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Assessing the Dynamic Linkages between External Debt, Energy Consumption, Inflation, and Oil Prices in Kazakhstan: An Autoregressive Distributed Lag Analysis

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ABSTRACT

This study investigates the dynamic linkages between external debt, energy consumption, inflation, and oil prices in Kazakhstan over the period 2001-2024. By applying the Autoregressive Distributed Lag (ARDL) framework, the research uncovers both short- and long-run interactions among these variables. The findings demonstrate that oil prices exert a strong and persistent positive influence on inflation, reflecting Kazakhstan's structural dependence on global energy markets. In contrast, energy consumption - particularly with a lagged effect - contributes to moderating inflationary pressures, underscoring the role of efficient energy use in stabilizing prices. The results also reveal that external debt, while less significant in the short term, remains a long-run concern due to its potential to weaken resilience if not managed prudently. Diagnostic and stability tests confirm the robustness of the model, highlighting the presence of a stable long-run equilibrium. Policy implications point to the importance of countercyclical fiscal and monetary strategies to cushion oil price shocks, investment in energy efficiency to align growth with sustainability, and prudent debt management to safeguard macroeconomic stability. Overall, the study emphasizes the need for Kazakhstan to diversify its growth model while maintaining stability in the face of global energy transitions and external vulnerabilities.

Keywords: External Debt, Energy Consumption, Inflation, Oil Prices, Kazakhstan, ARDL
JEL Classifications: C32, F34, Q43, O53

1. INTRODUCTION

Kazakhstan's economy rests on a delicate balance between its abundant natural resources and growing domestic demand, both of which shape the country's macroeconomic trajectory. This dual reliance creates resilience in some areas but also exposes vulnerabilities, as the interaction between external debt, energy consumption, inflation, and oil prices increasingly defines economic stability. Oil exports remain the cornerstone of fiscal revenues, while energy use expands alongside industrial development. Yet, persistent inflationary pressures and the accumulation of external debt raise legitimate concerns about long-term sustainability and diversification.

A considerable body of research points to the pervasive role of oil price volatility in shaping Kazakhstan's economic structure. Oil price shocks have been shown to exert asymmetric effects on agricultural and industrial production, transmitting global instability into domestic performance (Baisholanova et al., 2025; Talimova et al., 2025). Financial markets further amplify this sensitivity, as evidence demonstrates that stock returns of energy companies on the Kazakhstan Stock Exchange respond sharply to shifts in global oil and gold prices, underscoring the country's exposure to commodity cycles (Sultanova et al., 2024).

Energy consumption - both traditional and renewable - remains another critical pillar of Kazakhstan's growth. Studies highlight its strong connections to industrial output and agricultural productivity, confirming its importance as a driver of sustainable development (Abdibekov et al., 2024; Aidarova et al., 2024). Regionally, energy use has been identified as a key determinant of economic performance in Kazakhstan and Azerbaijan, while renewable energy adoption increasingly links growth to environmental quality and sustainability (Lukhmanova et al., 2025; Pirmanova et al., 2025). These findings highlight the challenge of balancing economic expansion with ecological priorities.

External debt and capital flows add further complexity to Kazakhstan's macroeconomic landscape. Evidence suggests that energy consumption, resource income, and foreign direct investment often have a stronger influence on growth than debt accumulation, implying that reliance on borrowing without diversification may heighten vulnerability (Baimagambetova et al., 2025; Ibyzhanova et al., 2024). Moreover, the close interconnectedness between exchange rates, stock returns, and energy company performance reveals the depth of Kazakhstan's integration into global financial and commodity markets (Sabenova et al., 2024).

Placed in a wider international context, Kazakhstan's experience reflects common challenges faced by resource-dependent economies. Historically, oil price shocks have triggered inflationary pressures and economic downturns (Hamilton, 2009). Global evidence shows that such shocks transmit through inflation and interest rate channels, shaping outcomes in both advanced and emerging markets (Ratti and Vespignani, 2016). Likewise, the long-run relationship between energy consumption and economic growth has been found to persist across both oil exporters and importers, pointing to the universality of energy-growth-inflation linkages (Apergis and Payne, 2014).

In sum, the interplay between external debt, energy consumption, inflation, and oil prices forms the backbone of Kazakhstan's macroeconomic performance. Understanding these dynamic linkages is essential not only for evaluating the country's exposure to external shocks but also for assessing inflationary dynamics and the sustainability of its growth model in the face of rising debt and global energy transitions.

2. LITERATURE REVIEW

The literature provides extensive evidence on the dynamic linkages between oil prices, inflation, and energy use, as well as the role of external debt in shaping macroeconomic stability. In this section, we focus only on the studies most relevant to the objectives of our research.

Anderl and Caporale (2023) explored how economic policy uncertainty and oil price volatility shape inflation across advanced and emerging economies using nonlinear ARDL techniques. Their findings reveal an asymmetric pass-through effect, with negative policy shocks generating stronger and more persistent inflationary pressures than positive shocks. Importantly, the authors highlight that transparent and credible policy communication can act as a stabilizing force, mitigating the transmission of oil market volatility into domestic prices.

Bouzidi et al. (2024) investigated the impact of global oil price shocks on inflation and banking sector efficiency in Saudi Arabia through panel ARDL and NARDL approaches. The results demonstrate that positive oil shocks exert a more significant upward pressure on inflation and banking efficiency than the corrective effect of negative shocks. This asymmetry underscores the importance of adopting proactive macro-financial policies to limit the destabilizing consequences of oil-driven inflation.

Sultana et al. (2024) examined the interplay between external debt, exchange rate fluctuations, and foreign portfolio investment in a panel ARDL framework. The study shows that rising external debt and adverse currency movements reduce capital inflows, while simultaneously heightening inflationary pressures in fragile economies. The authors conclude that strong debt management practices and credible exchange rate policies are essential to safeguard price stability in such contexts.

Abbas and Christensen (2010) assessed the relationship between public debt and economic growth across a broad sample of countries using nonlinear panel regressions. They reported that the debt–growth nexus is concave, meaning that beyond a certain threshold, debt accumulation produces disproportionately adverse effects on growth. The study further highlights that the maturity structure and composition of debt condition how economies respond to external shocks, including commodity price volatility.

Afonso and Jalles (2015) analyzed fiscal policy, public debt, and macroeconomic outcomes across OECD and emerging economies using panel regression methods. Their research demonstrates that high debt levels combined with procyclical fiscal behavior weaken growth and intensify inflation's sensitivity to external disturbances. The study also points to the importance of sound fiscal frameworks in mitigating the inflationary effects of commodity shocks.

Cao et al. (2025) focused on whether oil price shocks anchor inflation dynamics in G20 economies, employing ARDL bounds testing and dynamic simulated ARDL methods. They established that oil prices maintain a long-run linkage with inflation and that the direction and persistence of shocks crucially determine the extent of pass-through. Their evidence emphasizes the significance of distinguishing between short- and long-term effects when analyzing oil-driven inflation.

Apergis and Payne (2014) investigated the dynamic linkages among energy consumption, GDP, emissions, and oil prices in OECD countries using panel cointegration and error-correction models. They discovered a bidirectional causality between energy use and growth, indicating that energy consumption both drives and constrains long-term economic expansion. Furthermore, the study highlights that oil prices remain embedded in the long-run growth–inflation nexus, reinforcing their role as a structural determinant.

Zhang et al. (2024) examined the relationship between renewable energy consumption and inflation in G7 economies using ARDL analysis. They found strong evidence of a long-run cointegrating relationship in which greater reliance on renewable energy helps dampen inflationary pressures. In addition, short-run adjustments were observed following energy price fluctuations, with the deflationary effect of renewables particularly pronounced in economies with advanced financial markets and flexible pricing structures.

3. METHODS

The Autoregressive Distributed Lag (ARDL) approach, originally introduced by Pesaran and Shin (1995) and later refined by Pesaran et al. (2001), has become one of the most widely used tools in applied econometrics. Unlike conventional cointegration techniques such as the Engle-Granger or Johansen methods, which require all variables to be integrated at the same order, the ARDL bounds testing framework offers greater flexibility by allowing variables integrated at I(0) and I(1) to be analyzed together, provided that none are I(2). This advantage is particularly relevant in macroeconomic research, where variables often display different orders of integration (Narayan and Narayan, 2005). Another strength of the ARDL approach is its suitability for small sample sizes, which makes it especially valuable for studies based on annual data.

The general ARDL model with multiple regressors can be expressed as follows:

$$\Delta Y_t = a_0 + \sum_{i=0}^{m} a_{1i}\Delta Y_{t-i} + \sum_{i=0}^{m} a_{2i}\Delta M_{t-i} + \sum_{i=0}^{m} a_{3i} EY_{t-i} + a_{4i}\Delta Y_{t-1} + a_{5i}\Delta M_{t-1} + a_{6i}\Delta E_{t-1} + u_t \quad (1)$$

Where Y is the dependent variable, M and E are explanatory variables, Δ denotes first differences, and μ_t is the error term. This formulation captures both short-run dynamics and long-run relationships simultaneously within a single framework.

The estimation of an ARDL model typically involves two stages. First, the existence of a long-run relationship among the variables is examined using the bounds testing procedure, which relies on the F-statistic. According to Pesaran et al. (2001), if the F-statistic exceeds the upper bound critical value (I(1)), cointegration is confirmed; if it falls below the lower bound (I(0)), no cointegration exists; and if it lies between the bounds, the outcome remains inconclusive. If a long-run relationship is established, the second stage estimates the long-run coefficients alongside the short-run dynamics through the associated error correction model (ECM).

Before applying ARDL, the stationarity properties of the variables must be tested. Unit root tests such as the Augmented Dickey-Fuller (ADF) or Phillips-Perron are commonly used to confirm that none of the series is I(2). Once this is ensured, the optimal lag length for each variable is determined using criteria such as the Akaike Information Criterion (AIC), Schwarz Bayesian Criterion (SBC), Hannan-Quinn Criterion (HQ), or the Log-likelihood (LogL). Choosing the correct lag structure is essential to avoid model misspecification and to ensure efficient estimation (Narayan and Smyth, 2006).

After the model is estimated, several diagnostic checks are conducted to confirm its reliability. These include the Breusch-Godfrey LM test for serial correlation, the Breusch-Pagan-Godfrey or White test for heteroskedasticity, and the Ramsey RESET test to assess functional form specification. The stability of the estimated coefficients is further evaluated using the CUSUM and CUSUMSQ tests developed by Brown et al. (1975), which provide graphical evidence of structural stability across the sample period.

4. FINDINGS

This study explores the dynamic relationships between inflation, external debt, energy consumption, and oil prices in Kazakhstan. Inflation, measured by the GDP deflator, is employed as the dependent variable, since it captures overall price movements and serves as a key indicator of macroeconomic stability. External debt is incorporated to evaluate the influence of foreign liabilities on domestic economic performance. Energy consumption, expressed in kilograms of oil equivalent per capita, is used as a proxy for both domestic demand and productive capacity. Finally, oil price, measured by Brent crude prices in USD per barrel, is included as a critical global determinant, reflecting Kazakhstan's dependence on hydrocarbon exports and its exposure to international price fluctuations.

Brief descriptions of the research variables and data sources are given in Table 1. The analysis period covers the years 2001-2024. The research data were obtained from the websites https://data.worldbank.org, https://nationalbank.kz, and https://www.eia.gov (Date of access: September 27, 2025).

Descriptive and distribution statistics of the research variables are given in Table 2. Over the observation period, inflation (INFR)

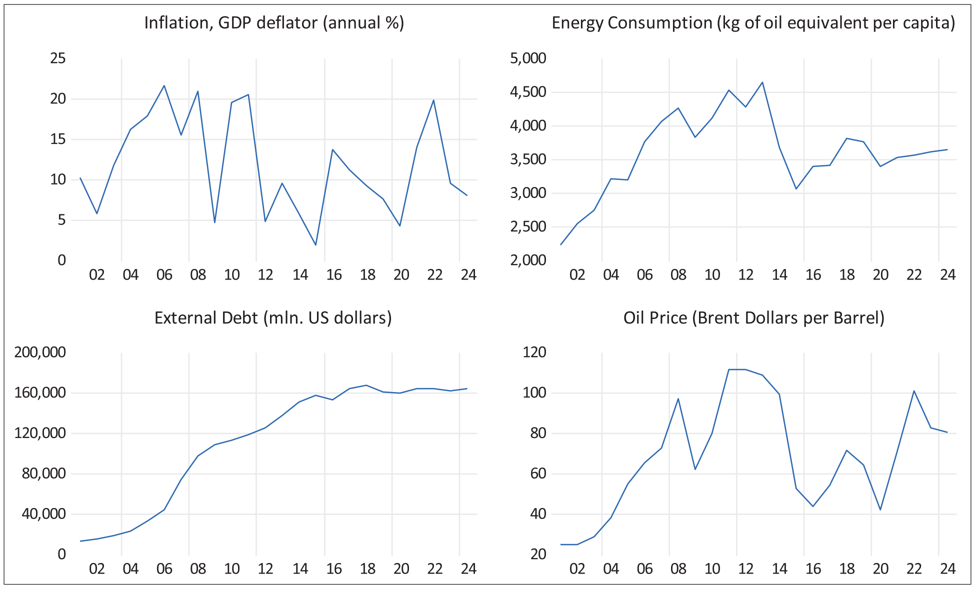
Table 1: Variable definitions and sources

Variable	Short Description	Source
INFR	Inflation, GDP deflator (annual %)	https://data.worldbank.org
EXDT	External Debt (mln. US dollars)	https://nationalbank.kz
ENRC	Energy Consumption (kg of oil equivalent per capita)	https://data.worldbank.org
OPRC	Oil Price (Brent Dollars per Barrel)	https://www.eia.gov

Table 2: Descriptive statistics findings of variables

Statistics	INFR	EXDT	ENRC	OPRC
Mean	11.81442	11.37426	8.171857	4.134719
Median	10.68377	11.78289	8.196166	4.218776
Maximum	21.55171	12.02864	8.443715	4.715190
Minimum	1.823550	9.444192	7.704171	3.197039
Standard Deviation	6.031772	0.864037	0.175674	0.455990
Skewness	0.187211	−1.196417	−0.872405	−0.648306
Kurtosis	1.809178	2.878372	3.700138	2.521394
Jarque-Bera	1.558249	5.740444	3.354555	1.910268
Probability	0.458808	0.056686	0.170797	0.384761

Graph 1: Time path graph of variables



averaged 11.81%, external debt (EXDT) was 11.37, energy consumption (ENRC) stood at 8.17, and the average oil price (OPRC) was 4.13. The Jarque-Bera test results confirm that all four variables are normally distributed, supporting their use in subsequent econometric modeling.

Graph 1 presents the time path of the research variables. Inflation (INFR) shows considerable volatility, with notable peaks above 20% in the mid-2000s and again in 2022, reflecting episodes of macroeconomic instability. Energy consumption (ENRC) followed a steady upward trend until 2012, after which it leveled off, fluctuating between 3,500 and 4,000 kg of oil equivalent per capita. External debt (EXDT) rose sharply from <40,000 million USD in 2002 to nearly 160,000 million USD by 2014, before stabilizing at relatively high levels. Oil prices (OPRC) mirrored global market cycles, climbing from 25 USD per barrel in 2002 to more than 110 USD in 2012-2013, then falling sharply and settling around 80-90 USD in recent years. Taken together, the graph illustrates strong volatility in inflation (INFR) and oil prices (OPRC), the sustained accumulation of external debt (EXDT), and the slowing pace of energy consumption (ENRC) growth - factors that underscore the relevance of employing ARDL analysis to capture both short- and long-run dynamics.

Augmented Dickey-Fuller (ADF) unit root test findings for the variables are given in Table 3. The findings indicate that inflation (INFR), external debt (EXDT), and energy consumption (ENRC) are stationary at their levels, as their test statistics exceed the critical values at the 5% significance level. In contrast, oil prices (OPRC) are non-stationary in levels but become stationary after first differencing, implying that this variable is integrated of order one, I(1). Overall, the results confirm that the variables under study consist of a mix of I(0) and I(1) processes, while none are integrated at order two. This validates the use of the ARDL bounds testing framework, which is particularly suitable for datasets with regressors of different integration orders.

Table 3: Augmented Dickey-Fuller unit root test findings of variables

Variable	Level		First diference	
	t-Statistics	P-value	t-Statistics	P-value
INFR	−3.744834	0.0102	−5.205479	0.0004
EXDT	−14.46498	0.0000	−1.599123	0.4662
ENRC	−3.150008	0.0367	−4.346751	0.0028
OPRC	−2.363758	0.1622	−4.101134	0.0051
Test critical values				
1% level	−3.752946		−3.788030	
5% level	−2.998064		−3.012363	
10% level	−2.638752		−2.646119	

The selection criteria for alternative ARDL model specifications are given in Table 4. The comparison across LogL, AIC, BIC, and HQ values highlights ARDL(2,3,1,1) as the preferred specification, since it yields the lowest AIC alongside consistent performance across the other criteria. In addition, this specification records the highest adjusted R^2 value (0.7197), reinforcing its suitability. Taken together, these results indicate that ARDL(2,3,1,1) provides the best balance of explanatory power and efficiency, and it is therefore selected for the subsequent empirical analysis.

The results of the ARDL bounds test used to examine the presence of a long-run equilibrium relationship are given in Table 5. The calculated F-statistic of 8.73 is well above the upper critical bound value of 4.66 at the 1% significance level. This finding strongly rejects the null hypothesis of no cointegration and provides clear evidence of a stable long-run relationship among inflation (INFR), external debt (EXDT), energy consumption (ENRC), and oil prices (OPRC). Consequently, the study proceeds with the estimation of the ARDL long-run form together with the corresponding error correction model (ECM) to capture both short-run adjustments and long-run dynamics.

The ARDL regression model findings for the relationship between inflation (INFR), external debt (EXDT), energy consumption

Table 4: Autoregressive distributed lag model selection criterion values

Model specification	LogL	AIC: Akaike information criterion	BIC: Bayesian Information Criterion	HQ: Hannan-Quinn information criterion	Adjusted R^2
ARDL(2, 3, 1, 1)	−47.317944	5.554090	6.101221	5.672831	0.719768
ARDL(1, 2, 3, 1)	−47.490232	5.570498	6.117629	5.689240	0.715132
ARDL(1, 2, 3, 3)	−46.062373	5.624988	6.271597	5.765319	0.689190
ARDL(2, 3, 1, 2)	−47.153748	5.633690	6.230560	5.763226	0.693462
ARDL(3, 3, 1, 1)	−47.169021	5.635145	6.232015	5.764681	0.693016
ARDL(1, 2, 3, 2)	−47.202797	5.638362	6.235232	5.767898	0.692027
ARDL(1, 3, 3, 1)	−47.236163	5.641539	6.238409	5.771075	0.691047
ARDL(2, 3, 2, 1)	−47.258728	5.643688	6.240558	5.773224	0.690382
ARDL(2, 3, 1, 0)	−49.287083	5.646389	6.143780	5.754336	0.692694
ARDL(3, 2, 3, 1)	−46.295402	5.647181	6.293790	5.787512	0.682215

Table 5: Autoregressive distributed lag bounds test findings

Test Statistic	Value	Signif.	I (0)	I (1)
F-statistic	8.732249	10%	2.37	3.2
k	3	5%	2.79	3.67
-	-	2.5%	3.15	4.08
-	-	1%	3.65	4.66

(ENRC), and oil prices (OPRC) are given in Table 6. The findings highlight two key relationships: oil prices (OPRC) exert a significant positive influence on inflation (INFR), while energy consumption (ENRC), with a one-year lag, has a negative effect. These results suggest that increases in global oil prices (OPRC) translate into higher domestic inflation (INFR), whereas greater energy consumption (ENRC) contributes to easing price pressures over time. The model exhibits strong explanatory power, with an adjusted R-squared of 0.719, indicating that nearly 72% of the variation in inflation (INFR) is explained by the included variables. Moreover, the significance of the F-statistic at the 1% level confirms the robustness of the estimated specification.

The diagnostic test outcomes for the ARDL model are given in Table 7. The Breusch-Godfrey LM test shows no evidence of serial correlation, and the Breusch-Pagan-Godfrey test confirms the absence of heteroskedasticity, indicating that the residuals are well-behaved. Furthermore, the Jarque-Bera test result suggests that the residuals follow a normal distribution. While the Ramsey RESET test points to potential specification issues, the overall diagnostics support the robustness and reliability of the estimated model, allowing for meaningful interpretation of the identified short- and long-run relationships.

The outcomes of the CUSUM and CUSUMSQ stability tests for the ARDL model are presented graphically in Graph 2. The CUSUM plot indicates that the cumulative residuals remain within the 5% significance bounds throughout the sample, confirming the stability of the estimated parameters. Likewise, the CUSUMSQ test shows no evidence of structural breaks, as the squared residuals also lie within the confidence limits. Taken together, these results demonstrate that the ARDL model is dynamically stable and that the estimated relationships are robust for both short- and long-run analysis.

The observed, fitted, and residual values derived from the ARDL model are given in Graph 3. The fitted values replicate the actual inflation trend closely, with particularly strong consistency during 2006-2012 and again in 2018-2022. Minor discrepancies appear in 2013-2015 and around 2020, which can be attributed to short-term shocks; however, residuals remain centered around zero and show no systematic bias. These results highlight the model's ability to capture the main dynamics of inflation and confirm its reliability for both short- and long-run analysis.

Table 6: Autoregressive distributed lag regression model findings

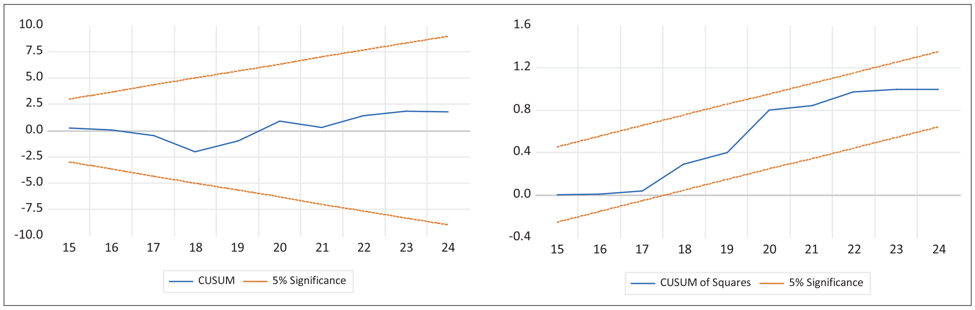
Variable	Coefficient	Std. Error	t-Statistic	Prob.
INFR(−1)	−0.169092	0.164844	−1.025767	0.3292
INFR(−2)	−0.283353	0.171465	−1.652541	0.1294
L_EXDT	−0.711122	11.18272	−0.063591	0.9505
L_EXDT(−1)	10.75597	17.01162	0.632272	0.5414
L_EXDT(−2)	6.164013	18.67609	0.330048	0.7482
L_EXDT(−3)	−16.45371	10.54114	−1.565359	0.1486
L_ENRC	16.09955	13.44489	1.197447	0.2587
L_ENRC(−1)	−37.19915	13.44482	−2.766802	0.0199
L_OPRC	17.73486	5.346129	3.317327	0.0078
L_OPRC(−1)	−6.530300	4.546843	−1.436227	0.1815
C	142.3790	109.8047	1.296656	0.2239
R-squared	0.859884	Mean dependent var		12.18323
Adjusted R-squared	0.719768	S.D. dependent var		6.304945
S.E. of regression	3.337645	Akaike info criterion		5.554090
Sum squared resid	111.3988	Schwarz criterion		6.101221
Log likelihood	−47.31794	Hannan-Quinn criterion		5.672831
F-statistic	6.136943	Durbin-Watson stat		2.292347
Prob (F-statistic)	0.004154			

Table 7: Autoregressive distributed lag diagnostic test findings

Test	Statistics	Prob.
Breusch-Godfrey Serial Correlation LM Test	F-statistic: 1.577821	Prob. F (2,8): 0.2645
Heteroskedasticity Test: Breusch-Pagan-Godfrey	F-statistic: 0.591257	Prob. F (10,10): 0.7899
Ramsey RESET test	F-statistic: 6.208055	Prob. F (1, 9): 0.0343
Test of normality	Jarque-Bera: 0.142404	Prob.: 0.931274

The short-run estimates of the ARDL error correction model are given in Table 8. The findings indicate that past inflation (D(INFR(-1))) exerts a positive influence on current inflation (INFR), while both energy consumption (D(L_ENRC)) and oil prices (D(L_OPRC)) emerge as significant short-run determinants,

Graph 2: 95% confidence interval for CUSUM and CUSUMSQ test



Graph 3: Time path chart for observation values and prediction and error values according to the Autoregressive Distributed Lag model

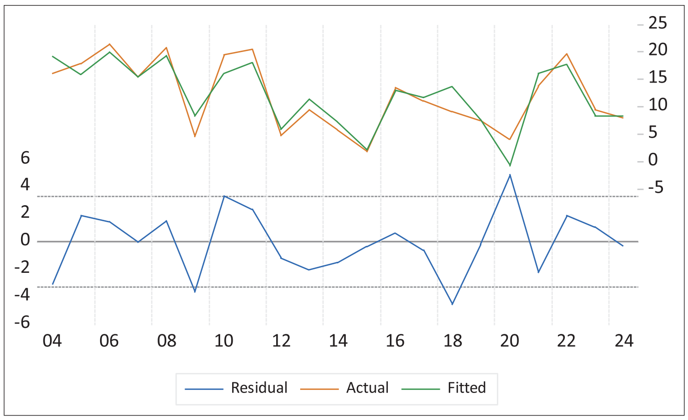


Table 8: Autoregressive Distributed Lag error correction regression model findings

Variable	Coefficient	Standard error	t-Statistic	Prob.
D(INFR(−1))	0.283353	0.120117	2.358975	0.0400
D(L_EXDT)	−0.711122	7.181956	−0.099015	0.9231
D(L_EXDT(−1))	10.28970	8.470750	1.214733	0.2524
D(L_EXDT(−2))	16.45371	7.483375	2.198702	0.0526
D(L_ENRC)	16.09955	7.964516	2.021410	0.0708
D(L_OPRC)	17.73486	3.054533	5.806077	0.0002
CointEq(−1)*	−1.452445	0.185775	−7.818295	0.0000
R-squared	0.913352	Mean dependent var		−0.175662
Adjusted R-squared	0.876217	S.D. dependent var		8.017627
S.E. of regression	2.820825	Akaike info criterion		5.173138
Sum squared resid	111.3988	Schwarz criterion		5.521312
Log likelihood	−47.31794	Hannan-Quinn criterion		5.248700
Durbin-Watson stat	2.292347			

with oil prices (OPRC) showing the strongest effect. The error correction term (CointEq(−1)) is negative and highly significant (−1.45), providing strong evidence of a long-run equilibrium and suggesting a rapid adjustment of deviations back to stability. The model demonstrates strong explanatory capacity, with an adjusted R-squared of 0.876, while the Durbin-Watson statistic (2.29) confirms the absence of serial correlation. Overall, the results underline the pivotal role of oil prices (OPRC) and energy consumption (ENRC) in driving short-run inflation (INFR), while the significant error correction term reinforces the presence of a stable long-run relationship.

5. CONCLUSION AND RECOMMENDATIONS

This study analyzed the dynamic interplay between inflation, external debt, energy consumption, and oil prices in Kazakhstan for the period 2001-2024 through the ARDL bounds testing framework. The results confirmed the existence of a stable long-run relationship among the variables. Oil prices were found to exert a strong positive effect on inflation, reflecting Kazakhstan's high exposure to fluctuations in global energy markets. By contrast, energy consumption displayed a negative impact, suggesting that greater efficiency in energy use helps to moderate inflationary pressures. The persistence of past inflation reinforces current trends, while the significant and negative error correction term confirms a rapid adjustment process toward equilibrium, underscoring long-run stability.

From a policy perspective, several implications emerge. First, Kazakhstan must reduce its vulnerability to oil price shocks through countercyclical fiscal and monetary policies, including building fiscal buffers during boom periods and adopting targeted measures to stabilize inflation during downturns. Second, investing in energy efficiency and infrastructure would both stimulate growth and contribute to price stability, aligning with sustainable development goals. Finally, although external debt was not a dominant short-run driver of inflation, its continued accumulation requires prudent management to ensure that borrowing is directed toward productive sectors capable of strengthening long-term resilience.

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