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Beyond the Resource Curse: Energy Structure and Sustainable Economic Growth in Kazakhstan

Özlem Ülger Danacı

Department of Economics, Batman University, Batman 72100, Turkey; ozlem.ulger@batman.edu.tr

Abstract

Achieving sustainable economic growth in resource-rich economies remains a major challenge in the context of the global energy transition. While fossil fuel dependence has historically supported economic expansion, it has also generated structural vulnerabilities associated with the resource curse. This study examines whether changes in energy structure can help move beyond the resource curse in Kazakhstan, a fossil-fuel-dependent transition economy. Using annual data for the period 1993–2023, the analysis applies the Autoregressive Distributed Lag (ARDL) bounds testing approach to investigate the short- and long-term relationships between per capita income, fossil fuel consumption, renewable energy production, carbon emissions, and capital formation. The results provide evidence of a long-term association, supported mainly by the error-correction mechanism. Fossil fuel consumption exerts a statistically significant negative effect on per capita income, supporting the resource curse hypothesis. In contrast, renewable energy production does not show a statistically significant impact on economic growth, suggesting that its contribution to economic growth remains limited within the sample period. Overall, the findings highlight the importance of energy diversification and structural transformation of the energy sector for aligning energy transition strategies with sustainable development objectives in resource-rich economies.

Keywords: sustainable economic growth; energy structure; renewable energy; resource curse; ARDL; Kazakhstan

1. Introduction

Kazakhstan, endowed with vast fossil fuel reserves and an expanding renewable energy potential, stands at a critical juncture in its economic development. The paradox arising from natural resource abundance, commonly known as the "resource curse", has long posed a challenge for resource-rich economies. Dependence on extractive and mining-based sectors in such economies is often associated with economic volatility, weak institutions, and limited diversification [1,2]. However, emerging approaches in development economics suggest that resource abundance can, under certain conditions, foster sustainable growth and modernization, particularly through strategic investments in renewable energy [3,4]. In this context, Kazakhstan's experience provides an important case for examining whether changes in energy structure can help move beyond the resource curse and support a more sustainable growth trajectory.

In recent years, Kazakhstan has taken significant steps toward diversifying its energy mix to decarbonize its energy sector and achieve sustainable development goals. The core framework of this transformation was established with the adoption of the Green Economy Concept in 2013 and the long-term policy vision Kazakhstan 2050 Strategy.

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These strategic documents emphasize the gradual increase of renewables in total energy production, the reduction of environmental impacts, and the enhancement of energy efficiency. Within this framework, wind, solar, and hydroelectric technologies have been identified as priority investment areas, with the target of generating 50% of the country's electricity from renewable sources by 2050 [5–7]. This transition represents not only an environmental necessity but also a strategic orientation aiming to strengthen Kazakhstan's macroeconomic resilience and support sustainable growth through energy diversification and structural transformation of the energy sector [4].

Nevertheless, the success of such a transition depends largely on Kazakhstan's institutional capacity, governance structures, and the extent to which renewable energy investments can be shielded from the structural challenges often observed in the fossil fuel sector. The dual nature of natural resources as both a curse and an opportunity raises critical questions. Can Kazakhstan successfully transform renewable energy development into sustainable economic growth? Or will these new sources pose the same structural difficulties that have historically accompanied the fossil fuel industry?

Even though there are many studies examining the energy-growth nexus [8], most studies tend to focus separately on fossil fuels or renewable energy, often overlooking the institutional and developmental context of energy transitions. Moreover, the number of studies on Kazakhstan is limited, with insufficient attention paid to disentangling the effects of fossil and renewable energy on economic growth using robust time series methodologies. This study aims to address this gap by empirically estimating the short- and long-term effects of fossil fuel consumption and renewable energy production on per capita income in Kazakhstan over the period 1993–2023 using a single-equation Autoregressive Distributed Lag (ARDL) framework. To provide a broader perspective on the energy–economy–environment nexus, the model incorporates carbon emissions and capital formation as control variables. The empirical analysis focuses on estimating single-equation relationships and does not aim to test bidirectional causality or institutional transmission mechanisms.

This study contributes to the energy-growth literature in several important ways. First, it provides empirical evidence for the resource curse hypothesis within the context of Kazakhstan, a middle-income transition economy that remains heavily dependent on energy exports. This contribution is significant in terms of enhancing the geographical diversity of resource abundance analyses, which have predominantly focused on African and Latin American countries. Second, by testing whether renewable energy production can offset the adverse growth effects of fossil fuel dependence, the study empirically evaluates the substitution effect of energy transformation. It builds on the assumption that the contribution of renewable energy to economic growth depends not only on the supply volume, but also on institutional capacity, investment climate, and technological competence. Third, by integrating environmental and structural variables (such as carbon emissions and gross fixed capital formation) into the model, the study examines Kazakhstan's economic transformation from a more holistic and multidimensional perspective, rather than limiting its scope to the direct relationship between energy supply and growth. Finally, the results offer not only policy implications specific to Kazakhstan but also generalizable insights for other developing economies with similar resource wealth and transformation pressures. In doing so, the study contributes to the political economy of energy transition and offers policymakers contextually grounded and actionable recommendations for advancing sustainable growth.

The remainder of the paper is organized as follows. Section 2 reviews the existing literature on the resource curse, energy-growth dynamics, and renewable energy transitions. Section 3 describes the dataset, variables, and methodology, including the ARDL approach.

Section 4 presents the empirical results, and concludes study with key policy implications and directions for future research.

2. Literature Review

2.1. Theoretical Foundations of the Resource Curse

Since the 1980s, the resource curse hypothesis has evolved to suggest that countries rich in natural resources, particularly oil and gas, tend to have lower rates of economic growth, weaker institutions, and higher levels of inequality compared to resource-poor nations [2]. This paradoxical outcome is commonly explained through mechanisms such as Dutch Disease, rent-seeking behavior, and institutional erosion [1]. Dutch Disease arises when revenue from resource exports leads to an appreciation of the real exchange rate, which in turn undermines the competitiveness of the manufacturing and agricultural sectors [9]. Meanwhile, the inflow of resource rents can weaken governments' incentives to maintain tax collection and accountability mechanisms, thereby deteriorating institutional quality and fostering authoritarian tendencies [10].

Empirical studies across diverse contexts have produced complex and sometimes contradictory findings. While some research identifies a negative relationship between resource dependence and economic growth [3], others argue that this relationship is mediated by institutional factors, claiming that resource abundance is not inherently detrimental but becomes problematic in environments characterized by weak governance [11]. Natural resources have supported long-term development in resource-rich countries with strong democratic institutions and transparent fiscal frameworks, such as Norway. Conversely, in many developing nations across Sub-Saharan Africa and Central Asia, the resource curse has manifested through economic volatility, conflict, and limited diversification.

In light of these general trends, Kazakhstan presents a compelling case that aligns closely with the empirical predictions of the resource curse hypothesis. Following independence, the country experienced rapid growth driven by substantial foreign direct investment and export revenues from fossil fuels; however, the benefits of these revenues have not been distributed equitably across society. Economic concentration in the energy sector, weak accountability mechanisms, and the slow pace of institutional reform have constrained the developmental contribution of resource wealth [12]. Moreover, Kazakhstan's economy remains highly vulnerable to international commodity price fluctuations, a vulnerability that has been clearly evident during episodes such as the 2008–2009 global financial crisis, the 2014 oil price collapse, and the post-2020 COVID-19 energy shocks.

2.2. Energy Consumption and Economic Growth: Divergent Perspectives

Even though there are many studies in the literature examining the relationship between energy consumption and economic growth, there is still no definitive consensus. Early neoclassical growth models largely treated energy as an intermediate input, thereby underestimating its role in economic expansion. In contrast, ecological and endogenous growth theories explicitly model energy as a key driver of productivity, technological progress, and structural transformation [13].

Within the empirical energy-growth literature, four principal hypotheses have emerged:

1. *Growth Hypothesis:* Energy consumption acts as a fundamental driver of economic growth.
2. *Conservation Hypothesis*: Economic growth leads to higher energy demand and consumption.
3. *Feedback Hypothesis:* Some studies suggest that a reciprocal causal relationship may exist between energy consumption and economic growth.
4. *Neutrality Hypothesis:* There is no statistically significant causal relationship between energy consumption and economic growth.

A large number of time-series and panel data studies tested these hypotheses using methods such as Granger causality analysis, vector error correction models (VECMs), and the ARDL framework. For instance, the meta-analysis conducted by Ozturk [8] revealed that results are highly sensitive to country characteristics, the time periods examined, the types of energy considered, and the econometric methods employed. Evidence from advanced economies tends to support the conservation hypothesis, whereas emerging and developing economies more frequently validate the growth or feedback hypotheses. Shahbaz and Lean [14], employing an ARDL model for Pakistan, found that energy consumption promotes economic growth; similarly, Apergis and Payne [15] identified a positive long-term relationship between renewable energy consumption and growth in OECD countries. However, the direction and strength of this relationship vary depending on a country's level of development, energy mix, and institutional framework [16].

2.3. Renewable Energy and the Challenge of Economic Diversification

Sustainable energy technologies have emerged not only as tools for environmental preservation, but also as strategic instruments for countries seeking economic diversification. In economies dominated by natural resource sectors, such investments can support structural transformation processes, thereby fostering more balanced and inclusive growth [17,18]. Within this framework, the energy transition is conceptualized through the dual lenses of the "green growth" paradigm and the "resource curse" hypothesis. The former seeks to sustain economic growth while safeguarding environmental sustainability, whereas the latter warns that dependence on natural resources may engender long-term economic vulnerability and institutional decay. Clean energy investments thus gain prominence both as a development tool and as a strategy to mitigate systemic fragility.

According to the International Renewable Energy Agency [19], renewable energy investments strengthen energy security by promoting decentralized energy systems, generating local employment, and reducing exposure to commodity price volatility. De la Río and Burguillo [20] further argue that this transformation yields broad-based multiplier effects, not only environmental but also in terms of technology transfer, skill formation, and regional development. Nevertheless, these effects are not automatic; they are profoundly shaped by policy coherence, institutional capacity, and the investment climate. For instance, Menegaki [21] reported no significant causal link between renewable energy consumption and economic growth in European countries, attributing the result to weak policy frameworks and the absence of economies of scale. In contrast, Apergis and Payne [15] identified a long-term cointegration relationship in OECD nations, suggesting that energy transition can indeed support economic growth. Taken together, these approaches indicate that the economic outcomes of energy investments are context-dependent, varying with governance quality and the functionality of institutional structures.

More recent empirical evidence further reinforces this conditional perspective. Wang, He, and Wu [22] demonstrate that renewable energy consumption functions as a "green engine of growth" in China when complemented by supportive environmental and energy policies, underscoring the decisive role of coherent policy frameworks in translating renewable energy investments into sustainable economic growth. Taken together, these findings indicate that the economic outcomes of renewable energy investments are highly context-dependent, varying with governance quality, institutional capacity, and policy effectiveness. Similar patterns were reported in studies focused on developing countries. Salim and Rafiq [23] concluded that clean energy investments can contribute to economic growth, but only when supported by robust financial systems and effective governance mechanisms.

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Within this context, Kazakhstan provides a theoretically and empirically significant testing ground. The country, which has long relied on fossil fuel exports, has increasingly positioned clean energy investments at the core of its diversification strategy [24]. This orientation reflects not only a desire to overcome structural vulnerabilities stemming from resource dependence but also an ambition to extend long-term growth potential across more balanced sectors. Nonetheless, as widely emphasized in the literature, structural constraints, such as infrastructural deficiencies, limited financial channels, and institutional weaknesses in public administration, continue to constrain the impact of this transformation [25]. Therefore, the effect of energy transition on economic diversification is not deterministic but conditional. Its realization depends on the simultaneous construction of technical infrastructure, institutional reform, governance quality, and sustainable financing mechanisms. Hence, energy investments should not be regarded as autonomous engines of growth but rather as complementary policy instruments that can become effective once an enabling structural environment is in place.

2.4. Institutions, Human Capital, and Energy Transitions

The literature on the impact of natural resources on economic growth demonstrates that factors such as the quality of institutional structures and the level of human capital play a decisive role in shaping this relationship. While classical growth theories posit that natural resources like energy contribute positively to economic expansion, the more recent "resource curse" literature has challenged this assumption, emphasizing that the contribution of resources to development depends largely on institutional arrangements and the quality of governance [26]. In the case of Kazakhstan, a growth model highly dependent on energy revenues has been adopted; however, according to a 2019 OECD report [27], this model has proven structurally fragile in terms of sustainability due to weaknesses in governance capacity. Kolstad and Wiig [28] also highlighted the influence of institutional elements such as transparency and accountability on the investment climate, noting that countries with transparent institutions tend to use energy revenues more efficiently and attract foreign investments in a more stable manner.

In this context, there is a strong consensus in the literature that energy-based growth is directly associated not only with institutional quality, but also with the level of human capital. Barro and Lee [29] emphasized the long-term positive effects of rising education levels on growth, while UNESCO [30] notes that Kazakhstan has increased its investments in education, though these investments do not sufficiently align with the structural needs of the labor market. Within the energy sector, the quality of technical and vocational education has become a decisive factor in productivity gains and technological adaptability. This aligns with the strand of literature suggesting that energy revenues should be directed not only toward physical infrastructure but also toward institutional reform and human capital development.

Moreover, recent academic discussions have increasingly focused on the roles of institutions and societal actors in energy transition processes. North [31] defined institutions as the "rules of the game" governing economic interactions, whereas Bhattacharyya [32] argued that there is a strong causal link between access to energy and democratic governance. When this theoretical framework is applied to Kazakhstan, it becomes evident that although energy reforms may be technically feasible, they often struggle to gain social legitimacy due to low public trust and weak participatory mechanisms. Therefore, for long-term energy policies to function sustainably, it is essential to strengthen not only technical infrastructure but also governance quality, public participation mechanisms, and human capital systems in an integrated manner.

2.5. Gaps in the Literature

Despite the growing academic interest in the energy–growth nexus, several important gaps remain in the literature. First, in the context of Kazakhstan, the number of studies that jointly examine the effects of fossil and renewable energy on economic growth within a unified econometric framework is limited. Most existing studies consider energy as a homogeneous input, overlooking the distinct dynamics of different energy sources. Second, in developing and resource-rich economies, empirical evidence on the relationship between renewable energy production and economic growth remains limited. Third, although the roles of institutions, governance, and human capital are widely discussed in the literature, empirical analyses often face data and methodological constraints when incorporating these factors into time-series models. In this study, these factors are considered as part of the broader theoretical and interpretative framework rather than being directly included in the econometric specification.

This study aims to address the first two gaps directly and discusses institutional and human capital factors within a broader interpretative framework. Using data from Kazakhstan covering the period 1993–2023, it empirically investigates the short- and long-term effects of fossil fuel consumption and renewable energy production on per capita income within the framework of the ARDL model. Capital formation and carbon emissions are incorporated as control variables, and the findings are discussed through the lenses of the resource curse hypothesis, energy transition, and sustainable development. In doing so, the study contributes to a clearer understanding of whether changes in energy structure can help move beyond the resource curse and support a more sustainable growth path in resource-rich transition economies.

2.6. Research Hypotheses

Based on the theoretical arguments presented in the resource curse and energy–growth literature, this study formulates two main research hypotheses tailored to the case of Kazakhstan. First, the resource curse perspective suggests that excessive dependence on fossil fuel–based energy structures may hinder long-term economic performance through mechanisms such as sectoral concentration, crowding-out of productive investments, and vulnerability to external shocks. Accordingly, the first hypothesis is defined as follows:

H1: *Fossil fuel consumption has a negative long-term impact on economic growth in Kazakhstan.*

Second, the energy transition and green growth literature emphasizes that renewable energy production may contribute to sustainable economic growth by promoting diversification, technological upgrading, and environmental sustainability. Within this framework, renewable energy is expected to offset the adverse effects associated with fossil fuel dependence. Thus, the second hypothesis is formulated as:

H2: *Renewable energy production has a positive long-term effect on economic growth in Kazakhstan.*

These hypotheses are empirically examined within the ARDL bounds testing framework, allowing for an assessment of whether Kazakhstan's evolving energy structure supports or constrains sustainable economic growth over the sample period.

3. Data and Methodology

3.1. Data Sources and Variable Definitions

This study employs annual time-series data for Kazakhstan covering the 1993–2023 period to empirically examine the relationship between energy structure and economic growth within the context of structural change and energy transition. The selected time

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span captures both the post-Soviet transition period and the recent phase of renewable energy expansion in Kazakhstan. The data were primarily obtained from the World Bank's World Development Indicators (WDI) database, which is widely regarded as reliable in terms of consistency and international comparability.

All monetary variables were expressed in constant prices, and natural logarithmic transformation was applied. This transformation ensures variance stability, reduces potential heteroskedasticity problems, and allows coefficients to be interpreted as elasticities [33]. Such properties are particularly important in long-term sustainability-oriented analyses involving macroeconomic and energy-related variables. The main variables and their definitions are presented in Table 1 below.

Table 1. Variables used in the analysis.

Variable	Explanation	Source
LNGDPPC	GDP per capita (constant LCU)	World Bank
LNFOSSIL	Fossil fuel consumption (TWh)	World Bank
LNRENEW	Total renewable electricity generation (solar, wind, hydro, geothermal, and biomass; TWh)	World Bank
LNCO2PC	Carbon dioxide (CO_2) emissions excluding LULUCF per capita (t CO_2e/capita)	World Bank
LNGFCF	Gross fixed capital formation (constant 2015 US$)	World Bank

The modeling approach employed in logarithmic form is regarded as a standard practice in the econometric literature. This transformation is preferred as it enables the capture of potential nonlinear relationships among variables and allows for a more reliable interpretation of the estimated results. Furthermore, due to data limitations and the relatively small sample size, institutional quality, governance, and human capital indicators are not included in the empirical model. These factors are therefore considered within the broader theoretical and interpretative framework of the study. Although GDP is measured in per capita terms, the energy variables are expressed in aggregate electricity units (TWh) to reflect the macro-scale evolution of Kazakhstan's energy structure. Under the log–log specification, estimated coefficients are interpreted in proportional terms, which reduces sensitivity to differences in measurement units across variables. Nevertheless, future research may consider per capita or intensity-based energy indicators as robustness checks.

3.2. Establishment of the Model

To analyze the short- and long-term relationships among the selected variables, this study adopts the ARDL bounds testing approach developed by Pesaran, Shin, and Smith [34]. The ARDL method is particularly suitable for empirical studies utilizing time series data with a relatively limited number of observations and structural characteristics commonly observed in transition and resource-dependent economies. One of the key advantages of this approach lies in its flexibility: it can accommodate regressors that are integrated of different orders, specifically I(0) and I(1). This feature provides a broader scope of applicability compared to conventional cointegration techniques that require all variables to be stationary at the same order of integration.

Furthermore, the ARDL model offers consistent estimations by accounting for potential endogeneity issues within the system. The methodology simultaneously captures both the short-term dynamics and the long-term equilibrium relationship among the variables, which is particularly relevant for assessing energy transition processes that evolve gradually over time. In this regard, the ARDL framework provides a robust analytical tool for examining short- and long-term relationships among variables, as well as the adjustment process toward equilibrium. The ARDL approach is employed to estimate single-equation short- and long-term relationships and does not aim to test bidirectional causality or structural transmission mechanisms.

$$LNGDPPC_t = \beta_0 + \beta_1 LNFOSSIL_t + \beta_2 LNRENEW_t + \beta_3 LNCO2PC_t + \beta_4 LNGFCF_t + u_t \quad (1)$$

In the model, each coefficient β represents the marginal impact of the respective independent variable on the dependent variable. The subscript t denotes the time dimension, while β_0 is the intercept term, capturing the influence of all other factors not explicitly included in the model. The error term u_t represents the portion of the variance unexplained by the model and measures the deviation between the predicted and observed values. This component is also critical for assessing the overall accuracy of the model and its sensitivity to external shocks. Carbon emissions (LNCO2PC) are included as an environmental control variable to capture the broader energy, economy and environment nexus. While emissions are partly determined by the energy mix and economic activity, their inclusion helps capture the environmental dimension of the energy economy nexus and may reduce omitted-variable concerns related to emission intensity.

The descriptive statistics presented in Table 2 provide essential insights into the distributional characteristics of the variables. The relatively narrow range between the minimum and maximum values indicates that the series exhibit a statistically homogeneous distribution. For the reliable application of parametric tests, it is important that the data approximately follow a normal distribution. In this context, the skewness and kurtosis coefficients were evaluated, revealing that all variables fall within the commonly accepted thresholds of ± 2 for skewness and ± 7 for kurtosis. These results suggest that the data largely satisfy the normality assumption, thereby supporting the validity of the classical regression framework [35]. Descriptive statistics are reported using the maximum available observations for each variable obtained from the database, which in some cases exceed the common estimation window. The econometric analysis, however, is conducted using a balanced sample covering the 1993–2023 period, yielding an effective sample size of 31 observations after aligning all series.

Table 2. Descriptive statistics.

Variable	Obs	Mean	Std. Dev.	Min	Max	Skew.	Kurt.
LNGDPPC	35	13.09	0.421	12.409	13.629	−0.315	1.541
LNFOSSIL	35	6.405	0.263	5.851	6.731	−0.526	2.012
LNRENEW	35	2.169	0.254	1.814	2.893	1.001	3.4
LNCO2PC	34	2.48	0.198	2.125	2.791	−0.291	2.17
LNGFCF	34	23.934	0.69	22.738	24.968	−0.466	1.892

To identify potential multicollinearity among the independent variables, the Variance Inflation Factor (VIF) test was conducted. This diagnostic is a standard procedure used to determine whether explanatory variables are highly correlated with each other. The results reported in Table 3 serve as an important preliminary assessment of the model's statistical reliability and predictive validity.

According to the results of the VIF analysis presented in Table 3, all independent variables have VIF values lower than the critical threshold of 10. This indicates that there is no evidence of severe multicollinearity among the regressors. It is widely accepted in the literature that a VIF exceeding 10 suggests a high degree of linear correlation among variables, which could undermine the statistical reliability of the model [36].

Table 3. Multicollinearity test results.

Variable	VIF	1/VIF
LNGFCF	8.28	0.121
LNCO2PC	5.33	0.188
LNRENEW	4.39	0.228
LNFOSSIL	4.34	0.23
Mean VIF	5.58	

The results in Table 4 are based on the ADF unit root test, which is widely used in the literature to assess the stationarity properties of time series data. Examining the level values of the variables, all corresponding p-values exceed the 5% significance threshold, indicating that the null hypothesis of a unit root (H_0: $\rho = 0$ and $\beta = 0$) cannot be rejected. This implies that the series are non-stationary at levels. However, after taking the first differences, the p-values of the ADF test statistics fall below the 5% significance level, leading to the rejection of the null hypothesis in favor of the alternative, namely that the series are stationary at first differences. The unit root test results indicate that none of the variables are integrated of order two, I(2), thereby satisfying the necessary conditions for the application of the ARDL bounds testing approach.

Table 4. Unit root tests.

Constant		ADF		Trend + Constant	ADF	
		t-stat	Prob		t-stat	Prob
LNGDPPC	Level	−1.197	0.675	Level	−2.388	0.386
	First Difference	−3.434	0.009	First Difference	−3.524	0.037
LNCO2PC	Level	−1.904	0.33	Level	−2.156	0.515
	First Difference	−2.865	0.049	First Difference	−4.41	0.002
LNFOSSIL	Level	−1.353	0.605	Level	−2.705	0.234
	First Difference	−4.321	0.000	First Difference	−4.86	0.000
LNRENEW	Level	−0.009	0.958	Level	−1.602	0.792
	First Difference	−4.008	0.001	First Difference	−4.32	0.003
LNGFCF	Level	−0.736	0.837	Level	−3.047	0.119
	First Difference	−4.578	0.000	First Difference	−3.746	0.019

Having established that none of the variables is integrated of order two, the ARDL bounds testing approach can be reliably applied to examine the existence of a long-term equilibrium relationship. The first step in estimating the long-term parameters of the model involves determining the optimal lag length. Correct lag selection is critical not only to accurately capture the dynamic structure of the model, but also to prevent potential issues such as autocorrelation. The results concerning the optimal lag structure used in this study are reported in Table 5.

Table 5. ARDL bounds test.

Statistic	I(0) 5%	I(1) 5%	I(0) 1%	I(1) 1%	Prob I(0)	Prob I(1)
F test	4.151	5.888	6.154	8.519	0.000	0.001
t test	−3.429	−4.475	−4.308	−5.514	0.236	0.513

The ARDL bounds testing results presented in Table 5 provide preliminary evidence regarding the existence of a long-term relationship among the model variables. Under the selected ARDL(3,3,0,2,0) specification, the computed F-statistic (4.151) falls below the upper critical bound value at the 5% significance level for I(1) (5.888), indicating that the bounds test does not provide conclusive evidence of cointegration under conventional decision rules. However, the subsequent Error Correction Model (ECM) estimation reveals a negative and statistically significant error correction term, suggesting the presence of a stable adjustment mechanism toward long-term equilibrium. Therefore, the existence of a long-term relationship is interpreted with caution and supported primarily by the ECM results rather than the bounds test alone.

The analysis subsequently proceeds with the estimation of a single-equation ARDL model extended through an Error Correction Model (ECM) representation. This specification allows for the examination of short-term adjustment dynamics and the potential existence of a long-term equilibrium relationship among the variables. In light of the inconclusive bounds test results, the ECM specification provides additional evidence regarding the adjustment process toward equilibrium. Table 6 reports the estimated short-term ECM results based on the ARDL(3,3,0,2,0) specification, together with diagnostic test outcomes assessing the model's statistical adequacy and structural stability.

The ARDL(3,3,0,2,0) estimation results reported in Table 6 provide suggestive evidence of long-term associations among per capita income, energy variables, and investment, which should be interpreted cautiously given the inconclusive bounds test results between per capita real income, energy components, and the level of investment. The model's ECM is estimated at −0.226, which is statistically significant and exhibits the expected (negative) sign. This finding suggests that approximately 22.6% of short-term disequilibria are corrected each year, implying that the system steadily reverts to its long-term equilibrium path. In other words, the half-life of the model is calculated to be around 2.7 years, indicating that short-term shocks are not persistent and tend to dissipate over time.

Since the model is estimated in a log–log specification, the long-term coefficient estimates can be interpreted as elasticities. The results suggest that a 1% increase in fossil fuel consumption (LNFOSSIL) is associated with an approximately 1.5% decrease in per capita income in the long run. This negative association is consistent with the "resource curse" and "Dutch disease" literature, which emphasize the potentially adverse growth effects of excessive dependence on fossil fuel–based energy structures.

In contrast, the estimated coefficients for renewable energy production (LNRENEW) and per capita carbon emissions (LNCO2PC) are −0.437 and 0.178, respectively, and neither is statistically significant. These findings suggest that, within the sample period, renewable energy production and carbon emissions do not exhibit a statistically robust association with per capita income in the long run. By comparison, the coefficient of gross fixed capital formation (LNGFCF) is positive and marginally significant, indicating that investment is positively associated with productive capacity and economic performance over the long term.

Diagnostic tests were conducted to evaluate the adequacy and stability of the estimated model. The Breusch–Godfrey LM test indicates no statistically significant serial correlation at the first and second lag levels, while only a marginal signal appears at the third lag, which does not point to a systematic autocorrelation problem in the model specification. The Breusch–Pagan/Cook–Weisberg test (p = 0.559) fails to reject the null hypothesis of homoskedasticity, suggesting that the variance of the error terms is stable over the sample period. Furthermore, the CUSUM stability test shows that the model coefficients remain within the critical bounds, indicating parameter stability throughout the estimation horizon. Overall, these diagnostic results provide supportive evidence regarding the adequacy and robustness of the estimated model.

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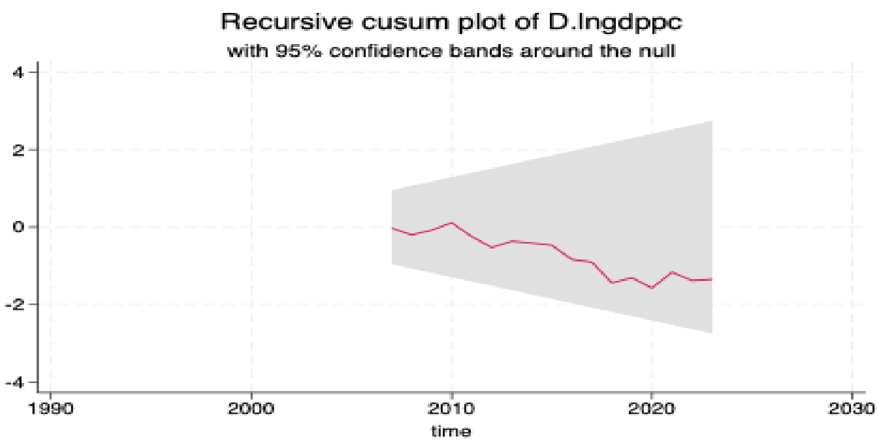
Table 6. Short-Term ECM.

Term	Coef.	Robust SE	t	*p*-Value
(ECM)	−0.226	0.093	−2.43	0.027
LR				
LNFOSSIL	−1.523	0.666	−2.290	0.035
LNRENEW	−0.437	0.278	−1.570	0.134
LNCO2PC	0.178	0.342	0.520	0.610
LNGFCF	0.340	0.172	1.980	0.064
SR				
$\Delta LNGDP_{t-1}$	−0.085	0.186	−0.460	0.654
$\Delta LNGDP_{t-2}$	−0.469	0.145	−3.240	0.005
$\Delta LNFOSSIL$	0.575	0.097	5.92	0.000
$\Delta LNFOSSIL_{t-1}$	0.366	0.1	3.64	0.002
$\Delta LNFOSSIL_{t-2}$	0.201	0.062	3.25	0.005
$\Delta LNCO2PC$	−0.161	0.077	−2.09	0.052
$\Delta LNCO2_{t-1}$	−0.203	0.075	−2.69	0.015
Constant	−16.99	4.224	−4.02	0.001
R^2				0.89
Root MSE				0.0176
N				31
Breusch-Godfrey LM Autocorrelation Test				
Lags	Prob			
1	0.366			
2	0.595			
3	0.05			
Note: H0: no serial correlation				
Breusch–Pagan/Cook–Weisberg Heteroskedasticity Test				
Chi2	Prob			
0.34	0.559			
Note: H0: Constant variance (Homoskedasticity)				
Parameter Stability CUSUM Test				



Overall, the findings suggest that over the 1993–2023 period, Kazakhstan's fossil fuel-dependent growth pattern is associated with lower levels of per capita income in the long run despite providing certain short-term economic benefits. By contrast, capital formation appears to be positively associated with economic performance, highlighting the potential role of infrastructure investment and capacity expansion in supporting long-term growth. The negative and statistically significant ECM coefficient indicates the presence of a gradual adjustment process, implying that short-term deviations tend to diminish over time. However, this adjustment mechanism should be interpreted cautiously and as indicative of convergence dynamics rather than definitive evidence of a fully stable long-term equilibrium relationship.

4. Conclusions and Policy Implications

This study employed the ARDL bounds testing approach to estimate the short- and long-term associations between fossil fuel consumption, renewable energy production, and economic growth in Kazakhstan over the period 1993–2023 within the broader framework of the resource curse literature and the energy–growth nexus. The primary objective was to assess whether Kazakhstan's current energy structure is associated with long-term sustainable economic performance.

The empirical findings suggest that fossil fuel consumption is negatively associated with per capita income in the long run, which is broadly consistent with the resource curse hypothesis in the context of Kazakhstan. This result indicates that continued reliance on fossil fuels may be linked to less favorable economic performance patterns over time. In contrast, renewable energy production does not exhibit a statistically significant association with economic growth within the sample period. While the estimated coefficient is not statistically significant, the findings imply that the growth contribution of renewable energy production may still be limited during the early stages of the energy transition process. Accordingly, the empirical evidence supports H1, whereas H2 is not supported for the sample period due to the statistical insignificance of the renewable energy coefficient in the long-term specification.

To provide an economic interpretation of this negative relationship, heavy dependence on fossil fuels may crowd out productive investments in diversified sectors, reduce incentives for technological upgrading, and reinforce sectoral concentration in extractive industries. Such structural dynamics can weaken long-term productivity growth and limit economic diversification, thereby constraining sustainable economic performance over time.

Overall, the results indicate that Kazakhstan's existing energy structure is more closely associated with constraints on sustainable economic growth than with growth-enhancing dynamics. However, this outcome should not be interpreted as an inherent limitation of renewable energy itself. Rather, it reflects the transitional nature of the current energy transformation process. In this regard, institutional quality, investment capacity, and policy coherence are discussed as contextual factors that may shape the effectiveness of renewable energy development, although they are not directly tested within the empirical specification.

A limitation of this study is the exclusion of institutional quality, governance, and human capital indicators due to data constraints and the relatively small sample size. Future research may incorporate these dimensions to provide a more comprehensive empirical assessment of the transmission channels linking energy structure and economic growth.

From a policy perspective, the findings highlight the importance of gradually reducing dependence on fossil fuels through subsidy reforms, carbon pricing mechanisms, and the strategic reinvestment of hydrocarbon revenues into diversified and productive sectors.

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Strengthening the regulatory and institutional environment supporting renewable energy production is also likely to be important for enhancing long-term investment incentives. Improving grid infrastructure, ensuring transparent and stable policy frameworks, and expanding renewable energy production capacity may help facilitate a more effective energy transition.

More specifically, given the positive long-term association between gross fixed capital formation and economic growth, the empirical findings suggest that redirecting resource rents toward productive investment may constitute a key policy channel for overcoming the growth constraints associated with fossil fuel dependence. In this regard, the establishment of sovereign wealth fund rules targeting infrastructure, industrial upgrading, and green technology investments, as well as fiscal frameworks linking hydrocarbon revenues to public capital expenditure, could help transform resource revenues into long-term productive capacity.

In addition, integrating human capital development into national energy strategies could support the transformation of renewable energy production into productivity gains over time. Investments in education, vocational training, and research capacity related to green technologies may contribute to improving the long-term economic benefits of the energy transition. Finally, enhancing institutional coordination and data transparency could support more evidence-based policymaking and improve accountability throughout the energy transition process. Taken together, these measures are important for aligning Kazakhstan's energy transformation with long-term sustainable development objectives and for addressing the structural challenges associated with resource dependence.

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