, metric tons per capita;
β_i – the coefficients of the equation.

The coefficients of the obtained equations were analyzed to increase their significance level. In this case, the student's t-test was used to test the statistical predictions. The assessment was based on comparing the statistical and critical values of the F-test (Fisher's test). Time series analysis was performed using the STATA 17 software.

Within the scope of the study, the residuals of the model variables, specifically the differences between empirical and theoretical variables, were also examined. This included testing for the normal distribution of the model residuals and considering the null hypothesis (H0) that there is no first-order autocorrelation in the vector of regression model residuals. For this purpose, the Durbin-Watson tests were used, as this test indicates whether autocorrelation in the residuals suggests the model is correctly specified or if time series patterns are accounted for in the model (Rybak et al., 2024).

Furthermore, look at the formula (2):

$$DW = \frac{\sum_{i=2}^{n}(\varepsilon_i - \varepsilon_{i-1})^2}{\sum_{i=2}^{n}\varepsilon_i^2} \qquad (2)$$

Where: ε_i – residuals of the regression model, n is the number of observations.

According to the hypothesis acceptance theory based on the Durbin-Watson criterion, the critical values form five regions for different statistical decisions (Kobzar, 2006).

In addition, in this study, Spearman's rank correlation test was used as a nonparametric test to assess the presence of heteroscedasticity in the random errors of the regression (econometric) model. Spearman's test allows for the evaluation of the strength and direction of the association between the ranked values of variables, making it a valuable tool for checking the robustness of model results against heteroscedasticity and other violations in the error distribution.

The procedure involves estimating the initial linear regression model and determining the regression residuals (εt). The residuals and the variable xt, on which the variance of the random errors is presumed to depend, are then ranked, and the Spearman's rank correlation coefficient is calculated (3):

$$\rho = 1 - \frac{6 \cdot \sum d_t^2}{n(n^2-1)} \qquad (3)$$

where: d_t^2 is the squared difference of the ranks of the variables ε_t and x_t. Under the null hypothesis, which assumes no heteroscedasticity, the test statistic $\rho \cdot \sqrt{n-1}$ asymptotically follows a standard normal distribution.

In this case, if the coefficient significantly deviates from zero, it may indicate the presence of heteroscedasticity (Corder & Foreman, 1972).

4. FINDINGS AND DISCUSSIONS

Empirical results of the analysis are presented, focusing on the relationships between renewable energy consumption, adjusted net savings, renewable electricity output, and carbon dioxide emissions. Descriptive statistics of the key variables are followed by the outcomes of the regression analysis, highlighting the implications of the findings for Kazakhstan’s renewable energy development.

Table 2 presents the descriptive statistics of the variables used in the model.

TABLE 2. Descriptive statistics

Variables	Obs	Mean	Std.dev.	Min	Max
RES	20	1.79	0.45	1.1	2.8
REO	20	11.05	2.13	8.1	15.24
ANS	20	17.52	2.90	9.98	23.47
CO_2	20	12.05	2.06	7.90	15.34

Note: Compiled by the authors using STATA 17

The table shows the number of observations for each variable based on 20 years of data (2001-2020). The average values were 1.79% for RES, 11.05% for REO, 17.52% for ANS, and 12.05 metric tons for CO2. These figures indicate that the share of renewable energy consumption is relatively low, while the share of renewable energy generation in total electricity is significantly high. The ANS value indicates the country's savings rate stability, while the CO2 value indicates the dependence on conventional energy sources.

The standard deviation indicators reflect the degree of deviation of variables from the mean value. For instance, the standard deviation for RES is 0.45, indicating a significant stability of the indicator. In contrast, the relatively higher deviations of the REO and CO2 variables suggest more significant variability, which certain external or internal factors may influence. The minimum and maximum values indicate the dynamics of the variables over time. For example, RES changed from 1.1% to 2.8%, which may indicate an increasing trend in renewable energy consumption. The minimum value of the REO variable is 8.1%, and the maximum value is 15.24%, indicating a steady increase in production. The ANS indicator fluctuates from 9.98% to 23.47%, indicating the significant role of economic savings in the country. CO2 emissions range from 7.9 to 15.34 metric tons, characterizing considerable variability in the environmental situation.

Overall, the table provides a crucial statistical basis for assessing the relationship between renewable energy consumption and production, environmental conditions, and economic sustainability in Kazakhstan.

Table 3 presents the regression analysis results for three different specifications of the model used to study the factors influencing renewable energy consumption in Kazakhstan.

TABLE 3. Results of time series analysis (dependent variable – RES)

Variable	Specification		
	I	II	III
REO	0.119*** (0.037)	0.175*** (0.012)	0.09** (0.037)
ANS	0.055** (0.026)	0,073*** (0.024)	
CO_2	-0.154*** (0.04)	-0.118*** (0.034)	-0.116*** (0.039)
Constant	1.378 (0.857)		2.184** (0.842)
Number of observations	20	20	20
R^2	0.842	0.99	0.81
Significance test	F (3,16) = 34.73 [0.0000]	F (3,17) = 636.42 [0.0000]	F (2,17) = 41.38 [0.0000]

Note:

1) Compiled by the authors using STATA 17;

2) **, *** – statistical significance of coefficients at the 5% and 1% levels, respectively.

The specifications of the models in Table 3 differ in terms of included variables, explanatory power and interpretation of the influence of factors on the consumption of renewable energy. Specification I includes three independent variables: renewable energy production (REO), adjusted net savings (ANS), and CO2 emissions. The coefficients of all variables are statistically significant at the 1% and 5% levels, which is confirmed by low p-values. The value of the ANS coefficient is 0.055, which indicates a positive influence of savings on the consumption of renewable energy. This means that a 1% increase in adjusted net savings raises the share of renewable energy in total consumption by 0.055%. Growth in savings is generally associated with increased investments in sustainable energy, contributing to its development.

The REO coefficient is 0.119, which also indicates a positive effect: an increase in the share of renewable energy production by 1% increases its consumption by 0.119%. This effect is explained by the fact that the increase in production reduces the cost of renewable energy and makes it more affordable for use. However, CO2 emissions have a negative impact, with a coefficient of -0.154. This means that an increase in emissions of 1 ton per capita reduces the consumption of renewable energy by 0.154%. This effect can be explained by the dominance of traditional energy sources. The increase in emissions in Kazakhstan is largely associated with the extensive use of conventional fuels such as coal and oil. This situation reduces the incentive to transition to renewable energy sources and supports the continued use of traditional energy sources. In addition, high emissions indicate a lack of effective environmental policies and the presence of barriers to the adoption of renewable energy.

Specification II demonstrates a higher explanatory power, with an R^2 value of 0.99, which indicates that the model explains 99% of the changes in the consumption of renewable energy. The coefficients of the variables in this specification are similar to those in Specification I; however, due to the removal of the constant from the model, their value is slightly higher. For instance, the coefficient for REO is 0.175, for ANS is 0.073, and for CO2 is 0.118. The high statistical significance of all variables (p-value less than 0.01) indicates that each of them has a significant influence on the dependent variable and is statistically significant at the 1% level. At the same time, the negative impact of CO2 highlights the need for stricter environmental regulations to encourage a shift toward cleaner energy sources.

Specification III excludes the variable ANS, retaining only REO and CO2. This reduces the value of R^2 to 0.81, which indicates that the model explains the variation of the dependent variable worse. Although the coefficient REO (0.09) and CO2 (-0.116) remain statistically significant, the absence of ANS makes the model less comprehensive, as it overlooks the impact of savings as a key factor.

The significance of the F-statistic, confirmed by the low level of Significance F across all three specifications, demonstrates that the proposed model adequately reflects the relationship between consumption and production of renewable energy, savings, and CO2 emissions.

A comparison of specifications shows that specification II is the best. The high value of R^2 (0.99) and the statistical significance of all variables confirm its reliability. Coefficients of variables demonstrate both positive (REO and ANS) and negative (CO2) impacts on consumption of renewable energy. The reasons for the positive effect include the improvement of the availability of renewable energy through the increase in its production and the growth of investments due to savings. The negative impact of CO2 emissions is associated with the competition of traditional energy sources and environmental pressures. These results highlight the need to stimulate renewable energy production and reduce emissions to increase its consumption. Thus, Specification II is the most suitable for analyzing the factors influencing renewable energy development in Kazakhstan.

Respectively, the general equation of the model is as follows:

$$RES = \underset{(0{,}012)}{0{,}175REO} + \underset{(0{,}024)}{0{,}073ANS} - \underset{(0{,}034)}{0{,}118CO_2} \quad (4)$$

This graph illustrates the relationship between the share of renewable energy production (variable REO) on the X axis and the consumption of renewable energy on the Y axis. The blue points reflect the observed values (Observed), that is, actual data, and the red line (Regression Line) represents a linear regression relationship between these two variables (see Figure 1).

The regression line has a positive slope, which indicates a direct relationship between renewable energy production and consumption. This means that when the share of renewable energy production increases, its consumption also rises. Most of the observed points are close to the regression line, which indicates a high degree of correspondence between the model and the actual data. However, some points significantly deviate from the line, which may be due to the presence of emissions or the influence of factors not taken into account in the model.

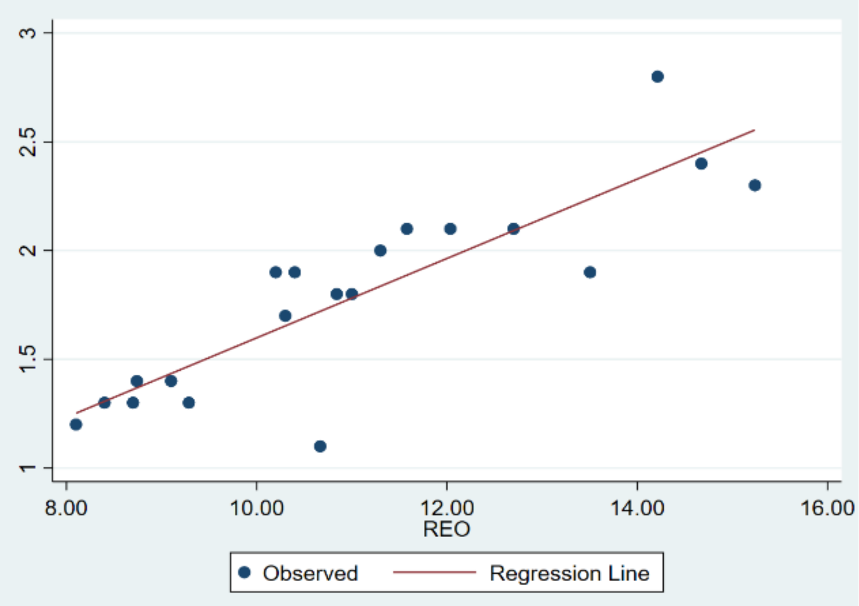

FIGURE 1. Graph of dependence between variables

Note: Compiled by the authors using STATA 17

The graph illustrates that the increase in the share of renewable energy (REO) production is positively correlated to its consumption, which confirms the results of the regression analysis.

Calculations based on the variables of the examined model show that the Durbin-Watson test value equals 2.19. Using Tables (Kobzar, 2006; Ayvazyan, 2001), the critical values of the Durbin-Watson statistic, specifically the lower bound (dl) and the upper bound (du), were determined based on the number of parameters in the regression model (k) and the number of observations (n).

In this case, the Durbin-Watson test value is 1.676<2.19<2.324. Accordingly, since the DW value lies in the range du ≤ DW ≤ 4 – du, it can be concluded that the residuals are not autocorrelated. This means that the model residuals do not depend systematically on the previous values, and the regression model adequately describes the data regarding the independence of errors.

When evaluating the presence of heteroscedasticity in the random errors of the regression model using Spearman's rank correlation test, the Spearman rank correlation coefficient (ρ) was found to be 0.19. Therefore, under the null hypothesis, the test statistic $\rho\sqrt{n-1}$ is observed to be asymptotically normally distributed. In this case, considering that the coefficient does not deviate significantly from zero, and based on the obtained results indicating the test statistic value is insignificant, it can be concluded that there is no heteroscedasticity in the examined model, and the residual variance is constant. The absence of heteroscedasticity confirms the model's validity and the reliability of the statistical results.

The residuals graph in Figure 2 confirms the results of the tests for autocorrelation and heteroskedasticity. This graph is used for visual analysis of the regression model's residuals. The residuals are the difference between the actual and predicted values of the dependent variable on the Y axis, and the linear predicted values are shown on the X axis.

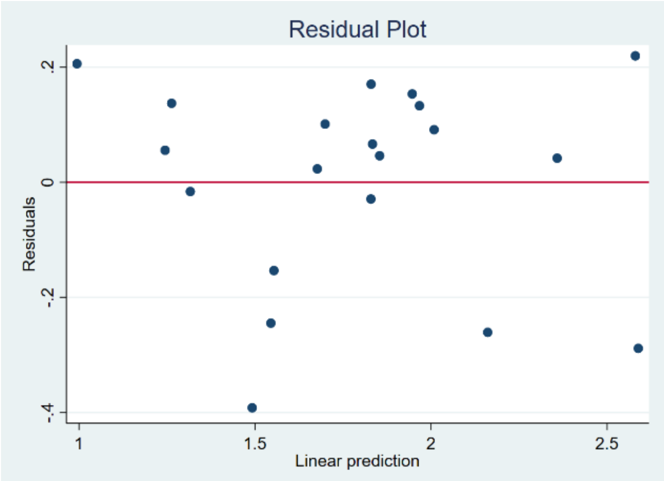

FIGURE 2. Graph of residuals

Note: Compiled by the authors using STATA 17

The main purpose of such a graph is to verify the validity of the assumptions of linear regression, such as the uniformity of the variance of the residuals (homoskedasticity) and the absence of systematic deviations (autocorrelation).

In this graph, the residuals are distributed around the line y = 0, which indicates that the model as a whole is correctly specified. This means that the forecast of the model is not systematically overstated or understated, and the residuals have a random character. If a clear dependency were observed in the plot, such as a curve or cone-shaped pattern, it would indicate an incorrect model specification or the presence of heteroscedasticity. If there is an increase or decrease in the residuals with the growth of the predicted values, it could indicate that the model is incorrectly constructed or that the data may have been improperly processed.

Figure 3 shows that in this model the residuals are generally randomly distributed around the line y = 0, indicating that the specification is correct and there are no obvious issues.

Thus, the regression results confirm that the model adequately describes the relationship between renewable energy consumption and the included factors. The key independent variables, such as the share of renewable energy production, adjusted net savings and carbon dioxide emissions, have a significant impact on renewable energy consumption.

The positive impact of renewable energy production on its consumption indicates that increased production volumes help reduce costs, enhance accessibility, and promote wider adoption of renewable sources. This underscores the need for further investment in infrastructure and technologies that enable the growth of clean energy production.

The role of savings in increasing renewable energy consumption is explained by their importance as a financial basis for investments in sustainable energy. A high level of savings reflects economic stability and create opportunities for long-term financing of green energy projects. This points to the need to develop mechanisms that support economic sustainability and encourage savings.

The negative impact of carbon dioxide emissions is due to the dominance of traditional energy sources. High emissions indicate a heavy dependence on coal, oil and gas, which slows the transition to renewable sources. This highlights the need for stricter environmental policies, the implementation of emission-reducing technologies and the creation of incentives for the use of renewable energy.

The model as a whole demonstrates high explanatory power and significance of the included variables. It confirms that the development of renewable energy requires an integrated approach, including stimulating production, maintaining economic stability through savings, and reducing the environmental impact of traditional energy sources. These results emphasize the importance of coordinated public policy and private investment to ensure a sustainable energy transition.

5. CONCLUSIONS

The study confirmed that the development of renewable energy is a key element of sustainable economic growth and environmental stability in Kazakhstan. Increasing the volume of electricity production from renewable energy sources (REO) contributes to the growth of their consumption due to lower costs and increased availability. The high level of adjusted net savings (ANS) supports long-term investments in green energy, ensuring the necessary financial stability. However, the high carbon intensity of the Kazakhstan's economy and dependence on traditional energy sources (oil, gas and coal) significantly hinder the development of renewable energy sources. The negative impact of CO_2 emissions on the use of renewable energy confirms the country's relatively low inclination toward adopting alternative energy, as the increase in CO_2 emissions does not significantly push the country towards adopting environmentally friendly policies.

Based on the results obtained in this study, it can be concluded that policymakers in Kazakhstan should increase the share of renewable energy in the overall energy mix to diversify the economy and achieve sustainable economic development targets. It is also important to note that given the limited supply of oil and the need to reduce the environmental impact of fossil fuels, it is crucial to prioritize the production and use of renewable energy. This requires a stricter environmental policy, the introduction of emission reduction technologies and the creation of incentive mechanisms for the transition to renewable energy sources. To achieve a sustainable energy transition, Kazakhstan should focus on increasing investments in renewable energy infrastructure and technologies, which will reduce costs and improve accessibility. Additionally, strengthening environmental policies with stringent CO_2 reduction regulations, alongside economic incentives such as tax breaks and subsidies for renewable energy, will accelerate the transition to clean energy. Finally, maintaining economic stability through the development of mechanisms for saving and effectively utilizing savings is essential to provide a financial foundation for sustainable investments in the renewable energy sector.

Kazakhstan has significant potential in both renewable energy and fossil fuel sectors. A substantial portion of national income comes from fossil fuel-related exports. However, the depletion of fossil fuels and the decreasing global demand for them indicate that Kazakhstan may lose this advantage in the future. In this regard, Kazakhstan needs to implement projects to harness renewable energy at the earliest opportunity. For this reasons comprehensive and effective research in the area of renewable energy has become a pressing issue. With its great potential in renewable energy, Kazakhstan can become one of the leaders in renewable energy production, just as it is in fossil fuel production, setting an example for oil-exporting countries.

The research results deepen scientific knowledge in the field of renewable energy economics and contribute to the development of interdisciplinary research in the fields of economics, ecology, and technology. The model and forecasts developed within the framework of the research can be used to optimize state energy policy.

In the future, the study can be further expanded through regional analysis, which will reveal differences in the potential for renewable energy development across various regions of Kazakhstan. Attention should also be given to studying the impact of external factors, such as Kazakhstan's participation in international environmental initiatives and the dynamics of global energy markets.

Furthermore, a promising direction for research is to explore the impact of renewable energy integration on social indicators, such as employment, living standards, and air quality, which will help develop comprehensive strategies for sustainable development..

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