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Governance Quality and Gas Flaring in Algeria: Asymmetric Effects and Dynamic Responses

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Abstract:
This study aims to analyze the asymmetric effects of governance quality on gas flaring in Algeria over the period 1996–2025 by distinguishing between the effects of improvements (GQ^+) and deteriorations (GQ^-) in governance quality and simulating the dynamic response of gas flaring to positive and negative governance shocks, while controlling for oil production, natural gas production, and economic growth. The significance of the study stems from Algeria's position as one of the world's major hydrocarbon exporters and a leading contributor to global gas flaring, as well as from the research gap arising from the limited evidence on the asymmetric effects of governance on this phenomenon specifically in Algeria. The study employs the NARDL approach, followed by **Dynamic ARDL (DYNARDL)** simulations, to trace the temporal path of gas flaring responses. The results reveal a strong cointegrating relationship among the variables, while the Wald test confirms statistically significant asymmetry between the effects of governance improvements and deteriorations on gas flaring. The DYNARDL simulations further reveal two clearly contrasting dynamic response paths of gas flaring to positive and negative shocks in governance quality, confirming that the direction of the governance shock shapes the dynamic trajectory of gas flaring.
Keywords: Gas flaring, Governance quality, DYNARDL model, Asymmetry, Algeria.
JEL Classification Codes : Q48; C22; O43

1. INTRODUCTION

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The persistent global reliance on fossil fuels has contributed to the continued practice of natural gas flaring, one of the major sources of environmental and economic waste associated with oil and gas production. Gas flaring involves the combustion of natural gas associated with oil production rather than its utilization, transportation, or reinjection. According to the Global Gas Flaring Reduction Partnership (GGFR), in collaboration with the International Association of Oil & Gas Producers (IOGP) and the International Petroleum Industry Environmental Conservation Association (IPIECA), global gas flaring remains close to 142 billion cubic meters annually, a volume sufficient to supply energy to Sub-Saharan Africa, despite the World Bank's initiative to "End Routine Gas Flaring by 2030" (Global Gas Flaring Reduction Partnership (GGFR), 2021). The persistence of flaring is generally associated with inadequate infrastructure for collecting, processing, and transporting associated gas, as well as weaknesses in regulatory and institutional frameworks in hydrocarbon-producing countries.

Algeria represents an important case in this context because of its strong dependence on the hydrocarbon sector and its position among the world's major gas-flaring countries. According to (Ouki, M, 2019), Algeria flared approximately 9 billion cubic meters of gas in 2018, equivalent to around one-fifth of domestic gas consumption, making it the second-largest gas-flaring country in the Middle East and North Africa after Iraq. The persistence of this practice has been associated with several structural and institutional factors, including aging hydrocarbon fields, insufficient investment in gas-processing infrastructure, bureaucratic constraints, and domestic gas-price subsidies that reduce incentives to monetize associated gas.

The Algerian gas-flaring trajectory also experienced a notable shift after 2012, when flaring increased considerably following a period of relative decline. This evolution suggests that production-related factors alone may not adequately explain the persistence of gas flaring. Instead, institutional capacity and regulatory effectiveness may play an important role in determining the ability of the state and operators to manage associated gas effectively.

Against this background, the present study focuses on governance quality, defined through the dimensions of Government Effectiveness and Regulatory Quality, as a potential determinant of gas flaring. Stronger governance may improve regulatory enforcement, reduce mismanagement, facilitate infrastructure investment, and create a more predictable institutional environment for associated-gas utilization. Conversely, deterioration in governance may weaken monitoring and enforcement mechanisms and allow inefficient or environmentally harmful practices to persist.

The central premise of this study is that the relationship between governance quality and gas flaring may be asymmetric. Improvements in governance may require time to translate into stronger institutions, infrastructure investment, and changes in firms' behavior, whereas governance deterioration may weaken existing control

mechanisms relatively rapidly. Consequently, gas flaring may react differently to positive and negative governance shocks.

Accordingly, the study addresses the following research question:

Do improvements and deteriorations in governance quality affect gas flaring differently in Algeria?

Three hypotheses are formulated:

H1: There is a long-run equilibrium relationship between gas flaring, governance quality, and the economic and energy-related variables in Algeria.

H2: Governance quality has an asymmetric effect on gas flaring.

H3: Gas flaring responds dynamically through different temporal paths to positive and negative shocks to governance quality.

The study aims to investigate these asymmetric effects by decomposing governance quality into two cumulative components representing improvements (GQ^{+}) and deteriorations (GQ^{-}), and subsequently simulating the dynamic response of gas flaring to shocks in each component. Oil production, natural gas production, and economic growth are included as control variables.

The study contributes to the literature by combining the Nonlinear Autoregressive Distributed Lag (NARDL) framework with Dynamic ARDL (DYNARDL) simulations. This approach makes it possible not only to test whether governance affects gas flaring asymmetrically, but also to examine how gas flaring evolves over time following positive and negative governance shocks. The analysis uses quarterly data covering 1996Q1–2025Q4. The empirical strategy involves preliminary descriptive and nonlinearity tests, cointegration analysis, NARDL estimation, the Wald test for long-run asymmetry, and DYNARDL simulations.

2. Theoretical Framework

2.1 Gas Flaring: Concept and Determinants

Gas flaring refers to the combustion of natural gas associated with oil production instead of utilizing it, transporting it to markets, or reinjecting it into reservoirs. Flaring may result from limited gas-collection and processing capacity, high utilization costs, insufficient transportation infrastructure, and technical or institutional constraints.

GGFR, IOGP, and IPIECA (2021) distinguish among three principal forms of flaring. Routine flaring occurs continuously during normal facility operations and represents the largest share of flared gas. Non-routine or intermittent flaring is associated with activities such as maintenance and well testing, whereas safety flaring occurs during emergency situations. This classification demonstrates that gas flaring is not exclusively a technical phenomenon but is influenced by economic, infrastructural, regulatory, and institutional conditions.

The consequences of gas flaring are both environmental and economic. Flaring releases carbon dioxide, methane, and black carbon while simultaneously wasting a

potentially valuable energy resource. The magnitude of these losses is illustrated by (Maaroof, A. A, Smith, J. D, & Zangana, M. H. S, 2026) in their assessment of Iraq over 2012–2024. Using VIIRS satellite data from the World Bank's GFMR database, the study estimates that routine flaring in Iraq represents a potential electricity-generation capacity of approximately 8,000–10,000 MW, while annual economic losses range between USD 1 and 2 billion, reaching approximately USD 3.3 billion in 2022.

Importantly, Maaroof et al. (2026) show that medium-sized flares account for the largest cumulative contribution to total flaring because of their large number and geographical distribution. Their evidence also indicates that the persistence of flaring cannot be explained solely by production volume. This finding is relevant to the present study because it supports the argument that the efficiency of associated-gas management and institutional capacity may be fundamental determinants of flaring.

Similarly, (Alola, A. A, Onifade, S. T, & Magazzino, C., & Obe, 2023), examining seven major gas-flaring economies including Algeria, demonstrate that infrastructure and government quality are important factors in explaining the relationship between gas flaring and environmental performance. Thus, understanding gas flaring requires consideration not only of oil and gas production but also of the institutional capacity to regulate production, enforce environmental standards, and promote investment in associated-gas infrastructure.

2.2 Governance Quality and Gas Flaring

Governance refers to the institutions, rules, and procedures through which public decisions are made, policies are implemented, economic activities are regulated, and resources are managed. In environmental contexts, governance quality reflects the ability of public institutions to formulate and enforce regulations, provide public services effectively, uphold the rule of law, reduce corruption, and ensure accountability.

These institutional dimensions are particularly important in the hydrocarbon sector because of its capital intensity, technological complexity, economic significance, and environmental consequences. The present study therefore focuses on Government Effectiveness and Regulatory Quality as two dimensions of governance that are directly connected to the state's capacity to implement policies and regulate economic activities (Alola et al., 2023).

Governance can influence gas flaring through several channels. First, stronger institutions can improve regulatory enforcement by monitoring firms and ensuring compliance with gas-management and environmental standards. Second, improved governance may reduce corruption and mismanagement, limiting opportunities to circumvent regulations or delay necessary investments. Third, stronger institutions can enhance resource-allocation efficiency, facilitating investment in gas gathering, processing, transportation, and utilization. Finally, greater regulatory stability and clarity may encourage firms to invest in infrastructure for associated-gas monetization.

These mechanisms are consistent with GGFR, IOGP, and IPIECA (2021), which emphasize the importance of stable institutional structures, clear regulations, and reliable systems for managing production and flaring data in reducing routine gas flaring.

Empirical evidence also supports this institutional perspective. Alola et al. (2023) find that government quality plays an important role in the relationship between gas flaring and environmental performance. Similarly, (Aigbe, G. O, Stringer, L. C, & Cotton, M, 2023), show in the Nigerian context that weak governance, inadequate regulatory compliance, policy inconsistency, and conflicts between environmental and economic objectives have constrained progress in reducing gas flaring.

These findings suggest that higher governance quality should generally contribute to lower gas flaring. However, the magnitude and timing of this effect may differ according to whether governance improves or deteriorates.

2.3 From Linear Effects to Asymmetric Responses

Traditional approaches generally assume that an increase and a decrease in an explanatory variable generate proportionate and opposite effects on the dependent variable. Such an assumption may be inappropriate in the governance–gas-flaring relationship.

Institutional improvements often require time to translate into effective regulation, infrastructure investment, and behavioral changes among firms. By contrast, deterioration in governance may weaken existing monitoring and enforcement mechanisms relatively quickly. Therefore, positive and negative governance shocks may generate different effects on gas flaring.

The conceptual framework proposed by (Emekwuru, N, 2024) provides additional support for this argument. The author distinguishes among three stages: pre-flaring, flaring, and post-flaring. In the pre-flaring stage, institutional intervention may be relatively inexpensive and geographically limited. Once flaring becomes established, however, the phenomenon becomes more difficult and costly to reverse. At the post-flaring stage, impacts become entrenched and remediation requires broader institutional and stakeholder involvement.

This framework suggests that improvements in governance may have a gradual effect because they require cumulative institutional capacity-building, whereas governance deterioration can rapidly weaken existing controls. Consequently, the response of gas flaring to positive governance changes may differ substantially from its response to negative changes.

The NARDL framework developed by (Shin, Y., Yu, B & Greenwood-Nimmo, M, 2014), provides an appropriate econometric mechanism for testing this hypothesis. It decomposes changes in an explanatory variable into positive and negative partial sums, allowing the effects of improvements and deteriorations to be estimated separately in both the short and long run. The equality of these effects can then be formally examined using the Wald test.

3. Previous Studies

The existing literature can broadly be divided into studies focusing directly on governance and gas flaring, studies examining the economic determinants and consequences of flaring, and recent research supporting the nonlinear and dynamic methodologies adopted in the present study.

Alola et al. (2023) provide one of the most directly relevant contributions. Their study examines seven major gas-flaring economies, including Algeria, using the Augmented Mean Group (AMG) estimator and annual data covering 2002–2020. The study emphasizes the role of government quality in the relationship between gas flaring and environmental performance. Its major relevance to the present study lies in establishing a direct connection between governance and gas flaring. However, the study employs a linear framework and does not distinguish between improvements and deteriorations in governance within the Algerian context.

Aigbe et al. (2023) provide complementary evidence from Nigeria using documentary analysis, stakeholder interviews, and expert surveys. Their results demonstrate that weak governance, inadequate regulatory compliance, inconsistent policies, and conflicts between environmental and economic objectives hinder gas-flaring reduction. The study highlights the importance not only of establishing regulations but also of ensuring their implementation and monitoring.

(Yayaji, I, Mu, X, & Zhu, T. , 2025) examine regulatory charges on gas flaring in Nigeria over a 52-year period. Their results indicate that the regulatory regime introduced after 2018 was considerably more effective than the previous regime, with the post-2018 system associated with an approximately 6.92% reduction in gas flaring compared with only 0.08% under the earlier system. Oil production and oil prices were also significant determinants. These findings indicate that regulatory effectiveness depends on the strength and design of regulatory instruments rather than their mere existence.

Using panel data for eight developing oil-exporting countries, (Pourhassan, S & Taravat, A, 2014) examine gas flaring in relation to oil prices, carbon emissions, and natural-resource rents. Their analysis covers 1994–2008 and employs a random-effects framework after the Hausman test. The authors find a positive and significant relationship between gas flaring and oil prices, carbon emissions, and resource rents. Although Algeria is included in the sample, governance is not incorporated and the analysis assumes a symmetric linear relationship.

(Okoye, L. U, Adeleye, B. N, & Okoro, E. E., Okoh, 2022) investigate the economic implications of gas flaring in Nigeria over 1990–2019 using ARDL-ECM, FMOLS, and CCR. Their estimates provide mixed evidence regarding the long-run effect of gas flaring on economic growth. Although their research focuses on economic performance rather than governance, it demonstrates the relevance of ARDL-type approaches for studying gas-flaring dynamics.

Emekwuru (2024) contributes a policy-oriented perspective by applying the concept of intervention timing to gas flaring in the Niger Delta. The distinction between pre-flaring, flaring, and post-flaring stages emphasizes the importance of early institutional intervention and suggests that the costs of addressing entrenched flaring increase over time.

From a techno-economic perspective, Maaroof et al. (2026) provide evidence from Iraq showing the substantial electricity and economic losses associated with persistent gas flaring. Their findings reinforce the view that inefficient management of associated gas, rather than production volume alone, contributes significantly to persistent flaring.

For Algeria specifically, Ouki (2019) provides important institutional and contextual evidence. The study links Algeria's persistent gas flaring to factors including the aging hydrocarbons regulatory framework, bureaucratic barriers to investment, and domestic gas-price subsidies that weaken incentives for associated-gas monetization.

The practical guidelines of GGFR, IOGP, and IPIECA (2021) further demonstrate the importance of national institutional and regulatory frameworks. International experiences indicate that sustained reductions in routine flaring require clear regulations, stable institutions, effective monitoring, and appropriate infrastructure.

Recent methodological studies in Algeria also support the use of nonlinear and dynamic models. (Boutalbi, H, Dahmani, M. D, & Moussi, C, 2025) apply a FA-NARDL framework to investigate oil-price shocks and economic variables and find asymmetric responses to positive and negative shocks. Similarly, (Bendahmane, A, Dahmani, M. D, & Attouchi, M., Bout, 2025) use DYNARDL to examine the effects of energy consumption, natural resources, trade openness, and foreign direct investment on environmental quality. Their findings demonstrate the usefulness of dynamic simulations for tracing the temporal response of Algerian economic and environmental variables to shocks.

3.1 Research Gap and Contribution

The reviewed literature reveals three main gaps.

First, although previous studies have established a relationship between governance and gas flaring, they have generally relied on linear approaches. Consequently, they do not determine whether improvements in governance have the same magnitude and timing of effects as deteriorations.

Second, nonlinear studies related to gas flaring have mainly focused on other countries or broader international samples, particularly Nigeria and Iraq. Despite Algeria's importance as a gas-flaring country, the asymmetric governance–gas-flaring relationship has not been explicitly examined for Algeria.

Third, existing studies have not combined an explicit test of governance asymmetry with a simulation of the separate dynamic responses of gas flaring to positive and negative governance shocks.

The present study addresses these gaps by examining Algeria over 1996–2025, decomposing governance quality into positive and negative cumulative components (GQ^+ and GQ^-), estimating their asymmetric effects using NARDL, testing long-run symmetry using the Wald test, and subsequently employing DYNARDL simulations to trace the dynamic response of gas flaring to positive and negative governance shocks.

4. Methodology and Data

4.1 Data Sources and Variables

The study relies on annual data for Algeria covering the period 1996–2025, which are converted to quarterly frequency (1996Q1–2025Q4; 120 observations) using the quadratic-match temporal disaggregation procedure developed by (Boot, J. C. G, Feibes, W, & Lisman, J. H. C, 1967). This approach has also been employed in recent studies to convert annual data into quarterly series, including (Razzaq, A., Sharif, A & Afshan, S., & Li, C. J, 2023), Given the limited number of annual observations (n = 30) relative to the data requirements of the NARDL framework with governance decomposition into positive and negative components (GQ^+ and GQ^-), quarterly conversion is adopted using the Quadratic-Match Sum method for flow variables, namely gas flaring, oil production, and natural gas production, and the Quadratic-Match Average method for level variables, namely governance quality and economic growth. This procedure is preferred to simple linear interpolation because it allows for greater variation in the disaggregated series and reduces the loss of information associated with point-to-point interpolation

All variables are transformed into natural logarithms, except for the GDP growth rate, which is retained in its original form because it takes a negative value in 2020 as a consequence of the COVID-19 shock, making logarithmic transformation mathematically infeasible.

Symbol	Variable	Source
GFL	Natural gas flaring	Energy Institute Statistical Review of World Energy 2026
GQ	Governance Quality (Government Effectiveness × Regulatory (Quality	Worldwide Governance Indicators (WGI) - World Bank
OIL	Oil production	Energy Institute Statistical Review of World Energy 2026
GPRD	Natural gas production	Energy Institute Statistical Review of World Energy 2026
GDP	GDP growth rate	World Development Indicators (WDI) - World Bank

4.2 Econometric Methodology

The study employs the Bounds Testing approach developed by Pesaran, Shin, and Smith (2001) to examine the existence of a long-run equilibrium relationship among the variables. This approach can be applied regardless of whether the variables are

integrated at level, I(0), or at first difference, I(1), provided that none of the variables is integrated of order two, I(2).

Following the detection of statistically significant nonlinearity in the gas flaring series using the BDS test, the relationship is estimated using the Nonlinear Autoregressive Distributed Lag (NARDL) model. This framework allows the effects of governance quality to differ according to the direction of change by decomposing governance quality into positive and negative partial-sum processes, denoted by GQ^+ and GQ^-, respectively. The NARDL specification is formulated as follows:

$$GQt = GQ0 + GQ+t + GQ-t\ ,\ \ GQ+t = \Sigma\ max(\Delta GQi\ ,\ 0),\ GQ-t = \Sigma\ min(\Delta GQi\ ,\ 0)$$

Where GQ+ represents the cumulative partial sum of positive changes in governance quality (governance improvements), while GQ- represents the cumulative partial sum of negative changes (governance deteriorations). The NARDL model is estimated in the following general form:

$$\Delta LNGFLt = \alpha + \Sigma\beta 1i\ \Delta LNGFLt\text{-}i + \Sigma\ (\beta 2i^{+}\Delta GQ^{+}t\text{-}i + \beta 2i^{-}\Delta GQ^{-}t\text{-}i) + \Sigma\beta 3i\Delta LNGPRDt\text{-}i + \Sigma\beta 4i\Delta LNOILt\text{-}i + \Sigma\beta 5i\Delta GDPt\text{-}i + \rho ECTt\text{-}1 + \varepsilon t$$

Long-run asymmetry is tested using the **Wald test**, with the null hypothesis of long-run symmetry specified as **H0: $\Sigma\beta 2i^{+} = \Sigma\beta 2i^{-}$** against the alternative hypothesis of long-run asymmetry, **H1: $\Sigma\beta 2i^{+} \neq \Sigma\beta 2i^{-}$.** Rejection of the null hypothesis provides statistical evidence of significant asymmetry.

In the final stage, the study is complemented by Dynamic ARDL (DYNARDL) simulations, following the methodology of Jordan and Philips (2018), which employs a common lag order for all variables. Based on 1,000 random simulations, the procedure generates an expected time path of the gas flaring response together with a 95% confidence interval, separately for a positive shock to GQ+ and a negative shock to GQ^-.

5. RESULTS AND DISCUSSION

5.1 Descriptive Statistics: Table 1 presents the descriptive statistics of the study variables.

Table 1. Descriptive Statistics

Statistics	LNGFL	LNGQ	LNOIL	LNGPRD	GDP
Mean	0.506997	-0.820396	5.985168	3.067344	3.120518
Median	0.560445	-0.830093	5.955415	3.063635	3.400251
Maximum	1.088159	-0.084802	6.214671	3.259445	7.016184
Minimum	-0.433948	-1.885680	5.785395	2.718358	-6.270494
Std. Dev.	0.446350	0.430410	0.119283	0.104869	2.191338
Skewness	-0.449188	-0.306343	0.660275	-0.347317	-1.722901
Kurtosis	1.973191	2.477144	2.383003	3.156910	8.128319
Jarque-Bera	9.307081	3.243815	10.622689	2.535689	190.866033

Probability	0.009528	0.197522	0.004935	0.281438	0.000000
Observations	120	120	120	120	120

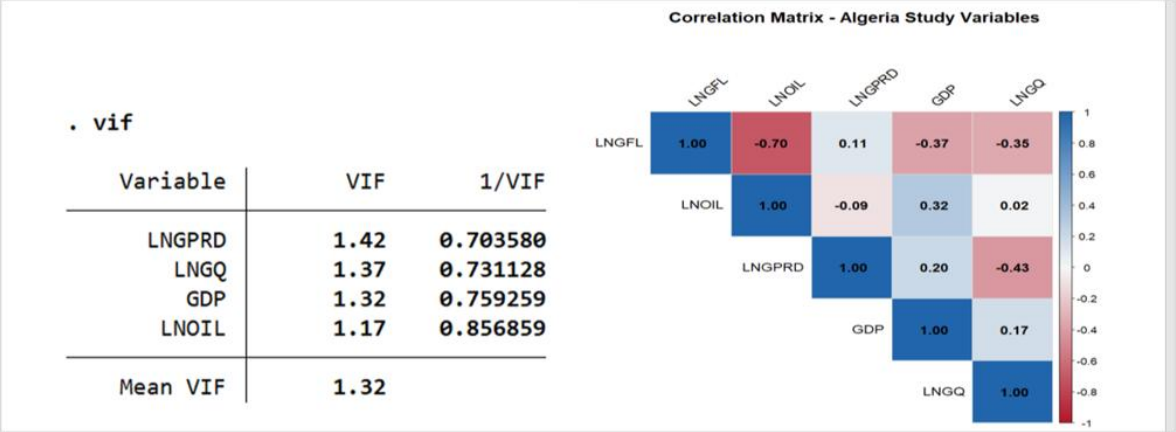
Source: Prepared by the researchers based on EViews 12 output.

Table 1 presents the descriptive statistics of the variables. The results indicate that LNOIL and LNGPRD exhibit relatively low dispersion around their means, as reflected by their low standard deviations, while GDP shows the highest degree of dispersion. The skewness statistics reveal that LNGFL, LNGQ, LNGPRD, and GDP are negatively skewed, whereas LNOIL is positively skewed. Regarding kurtosis, LNGPRD and GDP exhibit leptokurtic distributions, with GDP showing a particularly high degree of kurtosis, while LNGFL, LNGQ, and LNOIL are relatively platykurtic. The Jarque–Bera test indicates that LNGQ and LNGPRD are normally distributed at the 5% significance level, as their probability values exceed 0.05. However, normality is rejected for LNGFL, LNOIL, and GDP because their Jarque–Bera probabilities are below 0.05.

5.2 Correlation Matrix

Figure 1 presents the correlation matrix among the study variables, together with the Variance Inflation Factor (VIF) test.

Figure 1. Correlation Matrix and VIF Test



Source: Prepared by the researchers using R software.

The correlation matrix in Fig. 1 shows that LNGFL is strongly and negatively correlated with LNOIL ($r = -0.7030$, $p < 0.01$), while its correlations with GDP ($r = -0.3721$, $p < 0.01$) and LNGQ ($r = -0.3497$, $p < 0.01$) are moderate and statistically significant. In contrast, its correlation with LNGPRD is weak and statistically insignificant ($r = 0.1139$, $p = 0.2156$). Among the explanatory variables, the highest correlation is observed between LNGPRD and LNGQ ($r = -0.4289$, $p < 0.01$), followed by LNOIL and GDP ($r = 0.3155$, $p < 0.01$). The remaining correlations are weak, with LNOIL–LNGQ being statistically insignificant ($r = 0.0155$, $p = 0.8668$). Overall, although some significant correlations exist, none of the pairwise coefficients among the explanatory variables exceeds 0.43 in absolute value, suggesting that severe multicollinearity is unlikely.

5.3 Unit Root Tests

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Before proceeding with the cointegration analysis, the order of integration of the time series was examined using the Augmented Dickey-Fuller (ADF) test to ensure that none of the variables is integrated of order two, I(2), which is a fundamental requirement for the validity of the Bounds Testing approach of Pesaran et al. (2001).

To complement these conventional tests, and given the clear shift in the trajectory of the gas flaring variable observed visually during the second decade of the study period, the (Lee, J & Strazicich, M.C, 2003) test, based on the Minimum Lagrange Multiplier (Minimum LM) principle with two endogenous structural breaks, was also applied. This additional test allows the order of integration to be assessed while mitigating the potential bias arising from an unaccounted structural break.

Table 2. Augmented Dickey-Fuller (ADF) Unit Root Test Results

At Level						
		LNGFL	**LNGQ**	**LNOIL**	**LNGPRD**	**GDP**
Without Constant & Trend	t-Statistic	-0.8001	0.9407	0.1927	-3.6772	-0.7486
	Prob.	***0.3674***	***0.9069***	***0.7403***	***0.0003***	***0.3899***
		n0	n0	n0	***	n0
At First Difference						
		d(LNGFL)	d(LNGQ)	d(LNOIL)	d(LNGPRD)	d(GDP)
Without Constant & Trend	t-Statistic	-3.8147	-3.7410	-2.0543	/	-3.2272
	Prob.	***0.0002***	***0.0003***	***0.0388***	/	***0.0015***
		***	***	**	/	***

Table 3. Lee and Strazicich (2003) Unit Root Test With two Structural Break

Variables	**At level**			**At first difference**		
	DT1t	**DT2t**	**LM Statistic**	**DT1t**	**DT2t**	**LM Statistic**
LnGFL	2002Q3	2013Q1	**-4.3967**	2003Q3	2012Q1***	-6.3967
LnOIL	2002Q1	2021Q2	**-3.8993**	2002Q1	2011Q2***	-5.8993

LnGPRD	2001Q2***	2009Q3***	**-5.6456**	/	/	/
GDP	2004Q2	2001Q1	**-4.1153**	2014Q2	2021Q1***	-6.1153
LnGQ	2005Q3	2019Q2	**-4.2050**	2003Q3***	2009Q2***	-6.2050

Note: *, ** and *** indicate significance at 10%, 5% and 1% level, respectively. DT1t and DT2t refer to the first and second break dates, respectively.

To determine the order of integration of the variables, the Augmented Dickey–Fuller (ADF) test was first applied, followed by the LM unit root test allowing for two structural breaks. The ADF results indicate that LNGPRD is stationary at level, with a probability value of 0.0003, and is therefore classified as I(0). In contrast, LNGFL, LNGQ, LNOIL, and GDP are non-stationary at level but become stationary after first differencing, indicating that they are integrated of order I(1). These findings are further assessed using the LM test with two structural breaks, which accounts for possible structural changes that may bias conventional unit root tests. The LM results confirm the presence of significant structural breaks and indicate that LNGFL, LNOIL, and LNGQ become stationary after first differencing, while LNGPRD is stationary at level. The detected break dates also provide evidence of important structural changes in the underlying series. Overall, the combined results of the ADF and LM tests confirm that the variables are a mixture of I(0) and I(1), with none being integrated of order I(2). This satisfies the precondition for applying the ARDL/NARDL bounds-testing approach to investigate the long-run relationship and asymmetric effects among the variables.

5.4 Nonlinearity Test (BDS)

To verify the presence of nonlinearity that provides methodological justification for employing the NARDL model, the BDS test proposed by Broock, Scheinkman, Dechert, and LeBaron (1996) was applied to all study variables.

Table 4. BDS Test Results for Nonlinearity

Variables	**m = 2**	**m = 3**	**m = 4**	**m = 5**	**m = 6**
			z-Statistic		
LNGFL	***40.05602	***41.64944	***43.78037	***47.13888	***51.98475
LNGPRD	***32.03972	***32.99818	***34.41444	***36.85274	***40.32340
LNGQ	***31.67215	***31.87976	***32.39140	***33.76029	***36.10829
LNOIL	***29.49639	***30.98899	***32.82411	***35.54376	***39.25826
GDP	***16.06404	***15.79053	***15.87945	***16.52927	***17.48856

, *, *** indicate statistical significance at the 1%, 5%, and 10% levels, respectively.

The results presented in Table 4 provide strong evidence of nonlinearity in all the series considered, namely LNGFL, LNGPRD, LNGQ, LNOIL, and GDP, throughout the study

period. The null hypothesis that the time series is independently and identically distributed (IID) is rejected across all embedding dimensions (m = 2 to m = 6) at the 1% significance level. The z-statistics are notably large, ranging from 15.79 for GDP at m = 3 to 51.98 for LNGFL at m = 6. Their values generally increase as the embedding dimension rises across all variables, indicating a consistent rejection of linear dependence across different levels of dynamic complexity.

Notably, LNGFL records the highest z-statistics across all embedding dimensions, suggesting that its nonlinear dynamics are more pronounced than those of the other variables. This finding is consistent with the nature of gas flaring as a variable that may respond asymmetrically to positive and negative shocks in its determinants, particularly governance quality. GDP exhibits comparatively lower z-statistics; however, these remain statistically significant at the 1% level, confirming the presence of nonlinearity, albeit at a lower intensity.

The use of linear distributed-lag techniques, such as conventional linear ARDL models, for nonlinear series of this nature may produce potentially misleading results because such models cannot adequately capture asymmetric responses of the dependent variable to positive and negative shocks in the explanatory variables. These findings therefore provide a methodological justification for employing the Nonlinear ARDL (NARDL) framework proposed by Shin et al. (2014) rather than relying exclusively on the standard linear ARDL model.

5.5 NARDL Bounds Cointegration Test

The following table presents the results of the F-Bounds Test for the nonlinear NARDL model.

Table 5. NARDL Bounds Cointegration Test Results

Test	F-statistic	k	I(0) at 5%	I(1) at 5%	Conclusion
Nonlinear NARDL	17.21277	5	3.12	4.25	**Cointegration**

The results in the table above show that the F-statistic for the nonlinear model clearly exceeds the upper-bound critical value, I(1), at the 5% significance level, confirming the existence of a long-run cointegration relationship among the study variables and supporting Hypothesis 1 of the study.

5.6 Long-Run NARDL Results and Wald Test for Asymmetry

To test Hypothesis 2, the formal Wald test was applied to examine whether the long-run partial-sum coefficients of GQ^{+} and GQ^{-} are equal:

Table 6. NARDL Long-Run and Short-Run Estimation Results

Parameters	NARDL Model Coefficients	t	p values
Panel A: Long-run coefficients			
LNGQ_POS	-1.532666	-9.184367	0.000
LNGQ_NEG	-0.348630	-3.850095	0.000
LNGPRD	-0.634717	-2.199854	0.030

LNOIL	-4.058191	-14.68103	0.000
GDP	0.082898	4.493335	0.000
Panel B: Short-run coefficients			
D(LNGFL(-1))	0.897403	22.05029	0.000
D(LNGQ_POS)	-0.726576	-7.113641	0.000
D(LNGQ_POS(-1))	0.607309	5.838926	0.000
D(LNGQ_NEG)	-0.245824	-2.864003	0.005
D(LNGQ_NEG(-1))	0.422254	4.565914	0.000
D(LNGPRD)	-2.908386	-6.222703	0.000
D(LNGPRD(-1))	2.426799	5.291416	0.000
D(LNOIL)	-2.251924	-3.028543	0.003
D(LNOIL(-1))	1.540432	2.318439	0.023
D(GDP)	0.091138	7.984319	0.000
D(GDP(-1))	-0.092840	-9.257989	0.000
ECM(-1)	-0.186435	-10.41853	0.000
R-squared	0.879458	/	/
F-statistic	57.80553	/	0.000
Normality test	32.328	**Probability**	0.000
Serial correlation	1.922	**Probability**	0.167
ARCH test	0.154	**Probability**	0.901
Wald test			
Null Hypothesis	**F-statistic**	**Degrees of Freedom**	**Probability**
$\Sigma GQ^{+} = \Sigma GQ^{-}$	45.735	(1, 98)	0.0000***

Table 6 summarizes the results of the NARDL estimation. Panel A presents the long-run coefficients, indicating that both positive and negative changes in governance quality have statistically significant negative effects on gas flaring. The coefficient of LNGQ_POS is −1.533 (p = 0.0000), compared with −0.349 (p = 0.0002) for LNGQ_NEG, implying that the magnitude of the effect of improvements in governance quality is approximately 4.4 times larger than that associated with governance deterioration. Economically, this suggests that improvements in government effectiveness, regulatory quality, and enforcement capacity can strengthen the monitoring of hydrocarbon activities and encourage the recovery and utilization of associated gas. The weaker response to governance deterioration may reflect the persistence of existing infrastructure and institutional arrangements, which can moderate the immediate effects of declining governance quality.

Among the control variables, LNGPRD has a negative and significant long-run effect (−0.635, p = 0.0302), while LNOIL exhibits a larger negative effect (−4.058, p = 0.0000). Although these findings differ from the conventional expectation that higher hydrocarbon production should increase gas flaring, they may reflect the Algerian context, where production dynamics interact with gas-recovery capacity, infrastructure, field maturity, and investment conditions. In contrast, GDP has a positive and significant

coefficient (0.083, p = 0.0000), suggesting that economic expansion may increase pressure on energy and hydrocarbon activities and consequently contribute to higher gas flaring.

Panel B reports the short-run dynamics. Both positive and negative changes in governance quality generate significant and dynamic responses in gas flaring. LNGQ_POS has a negative contemporaneous effect (−0.727) followed by a positive lagged effect (0.607), whereas LNGQ_NEG records a negative contemporaneous effect (−0.246) followed by a positive lagged effect (0.422), with all coefficients statistically significant. These results indicate that the response of gas flaring to governance changes is not instantaneous but evolves over successive periods. The control variables also exhibit significant short-run dynamics, particularly LNGPRD, LNOIL, and GDP.

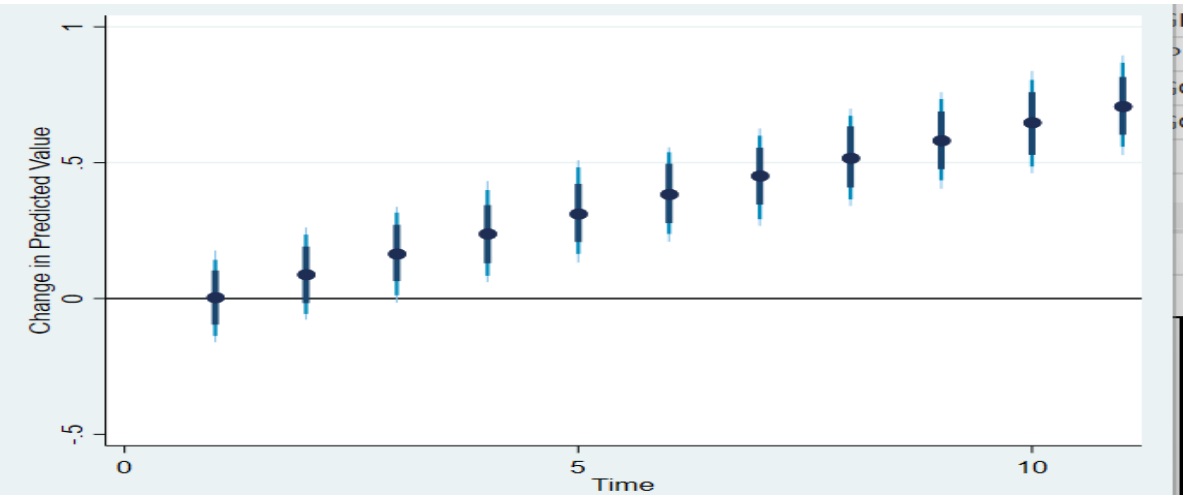
The error correction term (ECM−1) is negative and highly significant (−0.186, p = 0.0000), confirming the existence of a stable long-run relationship and indicating that approximately 18.6% of the previous period's disequilibrium is corrected each quarter. This relatively gradual adjustment is consistent with the capital-intensive nature of gas-recovery and processing infrastructure.

The existence of a long-run relationship is further confirmed by the NARDL bounds test, with an F-statistic of 17.213, substantially exceeding the upper-bound critical value at the 1% level (5.23). Finally, the Wald test strongly rejects the null hypothesis of long-run symmetry (F-statistic = 45.735, p = 0.0000), providing formal evidence that the effect of governance quality on gas flaring differs according to the direction of change. Overall, the findings demonstrate that improvements in governance quality are considerably more effective in reducing gas flaring than governance deterioration is in increasing it, thereby providing strong support for the asymmetric relationship specified in the NARDL framework and motivating the subsequent DYNARDL simulations of positive and negative governance shocks.

5.7 Results of the Dynamic ARDL (DYNARDL) Simulations

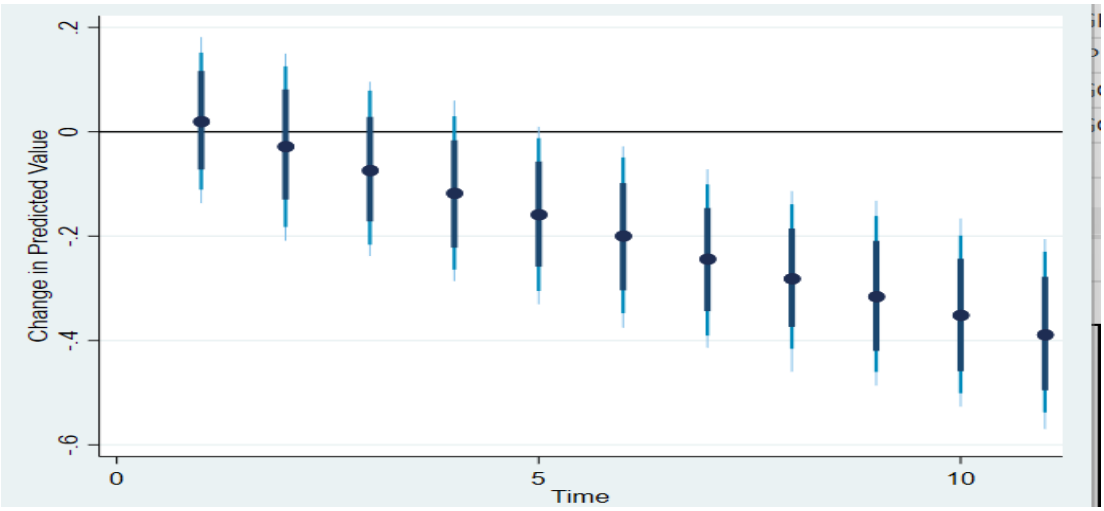
To test Hypothesis 3, the response of gas flaring was simulated over 20 future periods using Stata, based on 1,000 simulations with a 95% confidence interval, for two separate shocks: a positive shock to GQ^{+} representing an improvement in governance quality, and a negative shock to GQ^{-} representing a deterioration in governance quality. (Jordan, S & Philips, A.Q , 2018)

Figure 2. Response of Gas Flaring to a Positive Shock in Governance Quality (GQ^{+})



Source: Stata 17 output

Figure 3. Response of Gas Flaring to a Negative Shock in Governance Quality (GQ^-)



Source: Stata 17 output

Dynamic ARDL simulations are used to illustrate the dynamic response of gas flaring to positive and negative shocks in governance quality. Figure 2 shows that a positive shock in governance quality (GQ^+) generates a progressively negative response in gas flaring over the simulation horizon, indicating that improvements in governance quality contribute to a sustained reduction in gas flaring. The response becomes increasingly pronounced over time, suggesting that the effect of improved governance strengthens gradually rather than occurring immediately.

Conversely, Figure 3 shows that a negative shock in governance quality (GQ^-) produces a positive response in gas flaring, indicating that deterioration in governance quality tends to increase gas flaring. The effect also accumulates over the simulation horizon, confirming the persistent nature of governance shocks.

Overall, the dynamic simulations provide visual evidence of asymmetric responses:

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improvements in governance reduce gas flaring, whereas governance deterioration increases it. These simulated responses are consistent with the significant Wald test and the long-run NARDL estimates, thereby reinforcing the existence of an asymmetric governance–gas flaring relationship.

The diagnostic tests indicate no evidence of serial correlation or conditional heteroskedasticity, with p-values of 0.157 for the serial correlation test and 0.901 for the ARCH test, both of which are statistically insignificant. In contrast, the Jarque–Bera test rejects the null hypothesis of normally distributed residuals ($p = 0.000$). Non-normality does not necessarily constitute a serious problem for the NARDL/Dynamic ARDL model, particularly when emphasis is placed on the consistency of the estimated dynamic relationships and the results of the other stability and diagnostic tests.

5.8 Discussion of Findings

The findings are broadly consistent with the theoretical framework and previous empirical evidence. The long-run NARDL estimates show that both positive and negative changes in governance quality significantly affect gas flaring, with coefficients of -1.533 for GQ^{+} and -0.349 for GQ^{-}. The magnitude of the positive component is approximately 4.4 times larger, while the Wald test ($F = 45.735$, $p = 0.0000$) formally confirms significant long-run asymmetry. This result is consistent with Alola et al. (2023) regarding the negative role of governance quality in gas flaring, while extending their analysis by distinguishing between improvements and deteriorations in governance. Economically, stronger governance can improve regulatory enforcement, monitoring, and associated-gas recovery, whereas existing infrastructure and institutional arrangements may moderate the immediate effects of governance deterioration.

The negative and significant coefficients of LNGPRD (-0.635) and LNOIL (-4.058) differ from the conventional expectation that greater hydrocarbon production necessarily increases flaring. In the Algerian context, these coefficients should be interpreted cautiously, as they may reflect structural and temporal dynamics in the hydrocarbon sector, including declining oil production, field maturity, and limitations in gas-recovery infrastructure, rather than a direct causal reduction in flaring. GDP, by contrast, has a positive and significant effect (0.083), suggesting that economic expansion may increase pressure on hydrocarbon and energy activities.

The short-run estimates further indicate that governance shocks generate dynamic rather than instantaneous responses. The negative and significant contemporaneous effects of GQ^{+} (-0.727) and GQ^{-} (-0.246) are followed by significant lagged responses, while the DYNARDL simulations provide complementary graphical evidence of different response paths following positive and negative governance shocks. The error-correction coefficient (-0.186, $p = 0.0000$) confirms gradual adjustment toward long-run equilibrium, with approximately 18.6% of disequilibrium corrected each quarter. Overall, these findings reinforce the importance of governance quality as an institutional channel for reducing gas flaring in Algeria. This governance-based channel of emissions

reduction can be usefully contrasted with the technological substitution channel documented in adjacent contexts: (Ben Ammar, D, 2025) shows that expanding marine renewable energy capacity in Italy exerts a persistent downward effect on electricity carbon intensity through direct fossil-fuel displacement, whereas the present findings for Algeria point to an institutional pathway in which stronger governance curbs flaring primarily through improved regulatory enforcement and associated-gas recovery rather than outright energy substitution. The two studies thus suggest that decarbonization in hydrocarbon-dependent economies can proceed along complementary technological and institutional tracks.

CONCLUSION

This study examined the asymmetric effects of governance quality on gas flaring in Algeria over 1996–2025 using NARDL and DYNARDL approaches. The bounds test confirmed a significant long-run relationship among the variables (F = 17.213). The results further revealed significant asymmetric effects of governance quality, with the impact of improvements (−1.533) substantially exceeding that of deteriorations (−0.349), while the Wald test strongly rejected long-run symmetry (F = 45.735, p = 0.0000). DYNARDL simulations further illustrated distinct dynamic responses of gas flaring to positive and negative governance shocks.

Hypothesis testing: The hypothesis that governance quality significantly affects gas flaring is supported. The hypothesis that its effect is asymmetric is also supported, given the significant Wald test. The hypothesis concerning the existence of a long-run relationship is supported by the NARDL bounds test.

From a policy perspective, the findings highlight the need to strengthen governance, regulatory enforcement, and transparency in the hydrocarbon sector, while directing part of hydrocarbon revenues toward upgrading associated-gas recovery and processing infrastructure. Targeted flaring regulations and economic incentives may further reinforce these institutional improvements. In parallel, broader economic diversification through renewable energy development, as emphasized by (Mehraz, C & Ait Taleb, A , 2026) for the Algerian context, could reduce structural dependence on hydrocarbon revenues and complement governance reforms in curbing gas flaring over the longer term.

The study is subject to two main limitations: the quarterly conversion of originally annual governance and GDP data may constrain the interpretation of short-term fluctuations, and the analysis focuses exclusively on Algeria. Future research could therefore employ cross-country panel approaches and examine the interaction between governance quality and energy infrastructure investment.

6. Bibliography List:

Aigbe, G. O, Stringer, L. C, & Cotton, M. (2023). Gas Flaring in Nigeria: A Multi-level Governance and Policy Coherence Analysis. *Anthropocene Science, 2, 31–47.*

Alola, A. A, Onifade, S. T, & Magazzino, C., & Obe. (2023). The effects of gas flaring as moderated by government quality in leading natural gas flaring economies. *Scientific Reports, 13, 14394. https://doi.org/10.1038/s41598-023-38032-w*.

Ben Ammar, D. (2025). Leveraging Marine Renewable Energy for a Circular Carbon Economy: A Pathway to Carbon Neutrality in Italy. *Journal of Contemporary Economic Research, 8(2), 495–514.*

Bendahmane, A, Dahmani, M. D, & Attouchi, M., Bout. (2025). How do energy consumption, natural resources, trade openness and FDI affect environmental quality in Algeria? Fresh insights from the novel DYNARDL simulations and KRLS approach. *Theoretical and Applied Economics, XXXII(4/645), 121–142.*

Boot, J. C. G, Feibes, W, & Lisman, J. H. C. (1967). Further methods of derivation of quarterly figures from annual data. *Applied Statistics, 16(1), 65–75*.

Boutalbi, H, Dahmani, M. D, & Moussi, C. (2025). Uncovering the dynamic relationships between oil prices, economic growth, exchange rate, and their impact on remittances inflow in Algeria: New evidence from Fourier FAARDL and FA-NARDL approach. *MECAS, 21(2), 376–388.*

Emekwuru, N. (2024). Characterization of the Dominant Stages at Which Gas Flaring Is Introduced: Impacts and Policy Options to Ameliorate Them. *Environments, 11(7), 158. https://doi.org/10.3390/environments11070158*.

Global Gas Flaring Reduction Partnership (GGFR). (2021). *International Association of Oil & Gas Producers (IOGP), & International Petroleum Industry Environmental Conservation Association (IPIECA). (2021).* Flaring Management Guidance for the Oil and Gas Industry.

Jordan, S, & Philips, A.Q . (2018). Cointegration testing and dynamic simulations of autoregressive distributed lag models. *The Stata Journal, 18(4), 902-923.*

Maaroof, A. A, Smith, J. D, & Zangana, M. H. S. (2026). The cost of inefficiency: A techno-economic assessment of gas flaring in Iraq. *Energy Policy, 213, 115215. https://doi.org/10.1016/j.enpol.2026.115215*.

Mehraz, C, & Ait Taleb, A . (2026). Le développement des énergies renouvelables comme levier de la diversification économique en Algérie : atouts, défis et perspectives. *Revue Recherche Économique Contemporaine, 9(1), 80–96.*

Okoye, L. U, Adeleye, B. N, & Okoro, E. E., Okoh. (2022). Effect of gas flaring, oil rent and fossil fuel on economic performance: The case of Nigeria. *Resources Policy, 77, 102677. https://doi.org/10.1016/j.resourpo*.

Ouki, M. (2019). Algerian Gas in Transition: Domestic Transformation and Changing Gas Export Potential (OIES Paper: NG 151). *Oxford Institute for Energy Studies. https://doi.org/10.26889/9781784671457*.

Pourhassan, S, & Taravat, A. (2014). Effect of gas flaring on environmental variables in developing countries. *International Journal of Business and Management, II(1), 101–106.*

Razzaq, A., Sharif, A, & Afshan, S., & Li, C. J. (2023). Do climate technologies and recycling asymmetrically mitigate consumption-based carbon emissions in the United States? New insights from Quantile ARDL. *Technological Forecasting and Social Change* .

Shin, Y., Yu, B, & Greenwood-Nimmo, M. (2014). Modelling asymmetric cointegration and dynamic multipliers in a nonlinear ARDL framework. In R. *Sickles & W. Horrace (Eds.), Festschrift in Honor of Peter Schmidt: Econometric Methods and Applications (pp. 281–314). Springer.*

Yayaji, I, Mu, X, & Zhu, T. . (2025). Do regulatory tariffs curb gas flaring? Evidence from Nigeria. *Gases, 5(2), Article 10. https://doi.org/10.3390/gases5020010*.