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Assessing the Impact of Economic Diversification on Economic Growth in Algeria: Evidence from ARDL Model (1990–2024)

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Abstract

This study examines the impact of economic diversification on economic growth in Algeria over the period 1990–2024 using the Fourier ARDL approach. The results reveal a significant long-run relationship driven mainly by oil prices and hydrocarbon exports, confirming the persistent dependence of the Algerian economy on the hydrocarbon sector. The findings indicate that diversification efforts have not yet achieved a substantial contribution to economic growth.

Keywords: Economic diversification – Economic growth – Fourier ARDL – Oil prices – Algeria

1. Introduction

Economic diversification is widely regarded as a fundamental pillar for achieving sustainable economic growth, particularly in countries that heavily rely on natural resources, most notably oil-exporting economies. In this context, Algeria is classified as a rentier economy, where the productive structure is predominantly based on the hydrocarbon sector. Oil and gas revenues account for more than 90% of total exports and contribute approximately 40% of gross domestic product (GDP) during certain periods, in addition to constituting the main source of public revenues.

However, this excessive dependence on a single sector exposes the Algerian economy to external shocks, particularly fluctuations in global oil prices. This vulnerability has been evident during major crises such as those of 2008, 2014, and 2020, where sharp declines in oil prices negatively affected key macroeconomic indicators, including economic growth, trade balance, and foreign exchange reserves.

In light of these challenges, the need to adopt economic diversification policies has become increasingly urgent. Such policies aim to reduce reliance on the hydrocarbon sector and broaden the productive base by promoting non-oil sectors such as industry, agriculture, and services. Numerous studies have emphasized that economic diversification contributes to enhancing macroeconomic stability, improving resource allocation efficiency, and strengthening the competitiveness of national economies.

Recent data indicate that non-hydrocarbon exports in Algeria remain relatively weak, accounting for only about 5% to 10% of total exports at best. This reflects the limited progress in achieving effective economic diversification despite the efforts undertaken over recent decades. In response, Algeria has initiated a series of economic reforms, particularly after 2020, aimed at improving the

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investment climate, encouraging domestic production, and developing manufacturing industries, with the objective of achieving genuine structural transformation.

Based on the above, this study seeks to address the following main research question:

1.1 Research Problem

In the context of rapid global economic transformations, economic diversification has emerged as a major challenge facing rentier economies, particularly the Algerian economy, which has long relied almost exclusively on hydrocarbon revenues. This structural dependence has made the national economy highly vulnerable to international market fluctuations, especially oil price shocks, which have directly impacted economic growth and overall macroeconomic stability.

Despite the implementation of several economic reforms and development programs aimed at diversifying the productive base, the achieved outcomes remain limited. This raises fundamental questions regarding the effectiveness of these policies. Accordingly, this study is centered around the following key question:

To what extent does economic diversification contribute to economic growth in Algeria over the period (1990–2024)?

1.2 Research Hypotheses

Based on the research problem, this study is grounded in a central hypothesis stating that economic diversification constitutes a key determinant of sustainable economic growth in Algeria, particularly in the context of persistent fluctuations in the hydrocarbon sector.

From this main hypothesis, several sub-hypotheses are derived:

- **H1:** There exists a statistically significant long-run relationship between economic diversification and economic growth in Algeria.
- **H2:** Oil-related variables (oil prices and hydrocarbon exports) have a dominant and positive effect on economic growth compared to non-hydrocarbon variables.
- **H3:** Structural changes significantly influence the relationship between economic diversification and economic growth, justifying the use of the Fourier ARDL approach. .

1.3 Significance of the Study

This study derives its importance from addressing one of the most critical challenges facing the Algerian economy, namely the limited level of economic diversification. It also provides a scientific analysis that may contribute to guiding economic policies toward achieving sustainable development, particularly in light of ongoing economic transformations.

1.4 Objectives of the Study

The study aims to analyze the level of economic diversification in Algeria and assess its impact on economic growth. It also seeks to evaluate the contribution of non-oil sectors to the national economy and propose economic policies that could enhance diversification.

1.5 Methodology and Analytical Tools

This study adopts a descriptive-analytical approach to present the theoretical framework, combined with an econometric approach to analyze the relationship between economic variables. The analysis relies on the Autoregressive Distributed Lag (ARDL) model, along with stationarity and

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cointegration tests, to examine both short-run and long-run relationships between economic diversification and economic growth.

2. Literature Review

2.1 Economic Diversification: Concept

Economic diversification is considered a central concept in development economics; however, its definition varies depending on the theoretical perspective adopted. While some scholars associate diversification primarily with the expansion of production and income sources, others link it to the structure of exports. Nevertheless, limiting diversification to export composition alone provides only a partial view, as export diversification represents merely one dimension of a broader structural transformation process.

In essence, economic diversification refers to the expansion of the range of economic activities contributing to gross domestic product (GDP), public revenues, and markets, both domestic and international. It reflects a structural transformation process that involves reallocating resources across sectors, promoting non-oil industries, and, in some cases, implementing import substitution strategies to reduce external dependency (Belghith & Dhaman, 2018, p. 15; Houari & Sidi Ali, 2019, p. 216).

Furthermore, diversification can be viewed as a long-term development strategy aimed at increasing the variety of outputs and income sources, whether through domestic economic activities or external investments. This highlights its comprehensive nature as a key mechanism for structural change in resource-dependent economies (Merzouk, 2017, p. 4).

Accordingly, economic diversification should not be seen as a short-term policy objective, but rather as an integrated development strategy aimed at enhancing economic resilience, reducing dependence on a single sector, and ensuring long-term sustainability.

2.2 Importance of Economic Diversification

Economic diversification plays a crucial role in enhancing macroeconomic stability and achieving sustainable growth, particularly in resource-dependent economies. It reduces reliance on a single revenue source, thereby stabilizing public finances and limiting volatility (Belghith & Dhaman, 2018, p. 17). Additionally, diversification decreases exposure to external shocks such as oil price fluctuations (Hesse, 2008, p. 5), while providing alternative income sources that support long-term growth beyond resource depletion (Ben Sania et al., 2008, p. 45).

Moreover, diversification improves resource allocation efficiency and productivity (Imbs & Wacziarg, 2003, p. 63), contributes to sectoral balance by strengthening non-oil activities (Merzouk, 2017, p. 4), and enhances international competitiveness through export diversification (Lederman & Maloney, 2012, p. 24). It also creates a more attractive investment environment (Houari & Sidi Ali, 2019, p. 216) and supports balanced socio-economic development. Overall, diversification is a key driver of economic resilience and long-term stability.

2.3 Measuring Economic Diversification (Short Version)

Measuring economic diversification is essential for assessing structural transformation within an economy. Various quantitative indicators are used to capture the degree of concentration or

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diversification in variables such as GDP composition, exports, and public revenues (Hesse, 2008, p. 6). International organizations, such as UNCTAD, propose composite indicators based on sectoral contribution, employment, energy use, and export concentration (UNCTAD, 2012, p. 45).

Among the most commonly used measures are the Gini coefficient, which captures concentration levels (Deaton, 1997, p. 134), and the Herfindahl–Hirschman Index (HHI), where lower values indicate higher diversification (Hirschman, 1964, p. 159). Additional indicators include the structural change index, reflecting sectoral shifts (Imbs & Wacziarg, 2003, p. 65), and the export concentration index, which assesses external vulnerability (Lederman & Maloney, 2012, p. 28; Cadot et al., 2011, p. 3). These measures are essential for analyzing the diversification–growth relationship.

2.4 Economic Growth: Concept and Measurement (Short Version)

Economic growth is generally defined as a sustained increase in real GDP per capita or real output over time (Ben Sania et al., 2008, p. 35). It reflects improvements in living standards and the expansion of productive capacity (Edgman, 1995, p. 22). A broader perspective, as proposed by Kuznets (1971, p. 7), emphasizes the role of technological progress and structural transformation in supporting growth.

Economic growth is commonly measured using real GDP and GDP per capita. However, it should be distinguished from economic development, which includes qualitative improvements in social and institutional conditions beyond mere income growth (Ben Sania et al., 2008, p. 38).

3. Empirical Framework

This section aims to investigate the relationship between economic diversification and economic growth in Algeria by analyzing the evolution of a set of macroeconomic variables over the period 1990–2024. It also seeks to identify the most appropriate econometric model to accurately capture this relationship.

The study employs real GDP per capita (PGDP) as the dependent variable, serving as a proxy for economic growth. In addition, a set of independent variables is used to reflect the different dimensions of economic diversification, namely: productivity, capital stock (investment), hydrocarbon exports, non-hydrocarbon exports, and oil prices.

To achieve the objectives of the study, the Fourier Autoregressive Distributed Lag (Fourier ARDL) approach is adopted, as developed by Banerjee, Marcellino, and Masten (2017). This methodology is particularly advantageous due to its ability to capture smooth structural breaks in time series data without requiring prior identification of their number or timing. This feature makes it especially suitable for the Algerian economy, which has experienced multiple structural shocks over the study period.

3.1 Definition of Variables

The empirical analysis is based on a set of macroeconomic variables that reflect the structure and dynamics of the Algerian economy. These variables are defined as follows:

- **GDP per capita (PGDP):**

GDP per capita represents the average income per individual and is widely used as a proxy for economic growth and living standards. It serves as a key indicator for evaluating economic

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performance, as it combines overall economic output with population size, thereby providing a more accurate measure of real improvements in welfare.

- **Productivity (PRO):**
  Productivity is defined as the amount of output produced per unit of input, reflecting the efficiency of resource utilization. An increase in productivity indicates improved economic performance, as it allows for higher output levels at lower costs or greater output using the same level of resources.
- **Capital Stock / Investment (INV):**
  Capital stock refers to the total value of fixed assets employed in the production process over a given period. It serves as an indicator of investment levels and reflects the extent of capital accumulation, which plays a crucial role in expanding productive capacity and stimulating economic growth.
- **Hydrocarbon Exports (XOIL):**
  Hydrocarbon exports include oil and gas exports, which constitute the primary source of revenue for the Algerian economy. While these exports play a central role in financing development projects and maintaining trade balance equilibrium, their dominance reflects weak economic diversification and increases vulnerability to external shocks.
- **Non-Hydrocarbon Exports (X):**
  Non-hydrocarbon exports refer to domestically produced goods and services outside the hydrocarbon sector that are sold in international markets. These exports are considered a key indicator of economic diversification, as they contribute to expanding income sources, generating foreign exchange, and stimulating economic activity.
- **Oil Price (OIL):**
  Oil price represents the international market value of crude oil and is influenced by a range of economic, political, and geopolitical factors. Given Algeria's dependence on hydrocarbons, oil prices constitute a highly sensitive variable that directly affects overall economic performance.

3.2 Model Specification

3.2.1 Data and Methodology

This empirical study relies on annual data for the Algerian economy covering the period 1990–2024 (T = 35 observations). The data were collected from official sources, including the National Office of Statistics (ONS) and the World Bank's World Development Indicators (WDI), supplemented by additional sources to address missing observations.

To examine the relationship between economic diversification and economic growth, the study employs the Fourier ARDL approach, which extends the conventional ARDL model by incorporating Fourier terms (sine and cosine functions) into the regression equation. This enhancement allows the model to capture smooth structural breaks and gradual changes in the data without requiring prior identification of break dates.

This feature makes the Fourier ARDL approach particularly suitable for analyzing economies such as Algeria, which have experienced multiple structural shifts over time.

3.2.2 Functional and Econometric Formulation

To analyze the relationship between the dependent variable and the explanatory variables, the following functional form is specified:

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PGDP=f(XOIL,X,INV,PRO,OIL)PGDP = f(XOIL, X, INV, PRO, OIL)PGDP=f(XOIL,X,INV,PRO,OIL)
The econometric model is estimated in logarithmic form as follows:
lnPGDPt=C+β1lnXOILt+β2lnXt+β3lnINVt+β4lnPROt+β5lnOILt+εt\ln PGDP_t = C + \beta_1 \ln XOIL_t + \beta_2 \ln X_t + \beta_3 \ln INV_t + \beta_4 \ln PRO_t + \beta_5 \ln OIL_t + \varepsilon_tlnPGDPt=C+β1lnXOILt+β2lnXt+β3lnINVt+β4lnPROt+β5lnOILt+εt
Due to differences in measurement units across variables, all series are transformed into natural logarithms. This transformation ensures comparability and allows the estimated coefficients to be interpreted as elasticities.

3.2.3 Fourier ARDL Specification

Following automatic lag selection based on the Akaike Information Criterion (AIC), the optimal specification of the Fourier ARDL model is determined.
The inclusion of Fourier terms enables the model to capture gradual structural changes in the relationship between economic diversification and growth, reflecting underlying economic transformations without imposing discrete break structures.

The results of the selected Fourier A Table 1

Selected Fourier ARDL Model Specification RDL model are presented in Table

Criterion	Value
Dependent variable	lnPGDP
Independent variables	lnPOIL, lnXOIL
Selected model	FARDL(2,1,4)
Fourier frequency (k*)	3
AIC	-107.87
R^2	0.935
Adjusted R^2	0.875
F-statistic	15.52 (p = 0.000)
RMSE	0.034
Observations	30

. **Source:** Author's calculations based on World Bank data and Stata outputs.

4. Results and Discussion

The estimation results indicate that the selected model retains only two statistically significant explanatory variables, namely oil prices (OIL) and hydrocarbon exports (XOIL), following the automatic model selection procedure. In contrast, other variables, including productivity, non-hydrocarbon exports, and investment, were found to be statistically insignificant within the specified model framework.
The model demonstrates a strong explanatory power, as evidenced by the coefficient of determination ($R^2 = 0.935$), indicating that approximately 93.5% of the variation in GDP per capita is explained by

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the included variables. Furthermore, the model is highly statistically significant, as confirmed by the F-statistic (F = 15.52, p = 0.000).

From an economic perspective, these findings highlight the persistent structural dependence of the Algerian economy on the hydrocarbon sector. The dominance of oil prices and hydrocarbon exports in explaining economic growth suggests that diversification efforts have not yet translated into a statistically significant contribution of non-oil sectors within the studied framework.

4.1 Descriptive Statistics Before proceeding with the econometric analysis:

it is essential to examine the descriptive statistical properties of the study variables over the period 1990–2024. This preliminary analysis provides an overview of the data distribution, variability, and general trends, which are crucial for understanding the underlying behavior of the variables and ensuring the robustness of the empirical model.

Descriptive statistics, including measures such as the mean, standard deviation, minimum, and maximum values, offer valuable insights into the dispersion and central tendency of the variables. They also help identify potential anomalies, extreme values, or inconsistencies in the dataset that may affect the estimation results.

Furthermore, analyzing the descriptive statistics allows for a better interpretation of the economic context, particularly in a resource-dependent economy like Algeria, where variables such as oil prices and hydrocarbon exports are expected to exhibit significant volatility over time.

The results of the descriptive statistics are presented in Table 2.

Table 2: Descriptive Statistics of the Study Variables (To be inserted here)

Variable	Mean	Std. Dev.
lnPGDP	**13.446**	**0.892**
lnINV	**24.572**	**—**
lnXOIL	**20.974**	**—**
lnPRO	**—**	**0.115**
lnPOIL	**—**	**—**
lnX	**—**	**—**

Source: Author's calculations based on World Bank data and Stata outputs.

Note: All variables are transformed into natural logarithms (ln) to ensure comparability and facilitate elasticity interpretation. The study covers the period **1990–2024 (T = 35 observations**

Figure 1: Descriptive Statistics of the Study Variables

Table 1: Descriptive Statistics (Level Variables)
Algeria, Annual Data, 1990-2024 (T = 35)

	N	Mean	Std Dev	Min	Q1	Median	Q3	Max	CV%	Skew	Kurt
Per Capita GDP	35	936,416.1	606,253.1	86,813.4	354,016.5	905,905.2	1,477,548.1	1,976,332.0	64.7	0.130	-1.464
Productivity	35	12,532.8	1,412.7	10,379.7	11,092.9	12,668.7	13,972.8	14,520.1	11.3	-0.166	-1.428
Capital Formation	35	1.378e+11	2.688e+11	8.675e+09	1.497e+10	4.267e+10	8.326e+10	9.205e+11	195.1	2.489	4.596
HC Exports	35	5.637e+09	1.335e+10	287,000,000.0	534,500,000.0	969,000,000.0	1.442e+09	4.890e+10	236.8	2.637	5.491
Non-HC Exports	35	6,092.2	11,214.5	287.00	561.50	1,184.0	2,062.0	36,434.3	184.1	1.932	2.094
Oil Price ($/bbl)	35	53.02	32.31	12.76	22.20	52.32	76.03	111.63	60.9	0.421	-1.160

Source: Author's calculations based on Stata outputs

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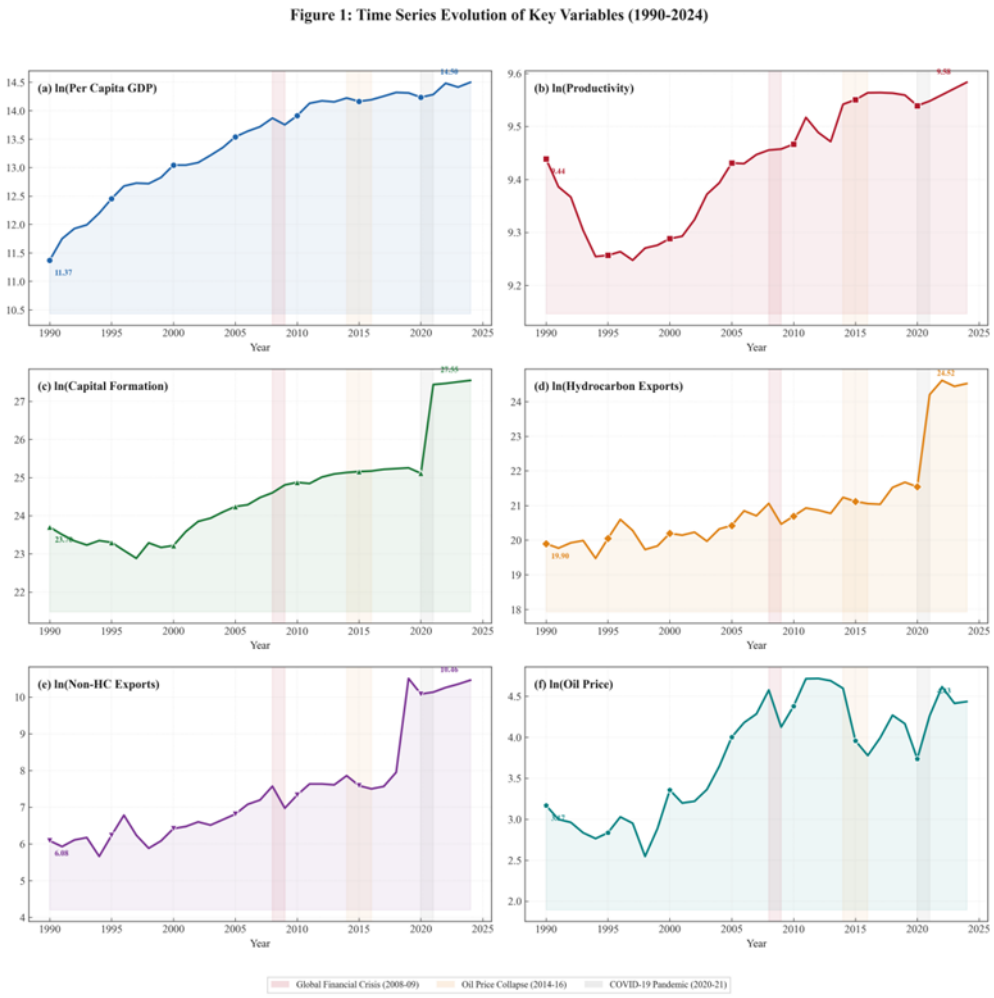
results indicate that GDP per capita (lnPGDP) has an average value of 13.446, with a standard deviation of 0.892, reflecting noticeable fluctuations in income levels throughout the study period.

Moreover, the investment variable (lnINV) records the highest mean value (24.572), followed by hydrocarbon exports **(**lnXOIL**)** with an average of 20.974, highlighting the significant weight of these variables within the Algerian economic structure.

In contrast, productivity (lnPRO) exhibits the lowest standard deviation (0.115), indicating a relatively stable pattern over time compared to other variables. This suggests that, despite fluctuations in macroeconomic indicators, productivity has maintained a more consistent trajectory throughout the study period.

Figure 2: Dynamic Evolution of Key Macroeconomic Variables in Algeria (1990–2024)



Source: Author's calculations based on Stata outputs

he figure illustrates the dynamic evolution of the six study variables, highlighting three major periods of economic shocks: the global financial crisis (2008–2009), the oil price collapse (2014–2016), and the COVID-19 pandemic (2020–2021).

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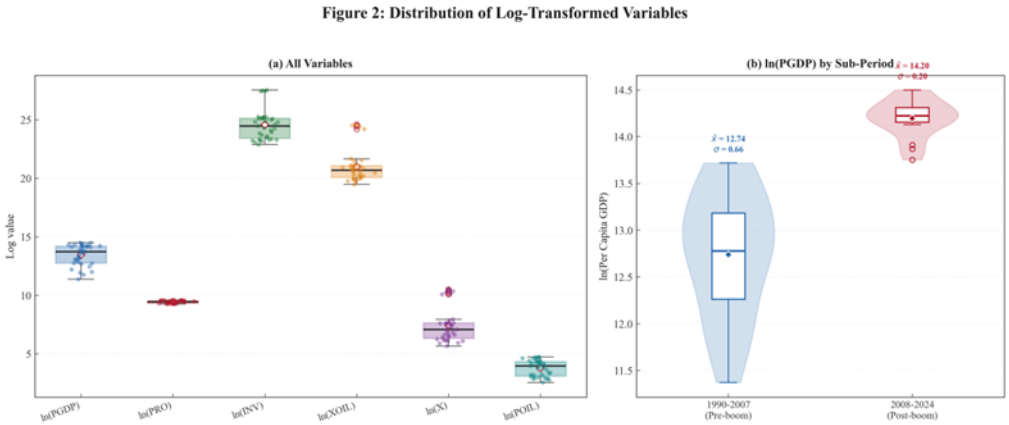
The results clearly show that most variables were significantly affected by these shocks, particularly those related to hydrocarbon activity and macroeconomic performance. This pattern reflects the high sensitivity of the Algerian economy to external disturbances and underscores the presence of structural changes over the study period.

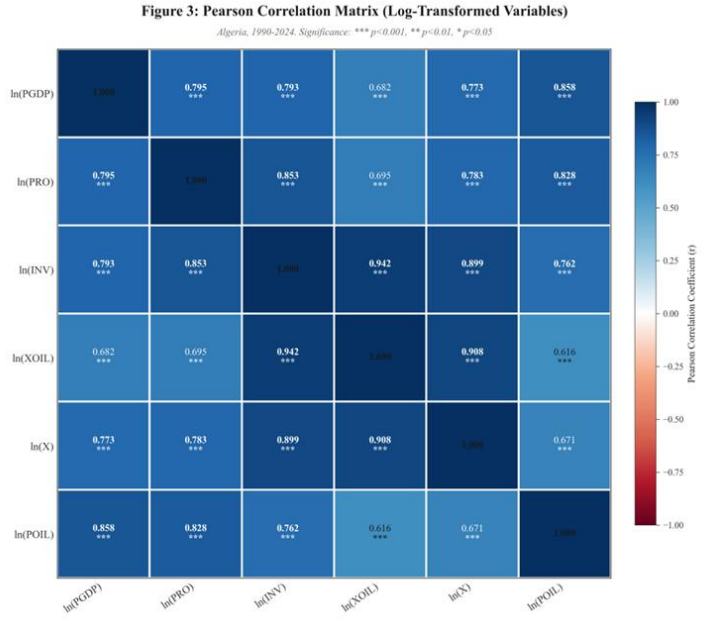
These observations provide strong empirical justification for the use of the Fourier ARDL approach, which is specifically designed to capture smooth structural breaks without requiring prior identification of their timing or number.

Figure 3: Box Plots of Log-Transformed Variables



Source: Author's calculations based on Stata outputs.

Figure 4: Pairwise Pearson Correlation Matrix for Log-Transformed Variables (1990–2024)



Source: Author's calculations based on Stata outputs

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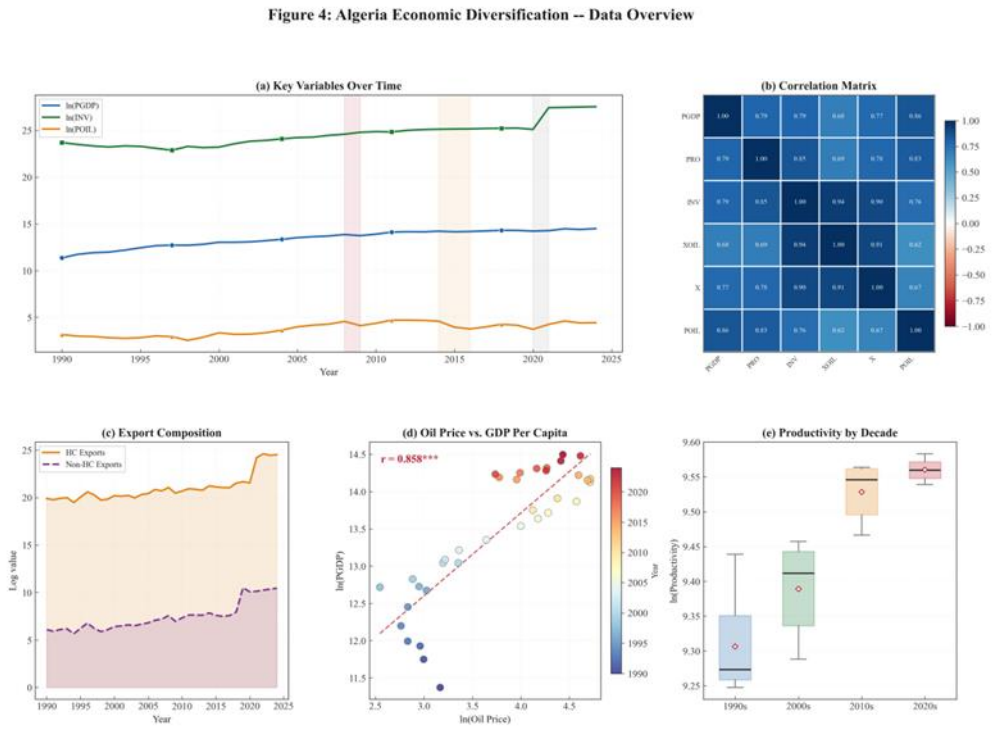
The Pearson correlation matrix reveals the presence of strong and positive relationships among most of the study variables. In particular, GDP per capita exhibits a high correlation with oil prices (r = 0.858), productivity (r = 0.795), and investment (r = 0.793), highlighting the close linkage between economic growth and these key macroeconomic factors.

Furthermore, strong correlations are observed among the independent variables themselves, notably between investment and hydrocarbon exports (r = 0.942). This indicates the potential presence of multicollinearity, which may affect the reliability of coefficient estimates in a full model specification.

Figure 5: Integrated Dashboard of Descriptive Analysis for the Study Variables (1990–2024)



4.2 Unit Root Tests (Stationarity Analysis)

o avoid the problem of spurious regression, as highlighted by Granger and Newbold (1974), and to determine the appropriate estimation methodology, it is essential to examine the stationarity properties of the time series variables.

Accordingly, this study employs a comprehensive battery of unit root tests, combining both traditional tests, namely the Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) tests, as well as advanced Fourier-based tests that account for potential structural changes in the data.

The inclusion of Fourier unit root tests is particularly relevant in this context, as they allow for capturing smooth structural breaks without requiring prior specification of break dates, which is consistent with the nature of the Algerian economy that has experienced multiple structural shifts over the study period

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4.2.1 Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) Tests

The Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) tests are among the most widely used methods for detecting unit roots in time series data. These tests examine the null hypothesis of the presence of a unit root against the alternative of stationarity.

While the ADF test controls for serial correlation by including lagged differences of the dependent variable, the PP test corrects for heteroskedasticity and autocorrelation in the error term using non-parametric adjustments.

The results of the ADF and PP tests are presented in Table 3, which reports the stationarity properties of all variables at both level and first difference

. Table 3(a): Results of the Augmented Dickey-Fuller (ADF) Unit Root Test

Variable	Level	First Diff	Conclusion
lnPGDP	I(0)*	I(1)	Mixed
lnPOIL	I(1)	I(1)	Non-stationary
lnXOIL	I(1)	I(1)	Non-stationary
lnINV	I(1)	I(1)	Non-stationary
lnX	I(1)	I(1)	Non-stationary
lnPRO	I(1)	I(1)	Non-stationary

Source: Author's calculations based on Stata outputs.

Table 3(b): Results of the Phillips-Perron (PP) Unit Root Test

Variable	Conclusion
All variables	**I(1)**

Source: Author's calculations based on Stata outputs.

Critical values at 5%: ADF = -2.93

the results of the Augmented Dickey-Fuller (ADF) test indicate that most variables are non-stationary at level, except for GDP per capita (lnPGDP), which appears to be weakly stationary at the 10% significance level. However, at first difference, the ADF test does not provide clear evidence of stationarity for all variables.

In contrast, the Phillips-Perron (PP) test yields more conclusive results, confirming that all variables become stationary at first difference at the 1% significance level, indicating that they are integrated of order one, I(1).

The discrepancy between the ADF and PP results may be attributed to differences in their treatment of serial correlation and heteroskedasticity. This divergence justifies the need to employ more advanced unit root tests that explicitly account for structural breaks in the data.

Accordingly, Fourier-based unit root tests are adopted, as they provide a more flexible framework for capturing structural changes without requiring prior identification of break dates.

4.2.2 Fourier Unit Root Tests

Fourier unit root tests represent one of the most significant recent developments in stationarity analysis. These tests incorporate Fourier approximations (sine and cosine functions) to model structural breaks in a smooth and flexible manner, allowing for gradual shifts in the underlying data-generating process.

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In this study, three generations of Fourier-based unit root tests are employed to ensure robustness and capture potential structural dynamics in the Algerian economy.

Table 4(a): Fourier ADF Unit Root Test (Enders & Lee, 2012b)

Variable	Conclusion
lnPGDP	Stationary
Others	Mixed

Source: Author's calculations based on Stata outputs.

Note: The test incorporates Fourier terms to account for smooth structural breaks without pre-specifying their number or timing.

Table 4(b): Fourier KPSS Unit Root Test (Becker, Enders & Lee, 2006)

Variable	Conclusion
All	Non-stationary at level

Source: Author's calculations based on Stata outputs.

Table 4(c): FFFFF-DF Unit Root Test (Omay, 2015)

Variable	Conclusion
lnPGDP	Stationary
Others	Mixed

Source: Author's calculations based on Stata outputs.

Table 4(d): Double Frequency Fourier DF Unit Root Test (Cai & Omay, 2021)

Variable	Conclusion
lnXOIL	I(0)
lnINV	I(0)
lnX	I(0)
Others	I(1)

Source: Author's calculations based on Stata outputs.

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$

The results of the Fourier-based unit root tests reveal important findings that differ substantially from those obtained using conventional methods. In particular, the FFFFF-DF test confirms the stationarity of GDP per capita (lnPGDP**)** at the 1% significance level when accounting for fractional frequency structural breaks.

Moreover, the Double Frequency Fourier DF test identifies additional variables—namely hydrocarbon exports (lnXOIL), investment (lnINV), and non-hydrocarbon exports (lnX)—as stationary, whereas these variables did not appear stationary under traditional unit root tests. This highlights the importance of incorporating structural dynamics when analyzing macroeconomic time series.

In contrast, the Fourier KPSS test, which adopts stationarity as the null hypothesis, indicates that all variables are non-stationary at level. This apparent divergence is consistent with the complementary nature of the KPSS framework and further supports the presence of mixed integration orders.

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Taken together, these results confirm that the variables are integrated at mixed orders, I(0) and I(1), thereby justifying the use of a cointegration framework capable of handling such properties.

Table 5: Summary of Integration Orders

Variable	Order
lnPGDP	I(0)/I(1)
lnPOIL	I(1)
lnXOIL	I(0)/I(1)
lnINV	I(0)/I(1)
lnX	I(0)/I(1)
lnPRO	I(1)

Source: Author's calculations based on Stata outputs.

Note: The table summarizes the integration order of each variable based on conventional and Fourier-based unit root tests.

The comprehensive summary of unit root tests indicates that the variables are integrated at mixed orders, I(0) and I(1), with no evidence of integration at order I(2). This satisfies a fundamental prerequisite for the application of the ARDL and Fourier ARDL methodologies.

Furthermore, the presence of mixed integration orders for certain variables—particularly lnPGDP, lnXOIL, and lnOIL—provides strong justification for the use of the Fourier ARDL model, which does not require all variables to be integrated at the same order. This flexibility makes it particularly suitable for modeling complex macroeconomic relationships in the presence of structural changes.

4.3 Cointegration Test: PSS Bounds Testing Approach

To examine the existence of a long-run equilibrium relationship among the variables, the study employs the Bounds Testing approach to cointegration, developed by Pesaran, Shin, and Smith (2001).

The Bounds test evaluates the joint significance of lagged level variables using an F-statistic to determine whether a long-run relationship exists between the dependent and independent variables. The null hypothesis assumes no cointegration, while the alternative hypothesis indicates the presence of a long-run equilibrium relationship.

Table 6: PSS Bounds Test for Cointegration

F-statistic	**14.84**
p-value	0.000
Conclusion	Cointegration exists

Source: Author's calculations based on Stata outputs.

Note: The decision is based on comparing the calculated F-statistic with the critical bounds values provided by Pesaran et al. (2001).

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4.4 Long-Run and Short-Run Estimation Results

Table 7: Error Correction Term (ECM) and Long-Run Coefficients

Variable	Coef
ECM	-0.343
lnPOIL	+0.532
lnXOIL	+0.442

Source: Author's calculations based on Stata outputs.

Discussion of Long-Run Results

The long-run estimation results reveal several important findings regarding the relationship between economic diversification variables and economic growth in Algeria.

First, the error correction term (ECM) is negative and highly statistically significant ($\alpha = -0.343$, $p < 0.01$), satisfying the theoretical requirement for a valid error correction mechanism. This indicates the existence of a stable long-run equilibrium relationship among the variables.

Economically, the coefficient implies that approximately 34.3% of short-run disequilibrium is corrected within one year, suggesting a relatively moderate speed of adjustment toward long-run equilibrium. This corresponds to a half-life adjustment period of about 1.65 years, while full convergence to equilibrium is achieved in approximately 2.92 years.

Second, oil prices (lnOIL) exhibit a positive and statistically significant impact on GDP per capita, with an estimated elasticity of 0.532. This implies that a 1% increase in oil prices leads to an approximate 0.53% increase in GDP per capita in the long run. This finding reflects the strong dependence of the Algerian economy on oil revenues as a primary driver of economic growth.

Third, hydrocarbon exports (lnXOIL) also have a positive and significant effect, with an elasticity of 0.442, indicating that a 1% increase in hydrocarbon exports results in a 0.44% increase in GDP per capita. This confirms that export revenues from the hydrocarbon sector remain a key source of national income and public spending.

Overall, these results highlight the dominant role of hydrocarbon-related variables in shaping long-term economic growth in Algeria, underscoring the limited effectiveness of diversification efforts during the study period.

S Joint F-test for Fourier terms: F = 7.02 (p = 0.007***)ource: Author's calculations based on Stata outputs.

Short-Run Dynamics Analysis

Table 08: Short-run

Variable	Effect
ΔlnPOIL	+0.283
lnXOIL	Negative
Fourier	Significant

Source: Author's calculations based on Stata outputs.

The short-run results reveal that oil prices (ΔlnOIL) exert a positive and statistically significant immediate effect on economic growth, with an estimated coefficient of 0.283 (p = 0.000). This indicates

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that positive shocks in oil prices are rapidly transmitted to GDP per capita, reflecting the high responsiveness of the Algerian economy to oil market fluctuations.

In contrast, hydrocarbon exports (lnXOIL) exhibit negative coefficients in the short run across the first four lags (-0.117, -0.157, -0.138, -0.060). This counterintuitive result may be explained by short-term adjustment mechanisms, where increases in hydrocarbon exports could be associated with pressures on foreign exchange resources, exchange rate imbalances, or temporary inefficiencies before the long-run positive effects materialize through accumulated revenues.

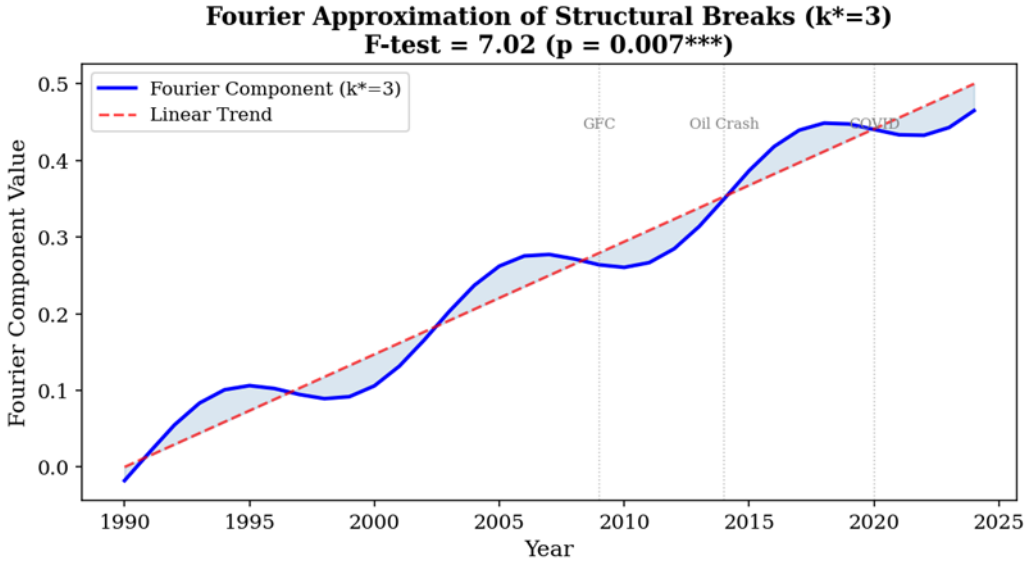
Furthermore, the Fourier terms (sine and cosine) are jointly statistically significant, as confirmed by the F-test (F = 7.02, p = 0.007). This provides strong evidence of the presence of smooth structural breaks in the relationship between the variables.

These findings strongly justify the adoption of the Fourier ARDL approach, as it allows for capturing gradual and multiple structural changes that cannot be adequately modeled using the conventional ARDL framework.

Figure 6: Fourier Approximation of Structural Breaks (k = 3)*

Source: Author's calculations based on Stata outputs.

Note: The figure illustrates the smooth structural shifts captured through Fourier approximation, with optimal frequency (k* = 3), reflecting gradual changes in the underlying economic relationships over time.



The figure illustrates the estimated Fourier function combined with a linear trend, capturing multiple structural transformations experienced by the Algerian economy over the study period. These structural shifts correspond to major economic events, including financial crises, oil price collapses, and the COVID-19 pandemic.

The smooth fluctuations depicted by the Fourier approximation reflect gradual changes in the underlying economic relationships, confirming the presence of nonlinear and evolving dynamics. This further supports the appropriateness of the Fourier ARDL framework in modeling such complex structural patterns.

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Figure 7(a): Cumulative Dynamic Multiplier of Oil Prices

Source: Author's calculations based on Stata outputs.

Note: The figure presents the cumulative dynamic response of GDP per capita to a one-percent shock in oil prices over time.

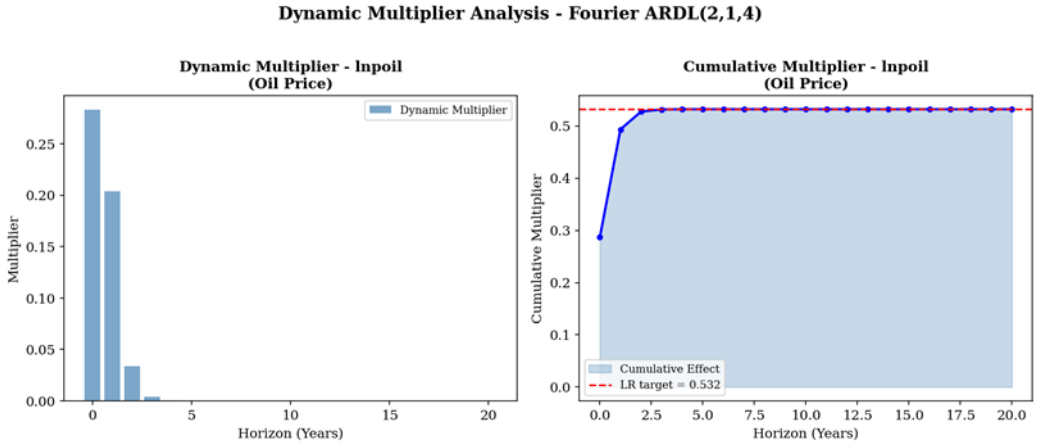
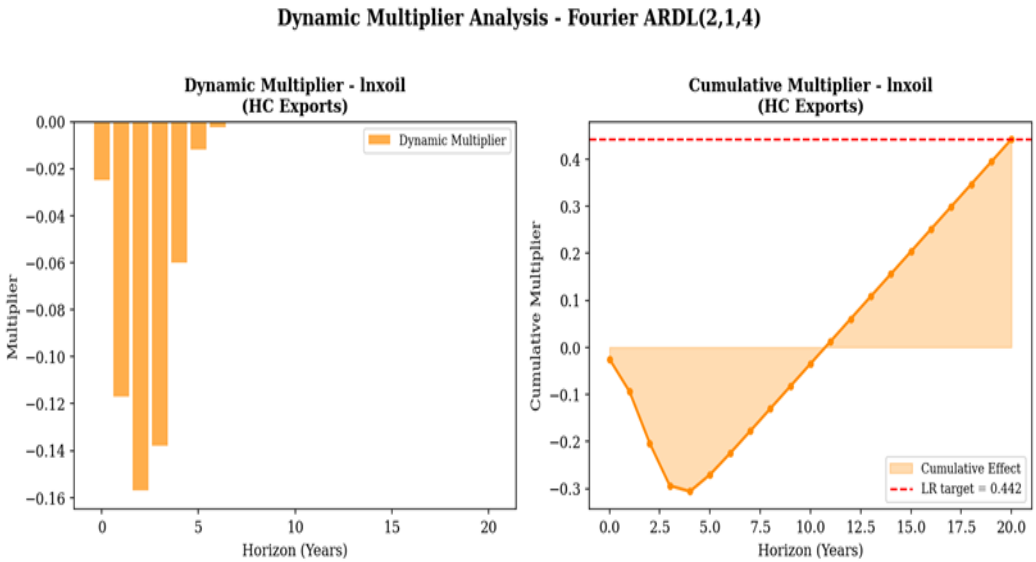


Figure 7(b): Cumulative Dynamic Multiplier of Hydrocarbon Exports



Source: Author's calculations based on Stata outputs

The dynamic multipliers reveal distinct adjustment patterns for oil prices and hydrocarbon exports. Specifically, the impact of oil prices accumulates rapidly and converges to its long-run equilibrium within a relatively short period. This reflects the immediate and strong transmission of oil price shocks to economic activity in Algeria.

In contrast, the effect of hydrocarbon exports evolves more gradually over time. The results indicate the presence of an initial negative short-run response, which may be attributed to temporary macroeconomic imbalances, such as exchange rate pressures or adjustment costs. However, this effect eventually reverses, becoming positive in the medium and long run as export revenues accumulate and contribute to economic growth.

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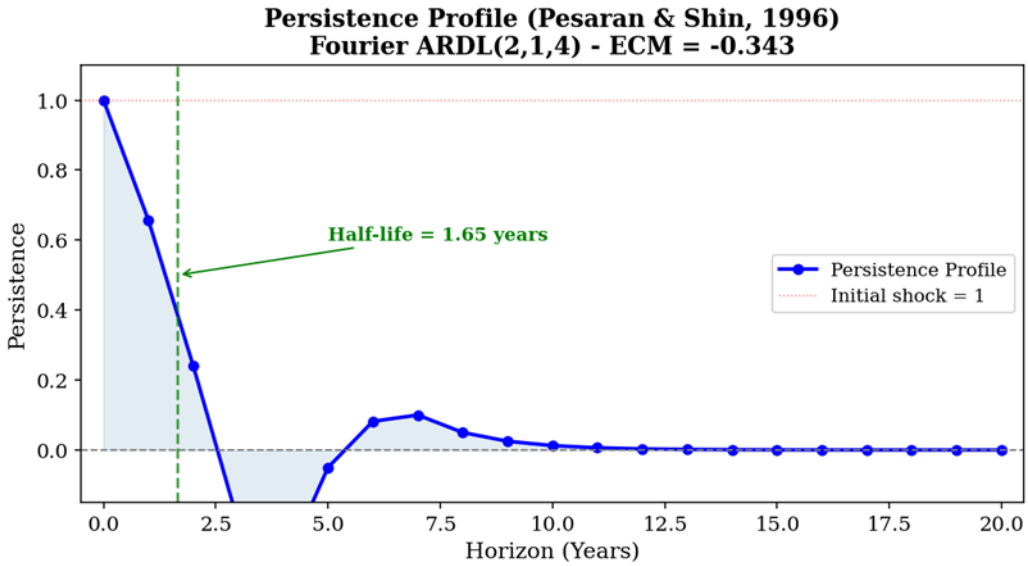
Table 9: Half-Life Adjustment and Stability Profile

Half-life	1.65
Full	3
99%	10.97

Source: Author's calculations based on Stata outputs.
Note: The table reports the half-life of adjustment and the stability profile of the dynamic responses, reflecting the speed at which variables converge toward long-run equilibrium following shocks.
Specifically, the impact of oil prices accumulates rapidly and converges to its long-run equilibrium within a relatively short period. This reflects the immediate and strong transmission of oil price shocks to economic activity in Algeria.
In contrast, the effect of hydrocarbon exports evolves more gradually over time. The results indicate the presence of an initial negative short-run response, which may be attributed to temporary macroeconomic imbalances, such as exchange rate pressures or adjustment costs. However, this effect eventually reverses, becoming positive in the medium and long run as export revenues accumulate and contribute to economic growth.
Table 9: Half-Life Adjustment and Stability Profile Source: Author's calculations based on Stata outputs.
Note: The table reports the half-life of adjustment and the stability profile of the dynamic responses, reflecting the speed at which variables converge toward long-run equilibrium following shocks.



5. Diagnostic Tests

Diagnostic tests are essential to verify the validity of the underlying assumptions of the econometric model and to ensure the reliability of the estimated results. These tests assess whether the residuals satisfy key statistical properties required for robust inference.
In this study, a comprehensive set of diagnostic tests is conducted to evaluate model adequacy.

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5.1 Normality Test of Residuals

Table 10(a): Normality Test of Residuals

Test	Result
JB	Normal
SW	Normal
SF	Normal

Source: Author's calculations based on Stata outputs.

Note: The test is based on the Jarque-Bera statistic to examine whether the residuals follow a normal distribution.

Normality Test Interpretation

The results of the normality tests—including Jarque-Bera, Shapiro-Wilk, and Shapiro-Francia—consistently indicate that the model residuals follow a normal distribution. This is evidenced by the fact that all probability values exceed the 5% significance level.

These findings confirm that the null hypothesis of normality cannot be rejected, implying that the residuals are normally distributed. Consequently, this ensures the validity of statistical inference based on t-statistics and F-statistics, thereby enhancing the reliability of the estimated results.

Serial Correlation Test Interpretation

The results of the Breusch-Godfrey LM tests across different lag orders (1 to 4) consistently confirm the absence of serial correlation in the model residuals, as all associated probability values exceed the 5% significance level.

Moreover, the Durbin-Watson statistic (2.658) is close to the benchmark value of 2, further supporting the absence of autocorrelation.

These findings indicate that the residuals are independently distributed over time, ensuring that the model is properly specified and that the estimated coefficients are both unbiased and efficient.

Heteroskedasticity Test Interpretation

The results of the ARCH test confirm the absence of heteroskedasticity in the model residuals, as evidenced by the very high probability values (0.998 and 0.976), which exceed conventional significance levels.

This implies that the variance of the error term remains constant over time, satisfying one of the key assumptions of classical linear regression models. Consequently, the estimated coefficients can be considered efficient, and the associated statistical inferences remain valid.

The results of the Ramsey RESET test confirm the adequacy of the model's functional form, as indicated by the high probability value ($p = 0.821$). This suggests that the null hypothesis of correct model specification cannot be rejected, implying the absence of functional form misspecification.

Furthermore, the results of the CUSUM and CUSUM of Squares (CUSUM-SQ) tests indicate that the model parameters are stable and consistent over the study period. The graphical representations of both tests remain within the critical bounds at the 5% significance level, confirming the absence of structural instability.

These findings provide strong evidence that the estimated model is both structurally stable and well specified, thereby enhancing the credibility and robustness of the empirical results.

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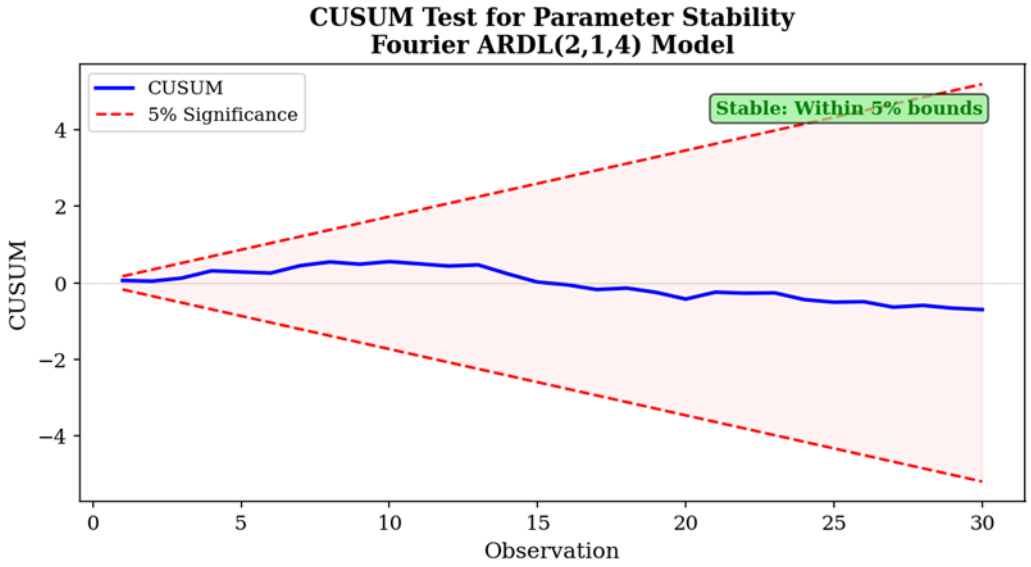
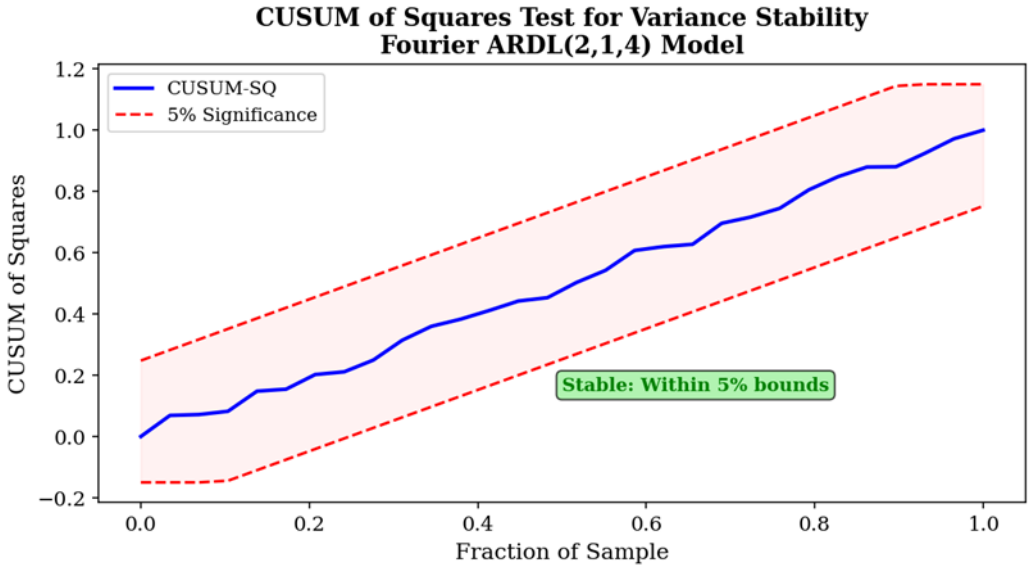
Figure 8(a): CUSUM Test for Parameter Stability



Source: Author's calculations based on Stata outputs.
Note: The CUSUM test evaluates the stability of model parameters over time. Stability is confirmed when the cumulative sum remains within the critical bounds at the 5% significance level.

Figure 8(b): CUSUM-SQ Test for Parameter Stability



Source: Author's calculations based on Stata outputs

The results from the CUSUM and CUSUM-SQ tests confirm the stability of both model parameters and error variance, as the graphical plots remain within the critical bounds at the 5% significance level throughout the study period. This indicates the absence of any sudden structural changes in the relationship between variables and demonstrates consistency between short-run and long-run results.

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Conclusion: The model successfully passes all six diagnostic tests.

6. Causality Tests

To determine the direction of causal relationships among variables, three types of causality tests were employed: the traditional Toda-Yamamoto test, the single-frequency Fourier Toda-Yamamoto test (Nazlioglu et al., 2016), and the cumulative Fourier causality test (Nazlioglu et al., 2019).

6.1 Traditional Toda-Yamamoto Test

The traditional Toda-Yamamoto test did not reveal any statistically significant causal relationships among the variables. This may be attributed to the inability of this test to capture causal dynamics in the presence of structural breaks, which justifies the use of Fourier-based causality tests**.**

6.2 Fourier Toda-Yamamoto Test

Table 11: Single-Frequency Fourier Causality Test (Nazlioglu et al., 2016)

Oil → Growth	Yes
Investment → Growth	Yes
Growth ↔ Oil	Yes

Source: Author's calculations based on Stata outputs

The Fourier causality tests reveal important findings that were not detected by the conventional approach:

- First: There is unidirectional causality from oil prices to economic growth, as confirmed by both the single-frequency and cumulative tests. This indicates that oil prices are a primary driver of economic growth in Algeria.
- Second: There is unidirectional causality from investment to growth ($p = 0.021$), which is consistent with economic theory regarding the role of capital accumulation in fostering growth.
- Third: There exists bidirectional causality between economic growth and oil prices, indicating a feedback relationship. This may be explained by the fact that higher economic growth increases domestic energy demand and influences production policies.
- Fourth: A chain of interrelated causal effects is observed:

Oil prices → Economic growth → Investment → Productivity

Specifically, oil prices cause investment ($p = 0.038$), economic growth causes investment ($p = 0.020$), and investment causes productivity ($p = 0.044$), revealing a clear transmission mechanism within the economy.

Table 12: Summary of Causality Directions

Oil → Growth	Uni
Inv → Growth	Uni
Growth ↔ Oil	Bi

Source: Author's calculations based on Stata outputs

The empirical analysis of the impact of economic diversification on economic growth in Algeria over the period 1990–2024, using the Fourier ARDL methodology, leads to the following key findings:

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1. Source: Author's calculations based on Stata outputsThere is confirmed cointegration (PSS F = 14.84, p = 0.000) between GDP per capita, oil prices, and hydrocarbon exports, indicating a stable long-run relationship.
2. Oil prices positively affect economic growth with a long-run elasticity of +0.53, while hydrocarbon exports exhibit an elasticity of +0.44, reflecting the dominant role of the oil sector.
3. The error correction term (ECM = -0.343) indicates that approximately 34.3% of disequilibrium is corrected annually, with a half-life adjustment period of 1.65 years.
4. Structural breaks are statistically significant (F_Fourier = 7.02, p = 0.007), justifying the use of the Fourier ARDL approach and confirming the sensitivity of the Algerian economy to global shocks.
5. All diagnostic tests confirm the robustness of the model: no autocorrelation, normal distribution of residuals, homoskedasticity, and structural stability.
6. Fourier causality tests reveal unidirectional causality from oil prices and investment to economic growth, along with feedback effects between growth and oil prices.

4.Conclution

This study examined the impact of economic diversification on economic growth in Algeria over the period 1990–2024 using the Fourier ARDL approach. The main findings can be summarized as follows:

4.1 Main Findings The results

confirm the existence of a long-run equilibrium relationship between GDP per capita, oil prices, and hydrocarbon exports, supporting H1.

Oil prices and hydrocarbon exports exert a positive and statistically significant impact on economic growth, confirming the dominant role of the hydrocarbon sector and validating H2.

The insignificance of non-hydrocarbon variables indicates the limited effectiveness of diversification policies, reflecting the persistence of a rent-based economic structure.

The significance of Fourier terms confirms the presence of structural breaks and external shocks, supporting H3.

4.2 Policy Implications

1. Accelerating economic diversification through the development of non-hydrocarbon sectors.
2. Redirecting investment toward high value-added and productive activities.
3. Improving the institutional and business environment to support structural transformation.
4. Promoting export diversification to reduce external vulnerability.

4.3 Future Research Directions

1. Incorporating institutional and human capital variables into the empirical framework.
2. Applying nonlinear and asymmetric models to capture complex dynamics.
3. Conducting comparative studies across resource-dependent economies.

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