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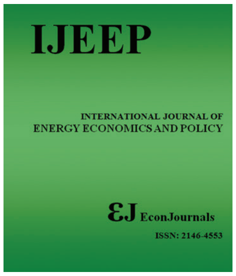

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The Relationship between Renewable Energy Consumption, CO_2 Emissions, Economic Growth, and Industrial Production Index: The Case of Kazakhstan

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ABSTRACT

CO_2 emission is an important parameter that indicates a country's development level and respect for nature. It's a well-known fact that a country's industrialization level and economic growth have a direct impact on CO_2 emissions. We must prioritize the use of energy obtained from renewable sources and be mindful of our impact on the environment. This study analyses the industrial production index, economic growth, and the percentage of energy produced from renewable energy sources in energy consumption and CO_2 emissions in Kazakhstan. The data are collected from the National Statistical Bureau of the Agency for Strategic Planning and Reforms of the Republic of Kazakhstan, Our World in Data, and the World Bank web pages. Research data were analyzed using the Johansen cointegration test, Vector Autoregressive (VAR) analysis, Granger causality analysis, and VECM model. In the study, we analyzed three key factors that impact CO_2 emissions in Kazakhstan. Our findings revealed that these factors account for 16.1% of the variability in CO_2 emissions, indicating the statistical accuracy of these variables. When deciding on renewable energy investments, it is very important to determine the causal relationship between renewable energy consumption and CO_2 emissions. It seems that industrial development and economic growth can occur without any major concerns about CO_2 emissions. This is based on the lack of statistical significance in the relationship between CO_2 emissions and both the industrial production index and economic growth.

Keywords: Kazakhstan, Renewable Energy, CO_2 Emission, Economic Growth, Industrial Production Index
JEL Classifications: C13, C20, C22

1. INTRODUCTION

In today's world, the increasing frequency and severity of natural disasters caused by global climate change have pushed humanity to reconsider our use of natural resources, production methods, and consumption habits. As a result, countries are actively searching for solutions to mitigate and slow down the effects of climate change. As we strive to promote economic growth, it's also crucial to consider its impact on the environment. Thankfully, renewable energy sources can reduce the CO_2 emissions that contribute to climate change. Therefore both developed and developing countries have shifted their focus toward sustainable economic development in recent years. Climate crisis, energy production, industrial production, agricultural production, and economic growth are all critical issues that should be addressed to achieve sustainable economic development (Nugraha and Osman, 2019).

Recent studies have shown that energy is one of the most fundamental factors in the development of a country, especially due to its role in the industry, agriculture, services, and transportation sectors (Javid and Sharif, 2016; Yazdi and Shakouri, 2014; Hinrichs and Kleinbach, 2013). An increase in energy production is expected to increase the economic activities in a country and bring along development and economic growth (Reddy and Assenza, 2009). CO_2 is released during both the production and consumption of energy and is a major contributor to global warming and climate change. Thus countries must reevaluate their strategic plans for energy and economy to decrease CO_2 emissions on a global level. The development of industry, agriculture, and service sectors is crucial for a country's growth and contributes significantly to the national income. The activities of all three sectors largely depend on the availability of energy input, and all indirectly increase the amount of CO_2 emissions (Nugraha and Osman, 2019).

Since gaining its independence in 1991, Kazakhstan had navigated four large-scale global economic crises. But the country had recovered from the initial crisis in the early 1990s following the dissolution of the USSR in 7-8 years. But, despite some improvements, the desired growth and development rates were not achieved during this period. The Asian crisis in 1998, the global crisis in 2007-2008, and most recently, the Covid-19 pandemic have all significantly impacted world economies. Kazakhstan's economy was negatively affected as well. These crisis periods, as in other countries, caused the economic growth of Kazakhstan to slow down (Özdil and Turdalieva, 2015). Kazakhstan did overcome these crises by boosting its exports and achieving consistent and robust economic growth.

After gaining independence, Kazakhstan had to undergo significant economic restructuring to keep up with the global markets and pave the way for the country's progress and prosperity. This process is called the transition period or transitional economy in the literature and has been challenging but ultimately successful thanks to various structural reforms. The abundance of natural resources in Kazakhstan has certainly played a vital role in overcoming the challenges faced by other nations with similar economic structures (Xiong et al., 2015; Myrzabekkyzy et al., 2022; Bolganbayev et al., 2022; Taibek et al., 2023; Bekzhanova et al., 2023; Kelesbayev et al., 2022a). Kazakhstan boasts an abundance of natural resources, including 3.2% of the global oil reserves, 1.5% of natural gas reserves, and 3.3% of coal reserves. However, Kazakhstan is also a hub for renewable energy sources. Thanks to its location, the country has a wealth of solar, geothermal, biofuel, hydroelectric, and wind energy resources (Zhussipova et al., 2023; Mashirova et al., 2023; Xiong et al., 2015; Ongarova, 2018; Bolganbayev et al., 2021; Niyetalina et al., 2023; Kelesbayev et al., 2022b; Abbasi et al., 2022; Li et al., 2022).

Although Kazakhstan has a significant renewable energy potential, the proportion of renewable energy in its overall energy supply has been quite low, ranging between 1% and 2%. In 2020, Kazakhstan achieved its goal of generating 3% of its electricity from renewable energy sources. Moving forward, Kazakhstan set its sights even higher and aimed to produce 15% of its electricity from renewable energy sources by 2030, excluding hydropower (IEA, 2022).

To better understand the state of the industrial sector, we can use valuable indicators such as the industrial production index, economic confidence index, and manufacturing capacity utilization rate. By tracking these indicators over time, we can comparatively monitor the ups and downs in production. The industrial production index is an indicator that tracks the state of the industrial sector and changes in production activity annually for comparison (Koç et al., 2016).

This study examined the correlation between renewable energy consumption, CO_2 emissions, economic growth, and industrial production index in Kazakhstan using data from 1990 to 2021. The data was analyzed using various methods including the Johansen cointegration test, Vector Autoregressive (VAR) analysis, Granger causality analysis, and VECM model. The information analyzed was sourced from https://old.stat.gov.kz/official, https://data.worldbank.org/, and https://ourworldindata.org.

2. LITERATURE REVIEW

The literature contains numerous studies on Kazakhstan, a developing economy that has experienced high growth rates since achieving independence. This article will provide an overview of the major ones relating to the subject matter.

A study conducted by Niyetalina et al. in 2023 investigated the connection between inflation and energy production in Kazakhstan. The study examined data from 2000 to 2021 and analyzed fossil fuels, low-carbon sources, and renewable sources using the VAR method within the framework of the Taylor rule. Based on research and following Taylor's Basic rule, it has been determined that inflation is affected by interest rates. Additionally, there is a notable correlation between energy production and inflation. The inflation caused by energy production from fossil fuels has been shown to increase, while inflation resulting from the use of renewable and low-carbon energy sources has a reducing effect. The study has revealed no causal relationship between inflation and energy production in Kazakhstan.

Nugraha and Osman (2019) conducted a study analyzing the cause-and-effect relationship between CO_2 emissions, energy consumption, economic growth, and household expenditures in Indonesia. They used the Granger causality test and annual data from 1975 to 2014. The research revealed that CO_2 emissions and energy consumption have a reciprocal impact on one another, but a rise in CO_2 emissions has a more substantial impact on energy consumption. They discovered that CO_2 emissions greatly affect energy consumption, the added value in the industrial sector, the final consumption expenses of households, and the added value both in the agricultural and service sectors.

In her analysis, Syzdykova (2020) assessed Kazakhstan's potential for renewable energy, following a detailed overview of the country's existing fossil fuel resources, including oil, natural gas, coal, and uranium. She also identified and examined the obstacles that currently impede the development of renewable energy systems in Kazakhstan. At the end of the study, recommendations were provided to eliminate any barriers that may hinder the renewable energy system.

In their study on the Sources of Economic Growth in the Kazakhstan Economy, Özdil and Turdalieva (2015) utilized the input-output analysis approach and analyzed data from input-output tables between 2006 and 2013. Through the use of the Syrquin decomposition model, the researchers were able to identify the key contributors to economic growth in Kazakhstan. The findings indicated that domestic demand was the primary source of growth, followed by export demand.

In 2016, Bhattacharya et al. conducted a study on the impact of renewable energy consumption on the economic growth of 38 countries using data from 1991 to 2012. Their findings showed that renewable energy consumption has a significant and beneficial impact on economic output in 57% of the countries that were analyzed. In the conclusion section, they emphasized the importance of collaboration between governments, energy planners, international cooperation agencies, and related organizations in increasing investments in renewable energy to achieve low carbon growth.

In their study, Syzdykova et al. (2021) examined data from Brazil, India, Indonesia, China, Chile, Mexico, South Africa, and Turkey to investigate whether renewable energy usage has a positive impact on economic growth. For the analysis of the data, the GMM estimator, a method of dynamic panel data, was utilized. They determined that a 1% increase in renewable energy use increases per capita GDP by 0.07688%, and a 1% increase in fossil-based energy use increases per capita GDP by 0.35021%. They explained the difference through the difference in shares of renewable energy systems and fossil-based energy systems in the global energy market, in which renewable energy systems have a much lower share.

Sarkhanov and Huseynli (2022) performed an econometric analysis on the relationship between renewable energy consumption and economic growth in Kazakhstan and Kyrgyzstan. After analyzing the data from 1996 to 2018, they found a direct correlation between economic growth and renewable energy consumption in both countries.

3. DATA AND ECONOMETRIC METHOD

The amount of CO_2 emissions can indicate a country's level of development and its approach toward the environment. Typically, a country's industrialization level and economic growth are also closely tied to it. It is crucial to prioritize energy consumption from renewable sources and be mindful of our impact on the environment. This study examines the correlation between the industrial production index, economic growth, the share of renewable energy sources in energy consumption, and its relation with CO_2 emissions in Kazakhstan. Table 1 presents the variables used in the research, along with their brief definitions. The data was collected from 1990 to 2021 and sourced from https://old.stat.gov.kz/official, https://data.worldbank.org/, and https://ourworldindata.org.

When analyzing financial time series, the first step is to assess whether the series is stationary. There are various methods to evaluate the stationarity of a time series besides graphical methods. This study investigated the stationarity of the series with the Augmented Dickey-Fuller (ADF) unit root test. The null hypothesis of unit root tests is that the series contains a unit root. When the null hypothesis is rejected at any difference level, the series is deemed stationary at the relevant difference level.

Table 1: Research variables and definitions

Variable	Definition
X01	Indices of industrial production (Total)
X02	GDP growth (annual %)
X03	Renewables (% electricity)
X04	CO_2 emissions (kt)

Table 2: Descriptive statistical findings for research series

Statistics	X01	X02	X03	X04
Mean	101.4000	2.515625	11.03436	193706.7
Median	102.6500	4.100000	10.75294	203534.0
Maximum	122.1000	13.50000	15.24087	260015.4
Minimum	72.00000	−12.6	8.255778	117443.4
Standard deviation	9.165574	6.868822	2.050916	43346.15
Skewness	−0.93859	−0.66252	0.324631	−0.35447
Kurtosis	5.210987	2.573607	2.069696	1.937418
Jarque-Bera	11.21640	2.583364	1.716009	2.175559
Probability	0.003668	0.274808	0.424007	0.336964
Observations	32	32	32	32

Table 3: ADF unit root test findings for research series

Series	Level		First diference	
	t-statistics	P-value	t-statistics	P-value
X01	−2.46906	0.1325	−3.2505	0.0298
X02	−2.06229	0.2604	−5.20522	0.0002
X03	−1.92898	0.3153	−4.52305	0.0012
X04	−1.41211	0.5636	−4.52944	0.0011
Test critical values				
1% level	−3.66166		−3.75295	
5% level	−2.96041		−2.99806	
10% level	−2.61916		−2.63875	

ADF: Augmented dickey-fuller

The vector autoregressive (VAR) model was introduced to the time series literature by Sims (1980) as a multivariate autoregressive model. The advantages of the VAR model in explaining and predicting the dynamic structure of economic and financial time series are well established (Yavuz, 2014). Although the model is structurally developed for econometric time series analysis, it is applied to all dynamic series with a mutual interaction structure. The mathematical form of the VAR model for two variables can be expressed with the following equations (Ertek, 2000):

$$Y_t = \alpha_1 + \sum_{j=1}^{m} \beta_j Y_{t-j} + \sum_{j=1}^{m} \delta_j X_{t-j} + \varepsilon_{1t} \tag{1}$$

$$X_t = \alpha_2 + \sum_{j=1}^{m} \theta_j Y_{t-j} + \sum_{j=1}^{m} \vartheta_j X_{t-j} + \varepsilon_{2t} \tag{2}$$

As seen in the model, the lagged values of X affect Y, and the lagged values of Y affect X.

Graph 1: Time path plot for research series

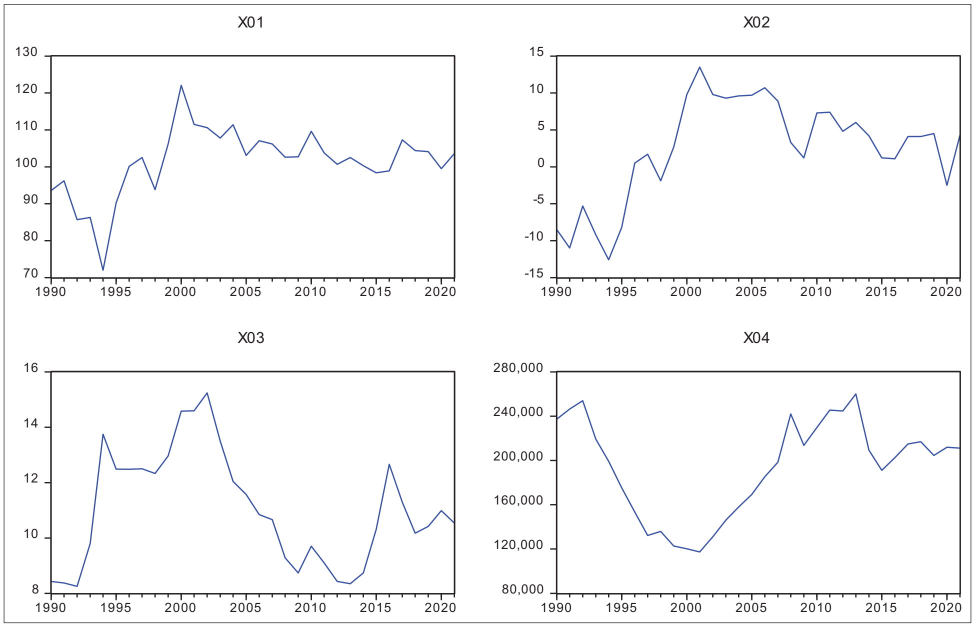


Table 4: VAR lag order selection criteria

Lag	LogL	LR: Sequential modified LR test statistic (each test at 5% level)	FPE: Final prediction error	AIC: Akaike information criterion	SC: Schwarz information criterion	HQ: Hannan-Quinn information criterion
0	−543.238	NA	2.89e+11	37.74052	37.92911*	37.79959*
1	−526.32	28.00092*	2.75e+11*	37.67726*	38.62023	37.97259
2	−512.355	19.26282	3.39e+11	37.81757	39.51490	38.34915

*Indicates lag order selected by the criterion. VAR: Vector autoregressive

VAR analysis decides the lag length with optimum lag length tests. This study utilized sequential modified LR test statistic (each test at the 5% level), Final Prediction Error (FPE), Akaike Information Criterion (AIC), Schwarz Information Criterion (SC), and Hannan-Quinn Information Criterion (HQ) methods (Widarjono, 2018). The test values were examined, the optimal lag length for each test method was compared, and a decision was made.

The compatibility and stability of the model are examined by checking whether the inverse roots of the AR characteristic polynomial are within the unit circle (<1 in absolute value) (Firdaus, 2020). Moreover, the existence of serial correlation and varying variance problems for the VAR model was examined and the econometric significance of the model was evaluated.

The existence of a long-term relationship between the variables is first investigated through the co-integration between the series. If there is a co-integration according to the results, it is further analyzed using the VECM method. Co-integration is a method applied to determine the existence of a long-term relationship in the analyzed series (Wayhudi and Palupi, 2023). This study used the Johansen co-integration test. The null hypothesis of this test is that there is no co-integration in the related series. In addition, for this test, the series must be stationary at the same level.

Table 5: Serial correlation and varying variance findings for the VAR (1) model

Residual serial correlation LM tests			
Lag	**LRE* stat**	**df**	**Prob.**
1	14.49562	16	0.5618
2	14.94141	16	0.5289
Residual heteroskedasticity Tests			
Chi-square		**df**	**Prob.**
152.9366		140	0.2147

VAR: Vector autoregressive

4. FINDINGS

This study aims to analyze the relationship structure between renewable energy consumption, CO$_2$ emissions, economic growth, and industrial production index in Kazakhstan from 1990 to 2021. The preparation phase of the analysis consists of two steps. In the first step, explanatory statistics and graphs are given for the variables. In the second step, the findings of the analysis of the stationarity of the series with the ADF test are given. The analysis phase was initiated using findings from these two steps. These findings were interpreted by applying VAR lag length, VAR model fit analysis, Granger causality analysis, co-integration analysis, and long-term effect analysis (VECM), respectively.

Table 2 presents the explanatory statistics of the research series. Economic growth, renewable energy consumption, and CO$_2$

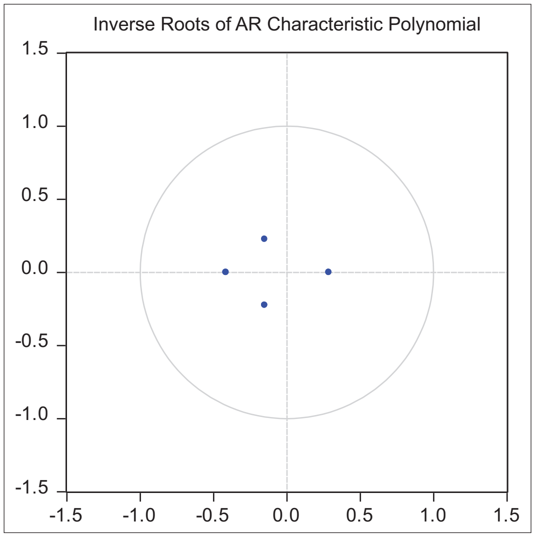
Table 6: Co-integration test findings for research series

Unrestricted cointegration rank test (Trace)				
Hypothesized No, of CE(s)	**Eigenvalue**	**Trace statistic**	**0.05 critical value**	**Prob.****
None*	0.744207	93.09580	47.85613	0.0000
At most 1*	0.629948	53.55761	29.79707	0.0000
At most 2*	0.458118	24.72839	15.49471	0.0015
At most 3*	0.213369	6.959877	3.841466	0.0083
Unrestricted cointegration rank test (Maximum Eigenvalue)				
Hypothesized No, of CE(s)	**Eigenvalue**	**Max-Eigen Statistic**	**0.05 critical value**	**Prob.****
None*	0.744207	39.53818	27.58434	0.0009
At most 1*	0.629948	28.82923	21.13162	0.0034
At most 2*	0.458118	17.76851	14.26460	0.0134
At most 3*	0.213369	6.959877	3.841466	0.0083

Table 7: Granger causality analysis findings

Dependent variable	Independent variable	Chi-square	df	Prob.
DX04	DX03	0.007002	1	0.9333
	DX02	0.510996	1	0.4747
	DX01	0.259289	1	0.6106
	All	0.548693	3	0.9081
DX03	DX04	13.25422	1	0.0003
	DX02	0.000109	1	0.9917
	DX01	0.148742	1	0.6997
	All	13.35451	3	0.0039
DX01	DX04	0.002109	1	0.9634
	DX03	0.795760	1	0.3724
	DX01	4.978664	1	0.0257
	All	5.674200	3	0.1286
DX01	DX04	0.160316	1	0.6889
	DX03	0.318223	1	0.5727
	DX02	0.049463	1	0.8240
	All	0.809122	3	0.8473

Graph 2: The plot of the inverse roots of the AR characteristic polynomial of the VAR(1) model



emission variables fit the normal distribution. Although the industrial production index does not comply with the normal distribution, it is considered to have a symmetrical distribution if its median and mean values are close to each other.

The time path graphs of the research series are presented in Graph 1. It is noteworthy that the industrial production index and economic growth were low in 1994, renewable energy consumption between 2009 and 2013, and CO_2 emissions between 1996 and 2004. However, the industrial production index, economic growth, and renewable energy consumption were high in the 2000s.

ADF unit root test findings of the research series are given in Table 3, and according to these findings, all series are stationary at the first difference level. Therefore, we used the first difference of the series in the analysis.

We performed a lag length criterion test to determine the model that best expresses the relationship structure between the variables, and the findings are presented in Table 4. The highest lag length value calculated was 1 (according to LR, FPE, and AIC criteria). The findings showed the VAR (1) model is the most suitable.

The test findings regarding serial correlation and varying variance in the VAR(1) model are given in Table 5. The test findings showed that the VAR(1) model was suitable according to the serial correlation criteria since it did not have a variable variance problem.

The inverse roots of the AR characteristic polynomial, which is another indication of the compatibility of the VAR(1) model, are calculated and presented in Graph 2. All roots are within the unit circle. Thus, the model is also suitable according to the AR characteristic polynomial inverse roots criterion.

Table 6 presents the co-integration test findings for the research series are given. According to trace and max-eigen statistics, there are at least three co-integration. This result proves that it is appropriate to analyze the relationship structure between the variables using the VECM model.

The causality relationship between the series was examined with the Granger causality test, and the findings are presented in Table 7. The findings reveal a causal relationship between industrial production index and economic growth, and between renewable energy consumption and CO_2 emissions. The causality effect of the other three variables on renewable energy consumption is also significant. When the findings in Tables 6 and 7 are evaluated together, it is best to test whether there is a long-term relationship between the variables using the VECM model.

Table 8: VECM forecasting findings

Cointegrating Eq:	CointEq1		
	Estimate	Std. errors	t-stat.
DX04-1	1.000000		
DX03-1	4797.109	5820.71	0.824
DX02-1	3848.010	3116.31	1.235
DX01-1	7944.227	1810.40	4.388

Error correction:	D (DX04)			D (DX03)			D (DX02)			D (DX01)		
	Estimate	Std. errors	t-stat.	Estimate	Std. errors	t-stat.	Estimate	Std. errors	t-stat.	Estimate	Std. errors	t-stat.
CointEq1	0.047	0.104	0.449	0.000	0.000	0.155	0.000	0.000	−3.070	0.000	0.000	−7.357
DDX04-1	−0.502	0.185	−2.713	0.000	0.000	−2.807	0.000	0.000	1.361	0.000	0.000	2.493
DDX03-1	3488.215	2872.680	1.214	−0.320	0.175	−1.827	−0.051	0.564	−0.091	−0.586	0.722	−0.811
DDX02-1	−771.178	1068.010	−0.722	−0.014	0.065	−0.210	−0.129	0.210	−0.615	1.126	0.268	4.195
DDX01-1	128.365	538.926	0.238	0.004	0.033	0.111	0.354	0.106	3.346	0.077	0.135	0.565
C	−479.482	4441.540	−0.108	−0.008	0.271	−0.029	0.110	0.872	0.126	0.717	1.116	0.643
R-squared	0.311			0.354			0.401			0.784		
Adj, R-squared	0.161			0.214			0.271			0.737		
F-statistic	2.076			2.526			3.085			16.659		
Log likelihood	−330.141			−48.679			−82.600			−89.764		
Akaike AIC	23.182			3.771			6.110			6.604		
Schwarz SC	23.465			4.054			6.393			6.887		

The results regarding the long-term relationship between the VECM method and research variables are given in Table 8. The first part of the table shows the forecast values of the long-term relationship, and the second part shows the short-term forecast values. The findings showed that the long-term effect of the industrial production index on CO_2 emissions is statistically significant and positive, and the long-term effects of other variables are statistically insignificant.

The second part of the table shows the effect of the one-term lagged value of CO_2 emission on itself and renewable energy consumption, the effect of the one-term lagged value of the energy production index on economic growth, and the effect of one period lagged value of economic growth on industrial production index are statistically significant. The findings are consistent with the Granger causality analysis findings. The corrected R-squared value of the CO_2 emission model was calculated as 0.161. This shows that 16.1% of the variability in CO_2 emissions can be explained by the energy production index, economic growth, and renewable energy consumption.

5. CONCLUSION AND RECOMMENDATIONS

CO_2 emission is the most important indicator of environmental awareness and sustainability. Controlling CO_2 emission starts with controlling the factors affecting this variable. This study examined three of the factors affecting CO_2 emissions in Kazakhstan. The fact that these factors explain 16.1% of the variability in CO_2 emissions is a valuable finding that proves the accuracy of selected variables. The causal relationship between renewable energy consumption and CO_2 emissions is especially critical for the contribution of renewable energy investments to CO_2 emissions. Moreover, the lack of statistical significance in the relationship between CO_2 emissions and the industrial production index and economic growth, proves that industrial development and economic growth can be achieved without any major concerns about CO_2 emissions.

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