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Impact of Oil Price, CO_2 Emissions and Renewable Energy Consumption on Socio-Economic Development: Asymmetric Evidence from Kazakhstan

Zhulduz Dildebayeva[1], Tolkyn Kakizhanova[2]*, Gulmira Andabayeva[2], Zhanar Askarova[2], Zhanar Oralbayeva[2]

[1]International Engineering Technological University, Almaty, Kazakhstan, [2]Al-Farabi Kazakh National University University, Almaty, Kazakhstan. *Email: tolkyn.kakizhanova@kaznu.edu.kz

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ABSTRACT

Preserving the environment while promoting socioeconomic growth is becoming increasingly important in the modern world. After all, the generation of energy causes the world climate to deteriorate. Alternative approaches to social and economic growth and damage reduction are therefore always pertinent. This study aims to evaluate how socioeconomic growth is affected by significant indicators including oil prices, CO_2 emissions, and the use of renewable energy. Socioeconomic development metrics were the GDP per capita and the Human Development Index. Nonlinear autoregressive distributed lag (NARDL) is the approach employed, and the data spans the years 1992-2021. The model results revealed that all indicators have a significant impact on the socio-economic situation, and it was observed that the results of previous years also have an impact on the next year. CO_2 emissions have a negative impact on the human development index in the short term and a negative impact in the long term. The positive impact of all other indicators on socio-economic development in the long term can be explained by the fact that the economy of Kazakhstan is oriented towards the export of raw materials, especially the mining and oil and gas sectors. Some policy implications presented in the final section.

Keywords: oil price, CO_2 emissions, renewable energy, socio-economic development, NARDL

JEL Classifications: O11, C52, O44

1. INTRODUCTION

Today, the world's economic problems are centered on «development» rather than «growth». Gradual qualitative and structural changes serve as the foundation for society's socioeconomic development. Due to various historical occurrences, different regions of the world have developed under various conditions (Prendecki et al., 2024). Inequalities have emerged in society as a result of the unequal growth of nations worldwide and the varying degrees of development of each nation. Global issues are created by this circumstance, and no single nation can solve them (Abdurakhmnonov, 2023). However, even within a state, there is a problem of uneven socio-economic development of regions (Elistratova et al., 2020).

In modern conditions, the socio-economic development of the country, if not all aspects, then the majority. With socio-economic development, it is important to carefully study not only the indicators of development, but also the indicators of degradation and regression, and determine the factors contributing to them. Goal 7: Affordable and clean energy, Goal 11: Sustainable cities and communities, Goal 13: Climate action are directly and other goals are indirectly connected with responsible energy use. Understanding how the utilization of renewable energy and sustainable development goals are related, both positively and negatively, is crucial (Tian et al., 2024). Sustainable energy is one of the key dimensions of sustainability and one of the key components of human development (Huo et al., 2023). Climate change is significantly influenced by the energy sources that are used. The use and supply of fossil fuels makes up almost two thirds of all over the world greenhouse gas emissions, and in order to help mitigate the effects of climate change, greenhouse gas emissions must be cut far more quickly (IRENA, 2017). One of the prerequisites for environmentally friendly development is the preservation of the natural environment (Prasetyo et al., 2023). Indeed, environmental sustainability is a long-term product of socio-economic development (Huo et al., 2023). For many nations, including Kazakhstan, using renewable energy resources is a top priority. Kazakhstan's energy mix is dominated by fossil fuels, despite the country's vast potential for renewable energy sources (Karatayev and Clarke, 2016; Askarova et al., 2022; Shakeyev et al., 2023). In this sense, the authors are curious in how much a nation's development can be impacted by energy indicators.

The purpose of the article is to assess impact of oil price, CO_2 emissions and Renewable energy use on socio-economic development of Kazakhstan. Thus wise, the article consists of Introduction, Literature review, Methodology, Data and Findings, Results and discussion, and Conclusion.

2. LITERATURE REVIEW

2.1. Socio-economic Development and Oil Price

Numerous studies have constantly examined the effects of different energy parameters, such as oil prices, on economic development (Hamilton, 1983; Zahid and Basit, 2016; Khin et al., 2024; Adeyemi et al., 2024). For instance, Adeosun et al. (2022) analyzed causal relationship between oil price and economic performance in seven advanced countries. Authors found evidence of the importance and impact of those countries' GDP growth forecasting ability in influencing the cyclical volatility of oil prices both before and after the COVID-19 pandemic. Applying Generalized Method of Moment, Deyshappriya et al. (2023) studied the effect of oil prices on 38 OECD nations' economic development between 2000 and 2020, and revealed that the overall negative impact of oil prices outweighs the positive.

Authors recommend that programs be directed to develop the use of renewable energy in order to reduce oil price fluctuations. Tillaguango et al. (2024) assess the impact of oil price, inflation and economic globalization on economic output of oil-produced Latin America countries. The evidence suggests acceleration effect of oil price on economic output of considered economies. For oil exporting countries it is very important to track non-oil revenue too (Fossong et al., 2021; Kreishan et al., 2023), since such countries' economic growth is very sensitive to oil price fluctuations (Bernard et al., 2024; Sule-Iko and Nwoye, 2025). Oil plays an important role in socio-economic developments in global crises (Liang and Ullah, 2024), and it is very important to understand how sensitive social and economic factors are to the price of oil.

2.2. Socio-economic Development and CO_2 Emissions

One of the global concerns is environment degradation driven by CO_2 emissions (Poudel et al., 2024). The effect of climate change on the nation's wealth is a topic that is always relevant (Khan, 2023). One effective strategy to reduce CO_2 emissions is to encourage the development of infrastructure and reduce resource usage (Elhassan, 2025). In this regard, in the modern world, clean and sustainable energy has emerged as a key goal (Rehman et al., 2024). Numerous factors, including Food production (Syrbek et al., 2025), economic expansion (Ghoshray and Lorusso, 2025), trade openness (Aldegheishem, 2024), and financial development (Khan et al., 2024), are linked to CO_2 emissions.

Using Autoregressive-Distributed Lag Bound Testing model and Toda–Yamamoto causality tests, Łącka et al. (2024) analyzed impact of social and economic development on CO_2 emissions in Visegrad countries. Authors suggest to reduce CO_2 emissions and achieve long-term sustainability in the Visegrad countries, policymakers should invest in socio-economic development and renewable energy. The complex relationships between carbon dioxide (CO_2) emissions and key socio-economic indicators across various sectors were examined by Ina et al. (2024). Results reveal economic activities are an important environmental impact driver and shifting energy policy away from coal may play decisive role in Poland. Khan and Hou (2021) studied the effect of socioeconomic indicators and environmental sustainability on CO_2 emissions in thirty countries. Their study revealed that economic sustainability leads to a rise in CO_2 emissions, while environmental sustainability results in a reduction of them.

2.3. Socio-economic Development and Renewable Energy Consumption

The latest geopolitical issues lead to high energy prices, leaving in concern many countries (Yelisieieva et al., 2023). The use of sustainable energy is described as a potentially effective alternative energy source capable of replacing traditional natural fuels (Dluhopolskyi et al., 2023). Renewable energy (RE) systems must be quickly implemented across the global economy in order to mitigate global warming (Virah-Sawmy and Sturm, 2025). Trying to examining nexus between energy, economy, and society, Ferhi and Helali (2024) evaluated how well renewable energy may mitigate the detrimental effects of CO_2 emissions on human development and economic progress.

Results showed that in addition to lowering CO_2 emissions per capita when renewable energy replaces non-renewable energy, this interaction also improves human development, economic progress, and health prospects. Da Silva et al. (2024) assessed a variation in the ability of power producing technology to stimulate environmental and socioeconomic development in a given region of Brazil.

The findings indicate that when it comes to GDP aggregation and direct employment creation, renewable energy plants outperform non-renewable ones. Mehmood et al. (2025) investigated at how carbon productivity was affected by socioeconomic development in the top 18 CO_2-emitting nations, which account for around 82% of worldwide greenhouse gas emissions. The study's findings emphasize the necessity of enacting stronger laws to increase energy efficiency and encourage the use of renewable energy sources like nuclear, solar, wind, and hydropower. In 19 rapidly rising African economies, Yuni et.al. (2023) examined the dynamic relationship between long-term environmental degradation (LED), socioeconomic advancement, and renewable energy consumption. The findings show that FDI, INSTQ, and human development all considerably slow down long-term environmental degradation. The unequal effects of renewable energy production on the economic development of North African nations were studied by Amoah et al. (2020).

Research questions of Literature review are as follows:

- RQ1: To what extent do Oil prices influence the socio-economic development of Kazakhstan?
- RQ2: To what extent do CO_2 emissions influence the socio-economic development of Kazakhstan?
- RQ3: To what extent does Renewable energy consumption influence the socio-economic development of Kazakhstan?

Table 1: Model variables and sources

Variables	Definitions	Sources
HDI	The Human Development Index	(Accessed on 18 March 2025). https://countryeconomy.com/government
GDPPC	GDP per capita (current US dollars)	Our World in Data (2025) https://ourworldindata.org (Accessed on 18 March 2025).
REC	Renewable energy consumption (% of total final energy consumption)	World Development Indicators (WDI) (accessed on 18 March 2025).
COP	Crude Oil Prices: West Texas Intermediate (WTI) (Dollars per Barrel)	U.S. Energy Information Administration https://www.eia.gov/international/data/world (accessed on 18 March 2025).
CO_2E	Annual CO_2 emissions (millon tons)	U.S. Energy Information Administration https://www.eia.gov/international/data/world (accessed on 18 March 2025).

Source: Authors

3. METHODS

Given the results of the reviews presented in the previous section and the importance of energy consumption in the economic process, we analyze the potential impact of energy consumption on socio-economic development indicators by defining econometric models that include data collected for the Republic of Kazakhstan from 1991 to 2021, such as Renewable energy consumption (REC), Crude Oil Prices (COP) and Annual CO_2 emissions (CO_2E).

The Human Development Index (HDI) and GDP per capita (GDPPC) were considered as socio-economic development indices, which are estimated by equation (1) and (2), respectively.

$$HDI_t = f\,(REC_t,\ COP_t,\ CO_2E_t) \quad (1)$$

Where all of their definitions and measurements are given in the Table 1.

Also, the relationship between GDP per capita and the same explanatory variables is estimated using the following regression model:

$$GDPPC_t = f\,(REC_t,\ COP_t,\ CO_2E_t) \quad (2)$$

During the study, based on the results of the ADF test, it was found that all the independent variables under study are stationary at the level of I(0) or first differences I(1) (Table 2), except for the dependent variable HDI. Therefore, for the first model (equation 3) the variable LOG(HDI) was used, for the second model LOG(GDPPC), in the case of 1^{st} difference without Intercept and trend (equation 4).

The ARDL methodology is also used, a maximum of one lag was selected using a special test, and the order of integration of

Table 2: ADF unit root tests

Variables	Intercept			Trend and intercept			None		
	Level	First diff.	Order of Integration	Level	First diff.	Order of Integration	Level	First diff.	Order of Integration
HDI	−1.524 (0.497)	−2.231 (0.200)	>I (1)	−1.744 (0.704)	−1.969 (0.591)	>I (1)	4.457 (0.999)	0.765 (0.867)	>I (1)
LOGHDI	−1.877 (0.334)	−1.111 (0.689)	>I (1)	0.501 (0.998)	−2.392 (0.371)	>I (1)	−0.421 (0.518)	−1.661* (0.090)	I (1)
GDPPC	−1.181 (0.667)	−3.08** (0.041)	I (1)	−1.845 (0.654)	−3.031 (0.143)	>I (1)	−0.105 (0.639)	−2.973*** (0.005)	I (1)
REC	−2.394 (0.153)	−4.10*** (0.004)	I (1)	−2.425 (0.359)	−3.992** (0.022)	I (1)	−0.215 (0.600)	−4.212*** (0.000)	I (1)
COP	−1.543 (0.497)	−3.897** (0.007)	I (1)	−1.165 (0.899)	−4.034** (0.020)	I (1)	−4.481 (0.498)	−3.956*** (0.000)	I (1)
CO_2E	−0.133 (0.936)	−3.305 (0.025)	I (1)	−2.823 (0.201)	−4.651*** (0.005)	I (1)	0.410 (0.795)	−1.781* (0.072)	I (1)

1) *, **, *** denote statistically significant at the 10%, 5% and 1% levels, respectively. P-value is inside brackets

Source: Authors. HDI: Human Development Index, LOG: logarithm, GDPPC: GDP per capita, REC: Renewable energy consumption, COP: Crude Oil Prices, CO_2E: Annual CO_2 emissions

Table 3: Selection order criteria

NARDL1 (1, 0, 1, 0)						
Lag	**LogL**	**LR**	**FPE**	**AIC**	**SC**	**HQ**
0	−213.3904	NA	115.7714	16.10299	16.29497	16.16007
1	−77.47632	221.4896*	0.016346*	7.220468*	8.180347*	7.505890*
NARDL2 (1, 1, 0, 0)						
Lag	**LogL**	**LR**	**FPE**	**AIC**	**SC**	**HQ**
0	−508.9833	NA	3.74e+11	37.99876	38.19074	38.05585
1	−419.3832	146.0150*	1.63e+09*	32.54690*	33.50678*	32.83233*

Source: Authors. NARDL: Nonlinear Autoregressive Distributed Lag

variables is considered to determine the suitability of the ARDL model for the study (Table 3).

The nonlinear models NARDL1 and NARDL2 were estimated using the first difference and logarithm, respectively, and long-term and short-term analyses of the relationship between the variables were carried out.

Based on the results of the Granger causality test using the first difference (Table 4), the logarithmic models NARDL1 and NARDL2 were constructed, and long-run and short-run analyses of the relationship between the variables were conducted.

In ARDL models with distributed lags, the procedure determines whether there is cointegration between the selected variables. The bounds test checks the long-run relationship, the results of the bounds test are presented in Table 5. Two main models were constructed. As in NARDL1 and NARDL2, the linear specification of the model was transformed into a logarithmic one. In the nonlinear ARDL model with distributed lags, the NARDL1 procedure is defined using 3 equations:

$$\Delta LOG(HDI_t) = \beta_0 + \sum_{k=1}^{m} \beta_1 \, LOG(HDI_{t-k}) + \sum_{k=0}^{n} \beta_2 \, LOG(REC_{t-k}) + \sum_{k=0}^{3} \beta \, LOG(COP_{t-k}) + \sum_{k=0}^{4} \beta \, LOG(CO2E_{t-k}) + \gamma_1 LOG(REC_{t-i}) + \gamma_2 LOG(COP_{t-i}) + \gamma_3 LOG(CO2E_{t-i}) + \varepsilon_t \quad (3)$$

Where, operator Δ represents the differencing operation.

The NARDL2 structure of model 2 is expressed in equation 4:

$$\Delta LOG(GDPPC_t) = \beta_0 + \sum_{k=1}^{m} \beta_1 \, LOG(GDPPC_{t-k}) + \sum_{k=0}^{n} \beta_2 \, LOG(REC_{t-k}) + \sum_{k=0}^{p} \beta_3 \, LOG(COP_{t-k}) + \sum_{k=0}^{q} \beta_4 \, LOG(CO2E_{t-k}) + \gamma_1 LOG(REC_{t-i}) + \gamma_2 LOG(COP_{t-i}) + \gamma_3 LOG(CO2E_{t-i}) + \varepsilon_t \quad (4)$$

Table 4: Noncausality tests in the sense of Granger for the vector autoregressive (1) (1992-2021)

Direction of causality	F-statistic	Prob.
HDI		
REC does not Granger Cause HDI	4.006980	0.1349
COP does not Granger Cause HDI	4.435949	0.1088
CO_2E does not Granger Cause HDI	6.169100	0.1047
GDPPC		
REC does not Granger Cause GDPPC	1.847279	0.3971
COP does not Granger Cause GDPPC	0.717059	0.6987
CO_2E does not Granger Cause GDPPC	0.122149	0.9408

Source: Authors. HDI: Human Development Index, GDPPC: GDP per capita, REC: Renewable energy consumption, COP: Crude Oil Prices, CO_2E: Annual CO_2 emissions

Table 5: Results of cointegration test

Model	F Statistics	Critical Bounds	Decision
NARDL1 (1, 0, 1, 0)	33.87108	3.1-4.84	Cointegration
NARDL2 (1, 1, 0, 0)	17.77968	3.1-4.84	Cointegration

Critical bounds are reported at 1% (***) and 10% (**) level of significance
Source: Authors. NARDL: Nonlinear Autoregressive Distributed Lag

4. DATA AND FINDINGS

4.1. Data

The purpose of this study is to examine the relationship between socio-economic development indicators and Renewable energy consumption, Crude Oil Prices and Annual CO_2 emissions in the Republic of Kazakhstan, taking into account the potential role of energy consumption and economic growth. For empirical observations and analysis, the data for the Republic of Kazakhstan cover the period from 1992 to 2021, which were obtained from the World Data Institute (WDI), https://countryeconomy.com/government, https://ourworldindata.org, https://www.eia.gov/international/data/world.

Table 1 provides a comprehensive explanation of the variables, including their dimensions and data sources. All of indicators' definitions and measurements are given in Table 1.

The dynamic change of all indicators presented in the table in the period 1992-2021 is depicted in the following graph:

It is clear from the analysis of the graph shown in graph 1 that the study variables are suitable for analysis. The graph shows obvious, consistent and stable time patterns, indicating that changes in the variables are suitable for further study.

Graph 1: Evolution of all variables for Kazakhstan (1992-2021)

Source: Authors

4.2. Descriptive Statistics

The study used time series variables as defined in Table 1. In the study, all values of descriptive statistics for each variable used in our model, and their respective characteristics are described in Table 2 below. The study validates the variables by mean, median, asymmetry, and minimum and maximum variables.

Based on the descriptive statistics, the median values for HDI and GDPPC are noted as 0.736655 and 5576.982 in current US dollars, respectively, while the standard deviations are 0.059811 and 4242.874. The computed Jarque-Bera statistics yield values of 2.755826 and 0.237739, with corresponding probabilities of 0.252104 and 0.237739. Since these probabilities exceed 0.05 for other indicators as well, it leads us to conclude that all economic variables within the Republic of Kazakhstan exhibit a normal distribution. As illustrated in Table 6, the asymmetry coefficient for the HDI and CO_2E indicators is negative, indicating that they possess negative asymmetry, whereas GDPPC, REC, and COP show positive asymmetry.

4.3. Unit Root Test

Our research initiates by assessing the stationarity of the series to analyze the enduring relationships among the variables. The Augmented Dickey-Fuller (ADF) tests for unit roots can be employed to verify if the dataset indicates stationarity or its absence. In this investigation, Augmented Dickey-Fuller (ADF) unit root tests were utilized to analyze either the levels or the differences of the variables deemed to be stationary. Certain variables can be applied at level I(0), while other variables display stationarity at the first difference I(1). Table 2 displays the outcomes of the Augmented Dickey-Fuller (ADF) unit root assessments for the series at both level and first difference since the optimal lag is set to one in the context of ARDL models. The ADF method tests the null hypothesis of non-stationarity, which is refuted if the ADF

Table 6: Values of descriptive statistics of the displayed series

Values	HDI	GDPPC	REC	COP	CO_2E
Mean	0.736655	5576.982	1.751724	49.19310	213.8810
Median	0.752000	5030.135	1.800000	43.29000	224.5500
Maximum	0.819000	13478.46	2.800000	99.67000	307.1700
Minimum	0.652000	1091.547	1.100000	14.42000	119.2700
Standard Deviation	0.059811	4242.874	0.426464	28.39019	53.25438
Skewness	−0.130526	0.328304	0.500845	0.480097	−0.089676
Kurtosis	1.512541	1.604774	2.689933	1.901770	1.820843
Jarque-Bera	2.755826	2.873161	1.328594	2.571430	1.718948
Probability	0.252104	0.237739	0.514635	0.276453	0.423385
Sum	21.36300	161732.5	50.80000	1426.600	6202.550
Sum Sq. Dev.	0.100165	5.04E+08	5.092414	22568.08	79408.82
Observations	30	30	30	30	30

Source: Authors. HDI: Human Development Index, GDPPC: GDP per capita, REC: Renewable energy consumption, COP: Crude Oil Prices, CO_2E: Annual CO_2 emissions

statistic is more negative or surpasses the absolute critical values of 1%, 5%, and 10%. The findings indicate that all independent variables, with the exception of HDI, are stationary at the first difference; consequently, the variable LOGHDI was included, being stationary without a trend and intercept. Moreover, GDPPC is stationary except when accounting for a trend and intercept.

Consequently, we can utilize these factors to evaluate NARDL models. The outcomes of the unit root analysis align with the preliminary hypotheses, indicating the necessity for a NARDL model examination to validate the presence of long-term connections between the indices of socio-economic advancement and the energy explanatory variables suggested in the research.

4.4. Granger causality test

To analyze the relationship of cause and effect between specific variables and socio-economic development measures, including the Human Development Index (HDI) and income per person (GDPPC), a Granger test is conducted. This test examines the null hypothesis that variations in the dependent variable are non-causal. Should the P-value from the Acceptance Test fall below 0.05, the null hypothesis will be dismissed. As shown in Table 4, the null hypothesis is dismissed across all variables.

4.5. Co-Integration Test

The ARDL bounds testing approach is employed in this research to analyze the long-term connections among Renewable energy use, Crude Oil Prices, Annual CO_2 emissions, and economic development indicators in the Republic of Kazakhstan. It is crucial to establish the appropriate lag length criterion prior to performing the cointegration analysis. The ARDL technique was chosen for exploring the long-term associations between the variables, considering a limited sample size. The chosen lag results are displayed in Table 3. The lag length criterion is derived from LR, FPE, AIC, SC, and HQ metrics. According to Table 3, the chosen lag length is set at 1, as indicated by the higher number of stars.

4.6. Results of long- and short run relationship

In the research, the non-linear NARDL1 (1, 0, 1, 0) model was analyzed through the use of logarithmic transformations and the first difference derived from the ADF test. For the purpose of assessing both the long-term and short-term connections between the variables, the findings are detailed in Table 2 below.

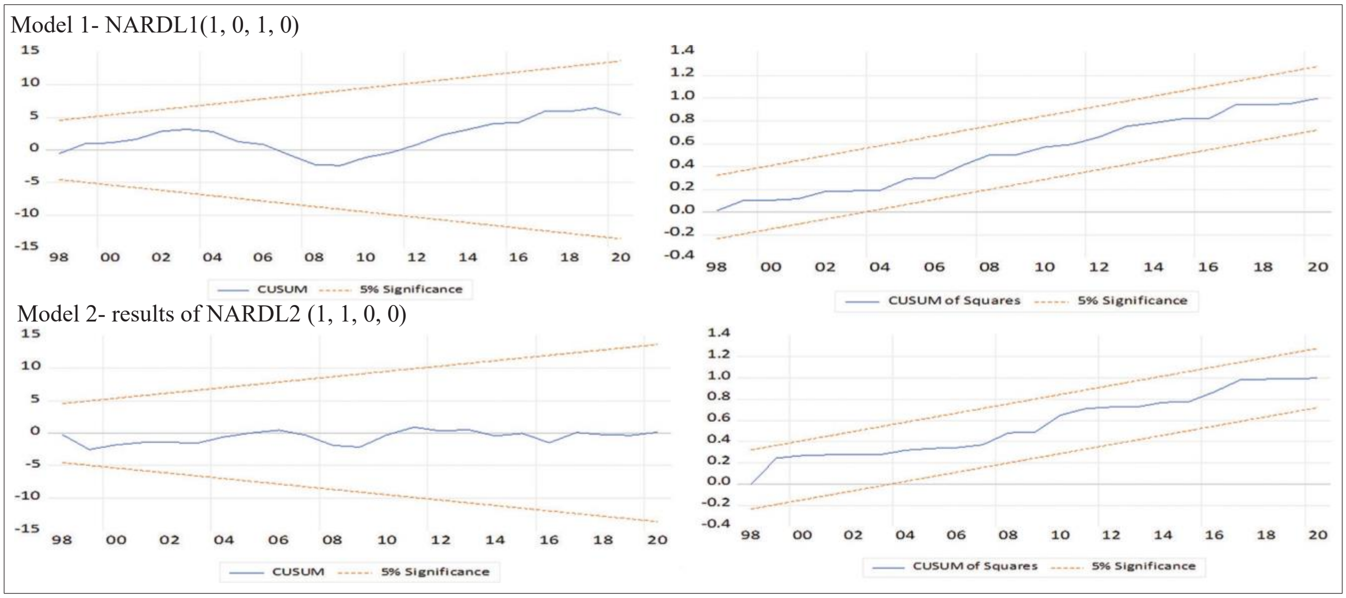
The F-test results for cointegration regarding NARDL1 (1, 0, 1, 0) presented in Table 2 indicate that the calculated F-statistic, which is 33.87108, surpasses the upper threshold of 4.84 and holds statistical significance at confidence levels of 1-10%. Likewise, in the case of the linear NARDL2 (1, 1, 0, 0) model, the F-statistic measured at 17.77968 also goes beyond 4.84. These findings confirm that the chosen variables exhibit cointegration, suggesting a long-term association among the factors in the context of Kazakhstan.

Since the chosen variables exhibit cointegration over an extended period, we can advance to the subsequent phase, which involves calculating both the long-term and short-term coefficients. Since the models NARDL1 (1, 0, 1, 0) and NARDL2 (1, 1, 0, 0) were analyzed in logarithmic terms, we can determine the impact of a 1% variation in the independent variables on the dependent variable in both the long-lasting and immediate contexts.

Based on the findings from the NARDL1 model, it is evident that the first-order lagged variable LOG(COP(−1)) along with the short-term growth of ΔLOG(COP) and long-term LOG(COP) (with elasticity coefficients of 0.015, 0.007, and 0.249, respectively) contributes positively to the improvement of ΔLOG(HDI) metrics. This indicates that fluctuations in Crude Oil Prices positively influence the advancement of the Human Development Index. Additionally, the research highlights a significant negative correlation between the growth of LOG(HDI) and Annual CO_2 emissions (CO_2E) over both short and long durations. Specifically, at a 5% significance level, a 1% rise in the present CO_2E results in a 0.014% drop in HDI growth in the short term and a 0.241% decline in the long term. Furthermore, the calculated short-term elasticity of REC growth in relation to GDP per capita growth is positive (0.018%) and shows statistical significance, indicating that there is a noteworthy association between these two factors. It is observed that a 1% rise in REC encourages HDI growth by 0.304% over the long term. Moreover, the analysis reveals a significant connection between economic growth (GDPPC) and Annual CO_2 emissions (CO_2E) in both the short and long term. At a 10% significance level, a current increase of 1% in CO_2E values boosts GDP per capita by 0.102% in the short run, and by 0.424% in the long run.

Based on the findings from the NARDL1 model, it is evident that the first-order lagged variable LOG(COP(−1)) along

Graph 2: CUSUM and CUSUM



Source: Authors

with the short-term growth of ΔLOG(COP) and long-term LOG(COP) (with elasticity coefficients of 0.015, 0.007, and 0.249, respectively) contributes positively to the improvement of ΔLOG(HDI) metrics. This indicates that fluctuations in Crude Oil Prices positively influence the advancement of the Human Development Index. Additionally, the research highlights a significant negative correlation between the growth of LOG(HDI) and Annual CO_2 emissions (CO_2E) over both short and long durations. Specifically, at a 5% significance level, a 1% rise in the present CO_2E results in a 0.014% drop in HDI growth in the short term and a 0.241% decline in the long term. Furthermore, the calculated short-term elasticity of REC growth in relation to GDP per capita growth is positive (0.018%) and shows statistical significance, indicating that there is a noteworthy association between these two factors. It is observed that a 1% rise in REC encourages HDI growth by 0.304% over the long term.

Moreover, the analysis reveals a significant connection between economic growth (GDPPC) and Annual CO_2 emissions (CO_2E) in both the short and long term. At a 10% significance level, a current increase of 1% in CO_2E values boosts GDP per capita by 0.102% in the short run, and by 0.424% in the long run.

The REC variable within the NARDL2 framework signifies Renewable energy consumption and includes one previous value, where its elasticity is a positive 0.186% in the short term. Moreover, the calculated short-term elasticity of REC growth in relation to GDP per capita growth stands at a negative (−0.200%) and is statistically significant. This suggests that the connection between these two factors is important. It appears that a 1% rise in the REC levels encourages economic growth by 0.775% over the long term. In both the short and long term, the respective elasticities for Crude Oil Prices are 0.3731% and 1.5581%, which underscores that a rise in Crude Oil Prices will contribute to an increase in GDP per capita.

In addition, the negative effect of the lagged variable LOG(GDPPC(−1)) in period t-1 on the level of ΔLOG(GDPPC) in period t in the short term (−0.240) and the negative effect of the lagged variable LOG(HDI(−1)) in period t-1 on the level of ΔLOG(HDI) in period t in the short term (−0.240) was proven.

To check the stability of the nonlinear models NARDL1 and NARDL2, diagnostic tests were carried out (Table 7). These include tests for serial correlation, normality and heteroscedasticity. For this model, the null hypothesis of no serial correlation, homoscedasticity and normality cannot be rejected. This indicates that the models are free of serial correlation and heteroscedasticity.

Table 7 presents the results of the diagnostic tests. For NARDL1 model, Serial correlation is 0.474083 and the probability value is 0.6290. As a result, we accept the null hypothesis in this analysis and conclude that there is no serial correlation in the model. Heteroscedasticity tests show that the F-statistic is 0.489629 and the probability is 0.7804, both values are >0.05% significance level, indicating that the model is homoscedastic. The model accepts the null hypothesis of normality test and concludes that the residuals are normally distributed, as evidenced by the F-statistic of 3.248909 and the probability value of 0.1970, all indicators have a significance level >5%. Finally, serial correlation diagnostic tests with Langrange multiplier, Jarque-Bera normality test and heteroscedasticity test are all successful, indicating the robustness of the NARDL1 model. The robustness of the NARDL2 model is also explained accordingly.

4.7. Stability Tests

The CUSUM and CUSUM-squares examinations assess if the parameters of the predicted models stay consistent throughout time, serving as a sign of the model's stability.

The findings from the CUSUM and CUSUMSQ robustness evaluations are illustrated in Graph 2. When assessed at a 5%

Table 7: Results of NARDL and ARDL Estimation (1992-2021)

Model 1- results of NARDL1 estimationΔLOG (HDI)			Model 2- results of NARDL2 estimationΔLOG (GDPPC)		
Variable	**Coefficient**	**t-Statistic (Prob.)**	**Variable**	**Coefficient**	**t-Statistic (Prob.)**
Short Run					
LOG (HDI(−1))*	−0.058430	−4.586 (0.0001)***	LOG (GDPPC(−1))*	−0.239671	−5.085 (0.0000)***
LOG (REC)**	0.017775	5.076 (0.0000)***	LOG (REC(−1))	0.185635	2.461 (0.0218)**
LOG (COP(−1))	0.014554	6.686 (0.0000)***	LOG (COP)**	0.373289	6.415 (0.0000)***
LOG (CO_2E)**	−0.014080	−6.462 (0.0000)***	LOG (CO_2E)**	0.101805	2.108 (0.0461)**
ΔLOG (COP)	0.007178	2.238 (0.03520)**	ΔLOG (REC)	−0.200069	−1.780 (0.0883)*
Long Run					
LOG (REC)	0.304212	3.315 (0.0030)***	LOG (REC)	0.774542	1.995 (0.0580)*
LOG (COP)	0.249080	6.271 (0.0000)***	LOG (COP)	1.557510	9.110 (0.0000)***
LOG (CO_2E)	−0.240971	−7.669 (0.0000)***	LOG (CO_2E)	0.424770	3.086 (0.0052)*
Diagnostic	**F-statistics**	**P-value**	**Diagnostic**	**F-statistics**	**P-value**
Serial correlation	0.474083	0.6290	Serial correlation	1.080368	0.3576
Heteroskedasticity	0.489629	0.7804	Heteroskedasticity	0.610419	0.6929
Jarque-Bera	3.248909	0.1970	Jarque-Bera	0.459598	0.7947

1) Coefficients are statistically significant at ***1%, **5%, *10% level of significance. 2) Compiled by the authors

Source: Authors. LOG: logarithm , HDI: Human Development Index, GDPPC: GDP per capita, REC: Renewable energy consumption, COP: Crude Oil Prices, CO_2E: Annual CO_2 emissions

significance threshold, not surpassing critical limits suggests that the model maintains its robustness. This examination is additionally utilized to investigate the long-term behavior of the regression.

5. RESULTS AND DISCUSSION

We employ the NARDL estimation technique, with the empirical findings displayed in Table 7. These results illustrate that the growth rates of both the Human Development Index and GDP per capita are influenced by fluctuations in the current and past values of the independent variable, which also includes the previous values of HDI and GDP per capita. The collected data suggest the existence of a consistent effect from the first-order autoregressive (lagged) values of the Human Development Index and GDP per capita. A negative coefficient signifies that during this time, HDI and GDP per capita significantly impede the expression of economic indicators, highlighting the adverse impact of the lagged HDI and GDP per capita on the current growth rates of socio-economic metrics.

Furthermore, both the present and first lagged values of Crude Oil Prices considerably affect HDI and GDP per capita as well as Renewable energy consumption. The pronounced positive impact of the lagged Crude Oil Prices and Renewable energy consumption implies that the level of economic activity from the previous period, represented by COP and REC, positively influences the current growth rates of the Human Development Index and GDP per capita, respectively. Conversely, the significant negative influence of Annual CO_2 emissions on the Human Development Index indicates that the economic activity level during that timeframe, as quantified by CO_2E, restricts HDI in the present period. The outcome of Model 1 clearly reveals that the current Annual CO_2 emissions exert a substantial positive effect on overall economic advancement.

6. CONCLUSION

This study was carried out by the authors to evaluate how certain energy variables affect social and economic development. While the price of crude oil, annual CO_2 emissions, and the Rrenewable energy consumption were considered as energy variables, the Human Development Index and GDP per capita were considered as socioeconomic indicators. The information was gathered from international statistical websites and spans the years 1992-2021. A nonlinear autoregressive distributed lag (NARDL) model was employed in the investigation.

6.1. The Following Outcomes were Displayed by the Model

The Human Development Index benefits both immediately and over time from the usage of renewable energy. The Human Development Index is negatively impacted by CO_2 emissions both in the short and long term. The Human Development Index is positively impacted in the short and long term by the lag effect of both the oil price and its increase. The lag variable of Renewable energy consumption has a positive short-term impact on GDP per capita, while the growth of Renewable energy consumption has a negative short-term impact, while Renewable energy consumption has a positive long-term impact. The GDP per capita has a positive short-term impact on CO_2 emissions and a positive long-term impact. The GDP per capita has a positive short-term impact on Oil price and a positive long-term impact. The model results show that all of the independent variables studied have a significant impact on the socio-economic development of the country.

6.2. Some Political Implications

It is not surprising that CO_2 emissions from mining have a large impact on GDP per capita given that Kazakhstan's economy is primarily dependent on the export of raw materials, such as gas, oil, and mining. Most of the time, the increase in oil prices benefits Kazakhstan's economy as well.

However, relying only on the production of basic materials makes the economy extremely vulnerable to shocks from around the world. The economy of our nation has also been significantly impacted by the volatility of oil prices brought on by different geopolitical circumstances. Thus, State policy should prioritize lowering CO_2 emissions, boosting the use of renewable energy, and strengthening the economy's resilience to fluctuations in the price of oil.

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