IS THERE A SYMMETRIC OR ASYMMETRIC IMPACT OF SHADOW ECONOMY SHOCKS ON NON-HYDROCARBON TAX REVENUES IN ALGERIA?

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The objective of this research paper is to investigate the effects of positive and negative shocks of the shadow economy on non-hydrocarbon tax revenues in Algeria, using semi-annual data covering the period from 1993 to 2020. The analysis employs the Non-Linear Autoregressive Distributed Lag (NARDL) model. The results of the unit root tests accounting for structural breaks, Zivot–Andrews (ZA) and Lee–Strazicich (LS) tests, indicate that all variables become stationary after first differencing. The econometric results reveal the existence of a long-run equilibrium relationship among the variables under study. The Wald test also provides weak evidence of long-run asymmetry in the impact of shadow economy shocks on non-hydrocarbon tax revenues. The result is statistically significant at the 10% level but not at the conventional 5% level. Non-hydrocarbon tax revenues appear to be more sensitive to negative shocks than to positive shocks. In the long run, a negative shock to the shadow economy leads to a 1.7424% increase in non-hydrocarbon tax revenues, whereas a positive shock leads to a 0.58% decrease. In the short run, the results indicate symmetric effects of positive and negative shocks to the shadow economy on non-hydrocarbon tax revenues.

Keywords: Shadow Economy; Non-hydrocarbon tax revenues; real gross domestic product excluding the hydrocarbon sector; NARDL; Asymmetric.

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INTRODCTION

Since the early 1990s, the global economy has experienced profound structural transformations driven by globalization, economic liberalization, and the transition toward market-oriented economic systems. These systems are fundamentally based on profit maximization and improvements in economic efficiency. Together with various economic and institutional factors, these transformations have contributed to the rapid expansion of the Shadow Economy across both developed and developing countries, making it a global phenomenon that has attracted considerable academic and policy interest.

The Shadow Economy has increasingly become a subject of interest among researchers and policymakers because of its widespread prevalence and its significant implications for economic performance. In this context, (Medina & Schneider, 2018) estimated the size of the Shadow Economy in 158 countries across different regions of the world over the period 1991–2015. Their findings indicate that the average size of the Shadow Economy represented approximately 31.9% of global gross domestic product (GDP). The lowest share was recorded in 2014 at 27.44%, whereas the highest reached 35.22% in 1993. At the country level, Georgia ranked first, with the Shadow Economy accounting for 71.95% of GDP in 1993.

The consequences of the Shadow Economy extend beyond economic considerations to encompass important social, political, and institutional dimensions. From a macroeconomic perspective, the informal sector affects several key indicators,

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including unemployment, the velocity of money circulation, tax collection, and the effectiveness of both fiscal and monetary policies. According to (Schneider, 2012), informal employment accounts for nearly 70% of the global labor force. During the period 2000–2007, informal employment represented approximately 50.1% of total employment in Central and South America, 70.2% in 34 Asian countries, and 60.5% of non-agricultural employment in African countries.

Governments continuously seek to strengthen their fiscal capacity to finance development programs and implement economic and social policies. Since tax revenues constitute the primary source of government revenue and one of the most important instruments of fiscal policy, the effectiveness of any tax system depends on its ability to ensure equity, comprehensiveness, and efficiency in tax administration. However, the expansion of the Shadow Economy undermines tax system performance by narrowing the tax base and increasing tax evasion and tax fraud. Consequently, government revenues decline, reducing the state's ability to finance public expenditure and achieve sustainable development objectives.

In Algeria, the Shadow Economy represented an average of 30.86% of GDP during the period 1993–2015. It reached its highest level of 38.88% in 1993 before declining to 23.98% in 2015 (Medina & Schneider, 2018). These figures indicate that, like many developing economies, Algeria is substantially affected by the widespread prevalence of informal and illegal economic activities, including tax evasion, tax fraud, informal employment, and informal trade. As a consequence, tax revenues have weakened, government income has declined, and adverse effects have been observed on the state budget, public expenditure, gross domestic product, and ultimately economic growth. To address these challenges, Algerian authorities have introduced a series of measures aimed at containing the expansion of the Shadow Economy and integrating its activities into the formal sector in order to broaden the tax base and promote sustainable economic growth.

Due to Algeria's heavy reliance on petroleum taxation to finance the government budget, periods of declining oil prices create uncertainty and concern among public authorities. Against this backdrop, the importance of this study lies in its attempt to analyze the dynamic relationship between positive and negative shocks to the Shadow Economy and ordinary tax revenues (excluding the hydrocarbon sector) by estimating a nonlinear model capable of identifying asymmetric effects.

Therefore, this study seeks to determine how the Shadow Economy affects tax revenues in Algeria over the period 1993–2020, by addressing the following sub-questions:

Q1: Is there an asymmetric effect of the Shadow Economy on ordinary tax revenues (excluding the hydrocarbon sector) in Algeria during the period 1993–2020?

Q2: What is the nature of the relationship between the Shadow Economy and ordinary tax revenues in Algeria during the period 1993–2020?

To address the main research problem and its related questions, the paper is organized as follows. The first section presents the introduction. The second section reviews the previous literature related to the topic of the study. The third section presents the study data and the methodology employed. The fourth section is devoted to the econometric analysis and discussion of the results. Finally, the conclusion summarizes the main findings and provides some recommendations

LITERATURE REVIEW

The relationship between the shadow economy and tax revenues has received considerable attention from both researchers and policymakers. Previous studies have addressed this issue from both theoretical and empirical perspectives, covering a wide range of national and international economies. The existing literature consistently suggests that the shadow economy represents a major challenge to governments' ability to mobilize tax revenues, as its expansion narrows the tax base and results in substantial fiscal losses (Cooray et al., 2017). Since shadow economic activities largely operate outside government regulation and taxation, they deprive governments of the financial resources required to finance public expenditure through formal channels (Mazhar & Méon, 2017). Furthermore, tax evasion associated with shadow economic activities undermines the efficiency and competitiveness of national tax systems (Tiutiunyk et al., 2022). Overall, empirical evidence indicates a strong and consistently negative relationship between the size of the shadow economy and tax revenue collection (Dokas et al., 2024).

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Empirical studies have employed various econometric techniques to estimate the fiscal losses associated with the shadow economy. Evidence from Ukraine indicates that the expansion of the shadow economy leads directly to a substantial decline in government budget revenues (Mishchuk et al., 2020). Likewise, evidence from the Baltic countries suggests that governments could significantly increase fiscal revenues by successfully integrating shadow economic activities into the formal economy (Putniņš & Sauka, 2011). Similar findings have been reported for Uganda, where the shadow economy has been identified as one of the principal constraints on tax performance (Mawejje & Munyambonera, 2016). Using the Autoregressive Distributed Lag (ARDL) model, a significant long-run negative effect of the shadow economy on tax revenues has been documented for Ethiopia (Kebede et al., 2024). Likewise, the expansion of shadow economic activities in Ukraine is estimated to have reduced government revenues by approximately 8% during certain periods (Bak et al., 2024). The study by (Ur Rahman et al., 2024) also showed that financial market development can help reduce the shadow economy in N-11 countries, provided that country risk is effectively controlled. Similarly, (Faisal et al., 2023), in their study of Pakistan, found that natural resource revenues and the shadow economy negatively affect financial institutions' depth, while institutional quality helps mitigate the adverse effects of the shadow economy.

The adverse effects of the shadow economy also differ across tax categories. Considerable revenue losses have been observed in value-added tax (VAT) and personal income tax collections in countries such as Poland and Hungary (Nchor, 2021). At the global level, shadow economic activities have also been found to reduce the efficiency of VAT collection (Leonov & Sokolov, 2020). In the BRICS countries, empirical evidence reveals a nonlinear relationship, whereby the adverse impact of the shadow economy on tax revenues becomes significantly stronger once it exceeds a critical threshold (Nguyen & Duong, 2022). Moreover, studies conducted in Qatar and Malaysia indicate that estimating tax evasion requires analyzing currency demand associated with shadow economic activities (Gamal et al., 2019; Tan et al., 2018). Consequently, reducing the size of the shadow economy has been identified as a prerequisite for ensuring the long-term sustainability of public finances in Russia (Musaeva et al., 2016).

Regarding methodological approaches, the Multiple Indicators Multiple Causes (MIMIC) model has become one of the most widely adopted techniques for estimating the size of the shadow economy across countries. In Tanzania, the application of the MIMIC model identified unemployment and inflation as the primary determinants of the shadow economy (Dell'Anno et al., 2018). Similarly, evidence from Uganda confirms that the shadow economy constitutes a major obstacle to improving tax performance (Mawejje & Munyambonera, 2016). In Zimbabwe, the expansion of the shadow economy has been shown to reduce the effectiveness of the tax system (Chamisa & Sunde, 2024). Using the ARDL model, recent evidence from Lithuania has provided valuable insights into the prospects for future tax revenue growth (Ulvidienė et al., 2023). Likewise, a strong long-run negative relationship between the shadow economy and tax revenues has been confirmed for Ethiopia (Kebede et al., 2024). Finally, evidence from dynamic panel analyses for African countries suggests that financial development contributes significantly to reducing the size of the shadow economy (Haruna, 2023).

Against this background, this study contributes to the existing literature by examining the asymmetric effects of positive and negative shocks in the shadow economy on non-hydrocarbon tax revenues in Algeria over the period 1993–2020. To the best of our knowledge, it is among the early studies to apply the NARDL model specifically to non-hydrocarbon tax revenues in Algeria. By investigating potential long-run and short-run asymmetries, the study provides empirical evidence that contributes to a better understanding of the relationship between the shadow economy and non-hydrocarbon tax revenues in the Algerian context.

DATA, METHODOLOGY, AND MODEL SPECIFICATION

This section investigates the response of non-hydrocarbon tax revenues to positive and negative shocks in the shadow economy by employing the Nonlinear Autoregressive Distributed Lag (NARDL) model.

Data and Variables

This study relies on annual data covering the period from 1993 to 2020. non-hydrocarbon tax revenues (excluding hydrocarbon tax revenues) are used as the dependent variable. The data are obtained from

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the statistical bulletin Statistical Summary of Public Finance 1960–2020, published by the Algerian National Office of Statistics (ONS). The independent variable is the size of the shadow economy in Algeria, measured as a percentage of gross domestic product (GDP), with the corresponding data obtained from the World Bank. It should be noted that the size of the informal sector was estimated using the Multiple Indicators Multiple Causes (MIMIC) approach (Elgin et al., 2021), which is considered one of the most robust and reliable methods in this field (Bati, 2025; Sisay & Mayburov, 2026).

Real gross domestic product excluding the hydrocarbon sector was also included as a control variable in the model, given that the level of economic activity directly affects the government's capacity to generate tax revenues and may simultaneously be associated with the size of the shadow economy. The inclusion of this variable aims to control for and isolate the effect of the level of economic activity, thereby allowing for a more accurate estimation of the net effect of the shadow economy on tax revenues, while reducing the potential bias arising from the omission of an influential variable. The data for this variable were obtained from the statistical bulletin Statistical Summary of National Accounts 1960–2020, published by the Algerian National Office of Statistics (ONS). The definitions of the variables and their respective data sources are summarized in Table 1.

Table 1: Definition of variables and data sources

Variables	Symbol	Definition and Unit of Measurement	Source
Dependent variable	NHTR	Real non-hydrocarbon tax revenues (constant prices), measured in local currency	National Office of Statistics (NOS) https://www.ons.dz/spip.php?rubrique395
Independent variable	SE	Size of the shadow economy in Algeria, measured as a percentage (%) of gross domestic product (GDP)	World Bank https://www.worldbank.org/en/research/brief/informal-economy-database
Control variable	RGDPNH	Real gross domestic product excluding the hydrocarbon sector (constant prices), measured in local currency	National Office of Statistics (NOS) https://www.ons.dz/spip.php?rubrique395

Source: Prepared by the author
Notes: The data sources were accessed on July 1, 2026

It should also be noted that a logarithmic transformation is applied to the variables under study in order to reduce the effect of differences in the scale of the variables, decrease the likelihood of heteroskedasticity, and facilitate the interpretation of the model coefficients in terms of elasticities. Furthermore, we use real variables, i.e., variables measured at constant prices, rather than nominal variables, with the aim of obtaining more robust econometric and statistical results.

Due to the limited annual frequency of the data over the period 1993–2020, which provides only 28 observations, the annual series of the variables were converted into semi-annual series using the Temporal Disaggregation technique in EViews. This resulted in a time series comprising 56 semi-annual observations. This approach is recognized in the economic literature as an established method for generating higher-frequency data while maintaining consistency with the original annual series (Ajao & Igbekoyi , 2013; Chen, 2007; Kostakis, 2026; Mosley et al., 2022; Müller & Haberlandt, 2018; Quilis, 2018).

It should also be noted that the Quadratic interpolation method was employed without using higher-frequency indicator series, meaning that the semi-annual values were estimated solely on the basis of the original annual series (Chow & Lin, 1971). This method allows for the estimation of a smoother within-year path compared with simply repeating the annual value, while maintaining consistency between the estimated semi-annual values and the original annual values. It should further be noted that the temporal disaggregation technique was selected according to the economic nature of each variable. For the variables NHTR and RGDPNH, the quadratic match sum method was used, as they are considered flow variables; consequently, the sum of the semi-annual values equals the corresponding original annual value. As for the SE variable, which measures the parallel sector as a percentage of GDP and is estimated using the MIMIC approach, the quadratic match average method was employed, such that the average of the semi-annual values corresponds to the original annual value (Lee, 2024).

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As a final consideration, the use of semi-annual data in this study should be regarded as a methodological procedure aimed at representing temporal dynamics in greater detail, rather than as a means of generating new economic information or merely increasing the numerical size of the sample. Although the availability of original semi-annual data for each variable would be the empirically preferable alternative, their absence over the entire study period necessitated the use of temporal disaggregation as an estimation procedure. This limitation should therefore be taken into account when interpreting the results of the estimated model and the associated tests.

The relationship between the shadow economy and real non-hydrocarbon tax revenues is illustrated by the scatter plot presented in Figure 1.

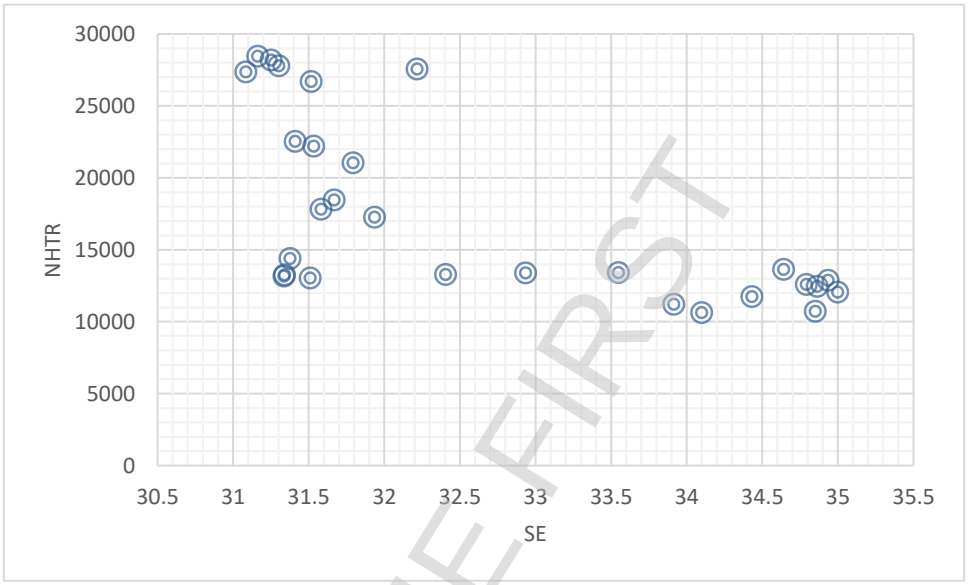

Figure 1: Scatter plot of the relationship between the shadow economy and real non-hydrocarbon tax revenues

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Methodology and Model Specification

This section presents the main preliminary tests, the econometric model employed in the analysis, and the complementary diagnostic procedures.

Unit Root Test

When analyzing time-series data and investigating cointegration, it is essential to examine the stationarity properties of the variables and determine their order of integration. Testing for stationarity is a fundamental step in empirical analysis because it prevents the estimation of spurious regressions and assists in selecting the appropriate econometric model.

Several unit root tests have been developed in the econometric literature. Among the earliest and most widely used is the Dickey–Fuller (DF) test (Dickey & Fuller, 1979), which remains one of the standard approaches for time-series analysis. Another commonly employed test is the Phillips–Perron (PP) test (Phillips & Perron, 1988), which is generally considered more robust to serial correlation and heteroskedasticity than the conventional DF test. Consequently, the PP test often provides more reliable results under these conditions (Kırca & Karagöl, 2019).

For both tests, the null hypothesis assumes that the series is non-stationary and contains a unit root, whereas the alternative hypothesis states that the series is stationary. The decision is based on comparing the absolute value of the calculated test statistic with the corresponding critical value. The null hypothesis is accepted when the absolute test statistic is smaller than the critical value at the chosen significance level. In such cases, stationarity is commonly achieved by taking the first difference, implying that the variable is integrated of order one, I(1).

Conventional unit root tests—including the Augmented Dickey–Fuller (ADF) test (Said & Dickey, 1984), the Phillips–Perron (PP) test

(Phillips & Perron, 1988), the DF-GLS test (Elliott et al., 1996), and the Ng–Perron test (Ng & Perron, 2001) generally perform well when the underlying time series does not experience structural changes. However, these tests tend to be biased toward accepting the null hypothesis of a unit root when structural breaks are present but ignored. Consequently, a stationary series with one or more structural breaks may be incorrectly classified as non-stationary (Perron, 1989; Shaeri & Katircioglu, 2018). This limitation is particularly relevant because macroeconomic and financial time series frequently exhibit structural changes resulting from policy shifts, economic crises, or institutional reforms.

To overcome this limitation, several unit root tests that explicitly account for structural breaks have been proposed. Among the most widely used is the Zivot–Andrews test (Zivot & Andrews, 1992), which allows for one endogenous structural break under the alternative hypothesis while assuming no structural break under the null hypothesis. The break date is determined endogenously during the estimation process rather than being specified a priori. Subsequently, (Lumsdaine & Papell, 1997) extended this framework by allowing for two endogenous structural breaks, arguing that most macroeconomic variables experience multiple structural changes over time.

Further developments include the Lee–Strazicich test (Lee & Strazicich, 2003), which incorporates two endogenous structural breaks under both the null and alternative hypotheses; the Kim–Perron test (Kim & Perron, 2009), which assumes one known structural break under both hypotheses and is particularly suitable for relatively small samples; and the Narayan–Popp test (Narayan & Popp, 2010), which allows for two unknown structural breaks under both hypotheses.

Mathematical Formulation and Econometric Specification of the NARDL Model

To examine the relationship between non-hydrocarbon tax revenues (NHTR) and the shadow economy (SE) in Algeria, this study employs the Nonlinear Autoregressive Distributed Lag (NARDL) model. The primary advantage of the NARDL framework is its ability to distinguish between the effects of positive and negative shocks in the explanatory variable while simultaneously estimating both the short-run and long run asymmetric relationships (Al-Tameemi et al., 2025; Fooladvand et al., 2024; Gamal et al., 2025; Nkoro & Uko 2016; Safuan et al., 2022; Shin et al., 2014).

The long-run functional relationship may be expressed as follows:

$$LNHTR_t = \mathrm{f}(LRGDPNH_t, LSE_t^+, LSE_t^-) \quad (1)$$

$$LNHTR_t = c + \theta_1 LNHTR_t + \theta_2 LRGDPNH_t + \theta_3^+ LSE_t^+ + \theta_4^- LSE_t^- + \mu_t \quad (2)$$

Accordingly, the corresponding NARDL conditional error-correction (ECM) model is given by:

$$\Delta LNHTR_t = c + \beta_1 LNHTR_{t-1} + \beta_2 LRGDPNH_{t-1} + \beta_3^+ LSE_{t-1}^+ + \beta_4^- LSE_{t-1}^- + \sum_{i=1}^{P} \gamma_i \Delta LNHTR_{t-i} + \sum_{i=0}^{q_1} \varphi_i \Delta LRGDPNH_{t-i} + \sum_{i=0}^{q_2} \omega_{1i}^+ \Delta LSE_{t-i}^+ + \sum_{i=0}^{q_3} \omega_{2i}^- \Delta LSE_{t-i}^- + \epsilon_t \quad (3)$$

Where $\theta_3^+ = -\frac{\beta_3^+}{c}$ and $\theta_4^- = -\frac{\beta_4^-}{c}$ represent long-run impacts of shadow economy increase and shadow economy decrease on the tax revenue. While $\sum_{i=0}^{q_2} \omega_{1i}^+$ and $\sum_{i=0}^{q_3} \omega_{2i}^-$ measure the short-run effects of an increase in shadow economy and a decrease in shadow economy, respectively on tax revenue
The positive and negative partial sums of changes in the shadow economy are defined as:

$$\begin{cases} LSE_t^+ = \sum_{j=1}^{t} \Delta LSE_j^+ = \sum_{j=1}^{t} \mathrm{Max}\,(\Delta LSE_j, 0) \\ LSE_t^- = \sum_{j=1}^{t} \Delta LSE_j^- = \sum_{j=1}^{t} \mathrm{Min}\,(\Delta LSE_j, 0) \end{cases} \quad (4)$$

Where:
- Δ denotes the first differences;
- c is the intercept term;
- $\theta_1, \theta_2, \theta_3^+, \theta_4^-$ represent the long-run coefficients;
- $\beta_1, \beta_2, \beta_3^+, \beta_4^-, \gamma_i, \varphi_i, \omega_{1i}^+, \omega_{2i}^-$ denote the short-run coefficients.

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The optimal lag structure p, q_1, q_2, q_3 for the model is determined using the Schwarz Bayesian Criterion (SBC) and Akaike Information Criterion (AIC) to eliminate serial correlation in the residuals. $\mu_t \rightsquigarrow \text{NID}(0, \sigma^2)$.

To test for the existence of cointegration among the variables, we estimate the joint F-test by testing the null hypothesis of no cointegration among the level variables in Equation (3), which is specified as follows: $H_0: \beta_1 = \beta_2 = \beta_3^+ = \beta_4^- = 0$, against the alternative hypothesis: $H_1: \beta_1 \neq \beta_2 \neq \beta_3^+ \neq \beta_4^- \neq 0$

After obtaining the computed F-statistic from Equation (3), the calculated F-statistic is compared with the critical values reported by (Narayan, 2005), which consist of the Lower Critical Bound and the Upper Critical Bound. First case: If the computed F-statistic is greater than the critical value of the upper bound, we reject the null hypothesis of no cointegration and accept the alternative hypothesis, indicating the existence of a cointegrating relationship among the variables. Second case: If the computed F-statistic is lower than the critical value of the lower bound, the null hypothesis cannot be rejected. Therefore, we conclude that there is no cointegration among the variables. Finally, the third case: If the computed F-statistic falls between the lower and upper critical bounds, the result is inconclusive. Consequently, we cannot confirm or conclusively determine whether a cointegrating relationship exists among the variables.

Long-Run and Short-Run Asymmetry Tests

The NARDL model allows the researcher to examine whether the dependent variable responds differently to positive and negative shocks in the explanatory variable. Accordingly, two Wald tests are performed to assess long-run and short-run asymmetry (Hong, 2026). We examine for long-run and short-run symmetry using the standard Wald test. The null hypothesis of long-run symmetry is $H_0: \theta_3^+ = \theta_4^-$ or $H_0: -\frac{\beta_3^+}{c} = -\frac{\beta_4^-}{c}$ against the alternative hypothesis $H_1: \theta_3^+ \neq \theta_4^-$ or $H_1: -\frac{\beta_3^+}{c} \neq -\frac{\beta_4^-}{c}$, The null hypothesis implies that positive and negative shocks in the shadow economy exert symmetric long-run effects on non-hydrocarbon tax revenues, whereas the alternative hypothesis indicates long-run asymmetry. Whereas the short-run symmetry restrictions is $H_0: \sum_{i=0}^{q2} \omega_{1i}^+ = \sum_{i=0}^{q3} \omega_{2i}^-$ against the alternative hypothesis $H_1: \sum_{i=0}^{q2} \omega_{1i}^+ \neq \sum_{i=0}^{q3} \omega_{2i}^-$. The null hypothesis is rejected in both tests whenever the corresponding p-value is smaller than the selected significance level.

RESULTS AND DISCUSSION

This section presents the empirical estimation of the nonlinear relationship between positive and negative shocks in the shadow economy (SE), real gross domestic product excluding the hydrocarbon sector (RGDPNH), and non-hydrocarbon tax revenues (NHTR) in Algeria. The empirical findings are then discussed and interpreted.

Descriptive Statistics and Correlation Matrix

Descriptive statistics provide preliminary information on the statistical properties of the variables under investigation and offer an initial understanding of the characteristics of the data. In addition, the correlation matrix is used to detect the potential presence of multicollinearity, particularly among the explanatory variables. Table 2 provides an overview of these characteristics, including descriptive statistics, correlations among the variables, and variance inflation factors.

Panel A reports the descriptive statistics for the variables included in the analysis. The Jarque-Bera test indicates that LRGDPNH is normally distributed, as evidenced by a test statistic of 3.15 with a corresponding p-value of 0.20. Therefore, the null hypothesis of normality cannot be rejected. Likewise, LNHTR and LSE also satisfy the normality assumption at 1%, indicating that all variables are approximately normally distributed over the sample period.

Panel B presents the correlation matrix. The results reveal no evidence of severe multicollinearity, particularly between the explanatory variables. The correlation coefficient between LSE and LRGDPNH equals –0.88, which remains below the commonly accepted critical threshold for multicollinearity.

This conclusion is further supported by the Variance Inflation Factor (VIF) values reported in Panel C. Since the VIF values for both explanatory variables are 4.49, well below the conventional threshold value of 5, multicollinearity does not appear to be a concern in the estimated model throughout the study period.

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Table 2: Descriptive Statistics and Correlation Matrix

Panel A: Descriptive Statistics							
Variables	**Mean**	**Max**	**Min**	**Std.dev**	**Skew**	**Kurt**	**JB**
LNHTR	4.85	5.12	4.62	0.17	0.50	1.71	6.18 (0.04)
LSE	3.48	3.55	3.43	0.044	0.504	1.53	7.41 (0.02)
LRGDPNH	15.10	16.61	13.71	0.86	–0.12	1.86	3.15 (0.20)
Panel B: Correlation Matrix							
Variables	**LNHTR**		**LSE**			**LRGDPNH**	
LNHTR	1		–0.707***			0.91***	
LSE	–0.707***		1			–0.88***	
LRGDPNH	0.91***		–0.88***			1	
Panel C: Variance Inflation Factor (VIF)							
LSE	4.49						
LRGDPNH	4.492						

Source: Prepared by the author

BDS Nonlinearity Test

The BDS test, originally developed by (Brock et al.,1996), is among the most widely used statistical procedures for detecting nonlinear dependence in time-series data. Owing to its high statistical power, the BDS test is capable of identifying a broad range of nonlinear data-generating processes (Sheikh et al., 2020).

The hypotheses of the BDS test are formulated as follows:

H0: The time-series observations are independently and identically distributed (IID), implying that the underlying relationship is linear.

H1: The time-series observations are not independently and identically distributed, indicating the existence of nonlinear dependence.

The BDS test is commonly employed to evaluate whether the Nonlinear Autoregressive Distributed Lag (NARDL) model constitutes an appropriate empirical framework (Shahbaz et al., 2018). More specifically, the test determines whether the underlying data-generating process exhibits nonlinear dynamics that cannot be adequately captured by conventional linear models (Ahad & Dar, 2017).

The results reported in Table 3 indicate that all computed BDS statistics are statistically significant at the 1% significance level for LNHTR, LSE, and LRGDPNH across all embedding dimensions. Consequently, the null hypothesis of independently and identically distributed observations is rejected in favor of the alternative hypothesis.

Table 3: BDS Nonlinearity Test

Variables	**m = 2**	**m = 3**	**m = 4**	**m = 5**	**m = 6**
LNHTR	0.18***	0.29***	0.37***	0.41***	0.44***
LSE	0.20***	0.34***	0.43***	0.49***	0.53***
LRGDPNH	0.20***	0.33***	0.43***	0.50***	0.55***

Source: Prepared by the author.
Notes: *** denote statistical significance at the 1% significance levels.

These findings provide strong empirical evidence that the time series exhibit nonlinear dependence and are therefore neither independent nor identically distributed. Accordingly, the presence of nonlinear dynamics justifies the application of the NARDL model to investigate the asymmetric effects of positive and negative shocks in the shadow economy on non-hydrocarbon tax revenues in Algeria.

Unit Root Test

This subsection applies the Zivot–Andrews unit root test with one endogenous structural break and the Lee–Strazicich unit root test with two structural breaks to determine the order of integration of the variables. The objective is to verify whether the variables satisfy the integration requirements necessary for the application of the Nonlinear Autoregressive Distributed Lag (NARDL) model.

The results of the Zivot–Andrews unit root test (Table 4) and the Lee–Strazicich unit root test with two endogenous structural breaks (Table 5) are used to determine the order of integration of the variables. The null hypothesis of both tests is that the series contains a unit root. The test statistics are compared with the corresponding critical values at conventional significance levels. A test statistic that is more negative than the relevant critical value leads to rejection of the unit-root null hypothesis. The results indicate that the variables are non-

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stationary in levels but become stationary after first differencing, suggesting that they are integrated of order one, I(1). These findings support the use of the NARDL framework, provided that none of the variables is integrated of order two, I(2).

Table 4: Results of the Zivot–Andrews Unit Root Test with One Structural Break

Variables	Level			First Difference			Order of Integration
	Model I	Model II	Model III	Model I	Model II	Model III	
LNHTR	-5.34 (4)	-2.82 (4)	-3.48 (5)	-6.44*** (3)	-6.70*** (3)	-7.00*** (3)	I(1)
TB	2011S2	2000S2	2011S2	2007S2	2015S2	2008S2	
LSE	-1.37 (3)	-2.35 (3)	-2.42 (3)	-5.50*** (2)	-5.90*** (1)	-6.52*** (1)	I(1)
TB	2002S2	2013S1	2007S2	2001S2	2003S2	2005S2	
LRGDPNH	-1.39 (4)	-2.25 (4)	-4.15 (4)	-7.39*** (1)	-6.46*** (1)	-7.42*** (1)	I(1)
TB	2010S2	2016S2	2012S2	2001S2	2008S1	2001S2	

Source: Prepared by the author.

Notes: TB denotes the estimated structural break date. Model I allows for a structural break in the intercept only; Model II allows for a structural break in the trend only; and Model III allows for structural breaks in both the intercept and the trend. The lag length (K) reported in parentheses was selected according to the Akaike Information Criterion (AIC) and the Schwarz Criterion (SC) to eliminate serial correlation in the residuals. *** denote statistical significance at the 1% significance levels.

Table 5: Results of the Lee-Strazicich Unit Root Test with Two Structural Breaks

Variables	Level		First Difference		Order of Integration
	Model I	Model II	Model I	Model II	
LNHTR	-2.76 (3)	-5.36 (3)	-4.18*** (2)	-6.87*** (3)	I(1)
TB1	2002S1	1997S1	1999S1	2007S2	
TB2	2014S1	2010S2	2006S2	2010S1	
LSE	-2.63 (3)	-5.63 (3)	-4.23*** (3)	-7.10** (3)	I(1)
TB1	2000S1	1998S1	2008S1	2005S1	
TB2	2009S1	2003S2	2016S2	2015S2	
LRGDPNH	-2.10 (1)	-7.13** (1)	-5.78*** (3)	-6.89** (1)	I(1)
TB1	2007S1	2011S2	2009S2	2010S1	
TB2	2012S2	2015S1	2014S2	2012S2	

Source: Prepared by the author.

Notes: TB1, TB2 denotes the estimated structural break date. Model I: Crash model, breaks in intercept; Model II: Break model, breaks in both intercept and trend. ( ): Max number of lags. **, and *** indicate significance at the 5%, and 1% significance levels, respectively.

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Bounds Test for Cointegration

The Bounds Test is employed to examine whether a long-run equilibrium relationship exists among the variables included in the model. The null hypothesis states that no long-run cointegration relationship exists among the variables. The decision is based on comparing the computed F-statistic with the lower and upper critical bounds. The null hypothesis is rejected whenever the calculated F-statistic exceeds the upper critical bound, indicating the existence of a long-run equilibrium relationship (Agrawal et al., 2026).

Table 6: Results of the Bounds Test for Cointegration

Test Statistic	Value	Significance Level	Lower Bound I(0)	Upper Bound I(1)
F-statistic	5.04	10%	2.01	3.10
Number of explanatory variables	3	5%	2.45	3.63
		1%	3.42	4.84

Source: Prepared by the author

The results of the Bounds Test (Table 6) clearly indicate the existence of a long-run cointegration relationship among the variables. Specifically, the calculated F-statistic (5.04) exceeds the upper

critical bound I(1) at the 1%, 5%, and 10% significance levels. Consequently, the null hypothesis of no cointegration is rejected in favor of the alternative hypothesis.

These findings provide strong empirical evidence of a long-run equilibrium relationship between non-hydrocarbon tax revenues (NHTR) and the explanatory variables, namely positive and negative shocks in the shadow economy (SE) and real gross domestic product excluding the hydrocarbon sector (RGDPNH). Accordingly, estimating the NARDL model is econometrically justified.

Estimation of the Short-Run and Long-Run Equilibrium Relationships

Having established the existence of a long-run equilibrium relationship through the Bounds Test, this section presents the estimation results of both the short-run and long-run relationships between positive and negative shocks in the shadow economy (SE), real gross domestic product excluding the hydrocarbon sector (RGDPNH), and non-hydrocarbon tax revenues (NHTR).

Estimation of the Short-Run Equilibrium Relationship

To estimate the short-run dynamics among positive shocks (LSE_t^+), negative shocks (LSE_t^-), real gross domestic product excluding the hydrocarbon sector (LRGDPNH), and non-hydrocarbon tax revenues (LNHTR), the following Error Correction Model (ECM) is estimated:

$$\Delta LNHTR_t = c + \sum_{i=1}^{p} \gamma_i \Delta LNHTR_{t-i} + \sum_{i=0}^{q_1} \varphi_i \Delta LRGDPNH_{t-i} + \sum_{i=0}^{q_2} \omega_{1i}^{+} \Delta LSE_{t-i}^{+} + \sum_{i=0}^{q_3} \omega_{2i}^{-} \Delta LSE_{t-i}^{-} + \psi ECT_{t-1} + \eta_t \quad (5)$$

where the ECT_{t-1} is the residual from the long-term model (i.e., Equations (2)) with oneperiod lag, which is stated as:

$$ECT_{t-1} = \mu_{t-1} = LNHTR_{t-1} - [\, c + \theta_1 LNHTR_{t-1} + \theta_2 LRGDPNH_{t-1} + \theta_3^{+} LSE_{t-1}^{+} + \theta_4^{-} LSE_{t-1}^{-}] \quad (6)$$

The ψ coefficient represents the error-correction (ECT_{t-1}) coefficient, which measures the speed at which the variables adjust towards their long-run equilibrium. This coefficient should be negative and statistically significant in order to conclude that there is a cointegrating relationship among the variables. The estimated short-run coefficients of the NARDL model, including the error-correction term, are reported in Table 7.

Table 7: Short-Run Coefficient Estimates Based on the NARDL Model

Variables	Coefficient	t-statistic	Probability
ΔLNHTR(-1)	0.5858	5.3914	0.000
ΔLRGDPNH	-0.2440	-2.6540	0.011
ΔLRGDPNH(-1)	0.2147	2.0689	0.045
ΔLRGDPNH(-2)	-0.1046	-1.0343	0.307
ΔLRGDPNH(-3)	0.1536	2.0156	0.051
ΔLSE^{+}	-0.2023	-0.2080	0.836
ΔLSE^{-}	1.8180	1.6280	0.112
$\Delta LSE^{+}(-1)$	-0.7096	-0.4337	0.667
$\Delta LSE^{-}(-1)$	-0.6186	-0.4337	0.667
$\Delta LSE^{+}(-2)$	0.8541	0.5075	0.614
$\Delta LSE^{-}(-2)$	0.1358	0.0979	0.922
$\Delta LSE^{+}(-3)$	1.6937	0.8432	0.404
$\Delta LSE^{-}(-3)$	0.1481	0.4604	0.647
ECT(-1)	-0.2389	-4.6865	0.000
Lag structure (2,4,4,4)	$R^2 = 0.6597$	$DW = 1.9972$	N=56

Source: Prepared by the author

The estimated coefficient of the error correction term (ECT) is negative and statistically significant

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(-0.2389; p<0.01), confirming the existence of a valid short-run adjustment mechanism toward the long-run equilibrium.

The magnitude of the coefficient indicates that approximately 23.89% of any short-run disequilibrium in non-hydrocarbon tax revenues is corrected within one semiannual period. In other words, whenever the system deviates from its long-run equilibrium, nearly one-quarter of the disequilibrium is eliminated during the following period, implying a relatively moderate speed of adjustment toward equilibrium.

Estimation of the Long-Run Equilibrium Relationship

The Bounds Test confirmed the existence of a long-run equilibrium relationship among positive and negative shocks in the shadow economy, real gross domestic product excluding the hydrocarbon sector, and non-hydrocarbon tax revenues. This conclusion is further supported by the negative and statistically significant coefficient of the error correction term obtained in the short-run specification. Table 8 summarizes the long-run effects of shadow economy shocks and non-hydrocarbon GDP estimated using the NARDL model.

Table 8: Long-Run Coefficient Estimates Based on the NARDL Model

Variables	Coefficient	t-statistic	Probability
LSE^{+}	-0.5871	-0.3487	0.728
LSE^{-}	1.7424	3.9281	0.000
LRGDPNH	0.3253	112.97	0.000

Source: Prepared by the author.

The long-run estimation results indicate that negative shocks in the shadow economy and real gross domestic product excluding the hydrocarbon sector exert statistically significant effects on non-hydrocarbon tax revenues at the 1% significance level.

Specifically, a 1% decrease in the size of the shadow economy is associated with an approximately 1.74% increase in non-hydrocarbon tax revenues, suggesting that the contraction of informal economic activities expands the effective tax base and improves tax collection.

By contrast, a 1% increase in the size of the shadow economy is associated with a 0.59% decline in non-hydrocarbon tax revenues. However, this coefficient is not statistically significant, indicating that the long-run effect of positive shocks cannot be distinguished from zero at conventional significance levels.

Furthermore, the estimated coefficient of LRGDPNH is positive and statistically significant, implying that a 1% increase in real gross domestic product excluding the hydrocarbon sector increases non-hydrocarbon tax revenues by approximately 0.33% in the long run. This finding is economically intuitive, as higher non-hydrocarbon economic activity expands the taxable base and consequently enhances tax revenue collection.

Long-Run and Short-Run Asymmetry Tests

Following the confirmation of a long-run equilibrium relationship and the estimation of both the short-run and long-run coefficients, the next step is to investigate whether positive and negative shocks in the shadow economy exert symmetric or asymmetric effects on non-hydrocarbon tax revenues. This objective is achieved through the Wald asymmetry tests.

Table 9: Results of the Long-Run and Short-Run Asymmetry Tests

Panel A: Long-Run Asymmetry Test			
Variable	**Test Statistic**	**Value**	**Probability**
LSE	F-statistic	3.194	0.082
	χ^2	3.194	0.073
Panel B: Short-Run Asymmetry Test			
Variable	**Test Statistic**	**Value**	**Probability**
LSE	F-statistic	0.004	0.940
	χ^2	0.004	0.940

Source: Prepared by the author.

According to Table 9, the Wald test yields a p-value of 0.082 for the F-statistic and approximately 0.073 for the χ^2 statistic in the long-run symmetry test. Both values are lower than the 10% significance level. Therefore, the null hypothesis of symmetry in the effects of positive and negative shocks to the size of the Shadow economy on non-hydrocarbon tax revenues is rejected at the 10% significance level in favor of the alternative hypothesis of long-run asymmetry. However, this result should be interpreted with caution, given that both p-values are above the 5% significance level. This indicates that the statistical evidence of asymmetry remains limited and does not reach statistical significance at the 5% level. Regarding Panel (B) of the same table, which reports the results of the short-run asymmetry test, the p-value of the F-statistic is approximately 0.94, while the p-value of the χ^2 statistic is also approximately 0.94. Both values are considerably

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higher than the 10% significance level. Therefore, the null hypothesis of symmetry in the effects of positive and negative shocks to the size of the Shadow economy on non-hydrocarbon tax revenues in the short run cannot be rejected. Accordingly, there is no statistical evidence of asymmetry in the response of tax revenues to positive and negative shocks to the Shadow economy in the short run.

These findings are consistent with the long-run estimates of the NARDL model. The coefficient of positive shocks to the Shadow economy is approximately -0.5871; however, this effect is not statistically significant, with a p-value of 0.728. In contrast, the coefficient of negative shocks is approximately 1.7424 and is highly statistically significant, with a p-value of 0.000. These results indicate that an increase in the size of the Shadow economy is associated with a negative estimated effect on non-hydrocarbon tax revenues; however, this effect is not supported by sufficient statistical evidence. By contrast, a decline in the size of the Shadow economy is associated with a statistically significant increase in non-hydrocarbon tax revenues in the long run. Based on the Wald test results, the difference between the responses of tax revenues to positive and negative shocks provides limited evidence of long-run asymmetry at the 10% significance level, while failing to reach statistical significance at the 5% level.

Overall, the NARDL results indicate that the response of non-hydrocarbon tax revenues to changes in the size of the Shadow economy in Algeria varies according to both the time horizon and the direction of the shock. In the short run, neither positive nor negative shocks to the Shadow economy have a statistically significant effect on non-hydrocarbon tax revenues, and the Wald test does not reveal significant differences between the responses of revenues to positive and negative shocks, indicating no statistical evidence of asymmetry in the short run. In the long run, however, the Wald test provides limited evidence of asymmetry at the 10% significance level. The long-run estimates show that an increase in the size of the Shadow economy is associated with a negative effect on non-hydrocarbon tax revenues, although this effect is not statistically significant, whereas a decrease in the size of the Shadow economy is associated with a statistically significant increase in tax revenues. Therefore, the relationship between the size of the Shadow economy and non-hydrocarbon tax revenues cannot be reduced to a symmetric linear relationship. Rather, the findings suggest that the response of tax revenues varies according to the direction of the shock and the time horizon, while emphasizing that the evidence of long-run asymmetry remains statistically limited.

The negative sign of the estimated effect of positive shocks is consistent with the prevailing economic interpretation in the literature, which regards the expansion of the shadow economy as a factor that reduces the tax base and limits the government's capacity to mobilize revenues. (Cooray et al., 2017) pointed out that the expansion of the shadow economy is associated with a reduction in the tax base and the loss of financial resources that could otherwise be used by governments to finance public expenditure. Similarly, (Mazhar & Méon, 2017) showed that activities operating outside the scope of formal regulation deprive governments of part of the financial resources that could potentially be collected through formal channels. (Tiutiunyk et al., 2022) concluded that tax evasion associated with informal activities weakens the efficiency of the tax system, while (Dokas et al., 2024) provide evidence of a negative relationship between the size of the shadow economy and tax collection.

The current findings are also consistent with the empirical evidence reported in the literature. (Mishchuk et al., 2020), in their study of Ukraine, found that the growth of the shadow economy is associated with a decline in budget revenues. Similarly, (Kebede et al., 2024) found a negative long-run effect of the shadow economy on tax revenues in Ethiopia. This result also corresponds with (Bak et al., 2024), who showed that the expansion of informal activities in Ukraine was associated with declining revenues, and with (Mawejje & Munyambonera, 2016), who highlighted the constraining role of the informal sector in improving tax performance in Uganda. Therefore, the negative direction identified in the present study is consistent with an important body of previous empirical evidence that considers the expansion of the shadow economy to be a challenge to public revenue mobilization.

However, the findings of the present study differ from this literature in one important respect. Previous studies reviewed have focused primarily on the existence of a general negative relationship between the shadow economy and tax revenues, whereas the results for Algeria reveal an asymmetric nature of this relationship. A positive shock to the shadow economy carries a negative sign, but its effect is not statistically significant,

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whereas a negative shock, i.e., a reduction in the size of the shadow economy, is associated with a significant increase in non-hydrocarbon tax revenues of 1.74% for every 1% decrease in the size of the shadow economy. Accordingly, the main contribution of this finding is not merely to demonstrate that the shadow economy adversely affects tax revenues -a result supported by previous literature-but rather to show that the tax response to a contraction in the shadow economy is stronger and more pronounced than the response associated with its expansion in the Algerian case.

This asymmetry can be explained by the differences in the mechanisms operating when the shadow economy expands compared with when it contracts. When informal activity expands, part of the potential revenue loss may not immediately materialize in tax collections, because collected revenues also depend on existing formal activities and other tax sources. Moreover, the tax administration may not be able to detect all changes in informal activity immediately. Consequently, an expansion of the shadow economy may generate a negative trend in revenues without the effect being sufficiently large to reach statistical significance.

In the case of a contraction in the shadow economy, however, the mechanism may be different. A decline in the volume of informal activity may be accompanied by the transition of part of economic activity into the formal sector, where such activities become more readily registered, monitored, reported, and subject to taxation. This transition gradually expands the tax base, improves compliance, and enhances the tax administration's capacity to collect revenues. Thus, the return of economic activity to the formal sector may generate more visible tax gains than the losses arising when activity moves in the opposite direction.

This mechanism helps explain why the absolute value of the elasticity associated with the negative shock (1.74%) exceeds that of the positive shock (0.58%), while it is important to emphasize that the coefficient associated with the positive shock is not statistically significant. Therefore, the two results should not be interpreted as causal effects of equal strength. Rather, the econometric evidence provides stronger support for the relationship associated with a contraction in the shadow economy, whereas it does not provide sufficient statistical evidence of a comparable effect resulting from its expansion.

The idea of a transition of activities from the informal to the formal sector is consistent with the findings of (Putniņš & Sauka, 2011) in the Baltic States, whose results indicate the potential for increasing public resources through the integration of economic agents into the formal economy. It is also indirectly consistent with (Musaeva et al., 2016), who emphasize the importance of reducing the shadow economy for the sustainability of public finances. From this perspective, the findings for Algeria add that the fiscal benefit of reducing the shadow economy may arise not only through limiting revenue losses but also through additional revenues generated by the integration of informal activities into the formal system.

The findings are also consistent with evidence concerning different types of taxes, which suggests that the shadow economy can affect the efficiency of tax collection. (Nchor, 2021) identified revenue losses associated with the shadow economy in value-added tax and personal income tax revenues across a number of countries, while (Leonov & Sokolov, 2020) found a negative effect of informal activities on the efficiency of value-added tax collection. These findings support the argument that the transition of economic activity into the formal sector can broaden the base of taxable activities. However, the present study focuses on non-hydrocarbon tax revenues as a whole and, therefore, its results do not allow us to identify which specific type of tax accounts for the largest share of this effect.

The findings of studies addressing nonlinear relationships provide further support for the importance of moving beyond the simple linear assumption. (Nguyen & Duong, 2022) found a nonlinear relationship between the shadow economy and tax revenues in the BRICS countries, whereby the shadow economy becomes more harmful to tax revenues once it exceeds a certain level. Although the mechanism and methodology differ from those employed in the present study, this finding is consistent with the view that the relationship between the shadow economy and tax revenues may not remain constant or linear across all circumstances. The present study contributes to this line of research by focusing on asymmetric responses according to the direction of the shock, rather than solely according to the level of the shadow economy.

The absence of significant effects of positive and negative shocks in the short run suggests that the

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fiscal effects of changes in the size of the shadow economy require time to fully materialize. This can be explained by the time lag between changes in informal economic activity and the ability of the tax administration to detect, register, and incorporate such changes into the tax base. Even when an economic activity moves from the informal to the formal sector, this transition does not necessarily imply immediate tax liability, as the formalization process may involve several stages related to registration, reporting, monitoring, and collection. Similarly, an expansion of the shadow economy may not result in an immediate decline in collected revenues, particularly if other revenue sources remain stable in the short term.

This result supports the dynamic interpretation of the relationship between the shadow economy and tax revenues. The statistically insignificant symmetric effect of the shadow economy shocks suggests that the impact of changes in the shadow economy accumulates over time. Therefore, the absence of short-run significance should not be interpreted as evidence that no economic relationship exists between the two variables. Rather, it indicates that the mechanism linking changes in informal economic activity to tax revenues requires time before its full effects are reflected in tax collections.

On the other hand, real gross domestic product excluding the hydrocarbon sector has a positive and statistically significant effect on non-hydrocarbon tax revenues, with a 1% increase in real non-hydrocarbon GDP leading to an increase in tax revenues of approximately 0.32%. This finding is consistent with the economic rationale that an expansion of formal economic activity outside the hydrocarbon sector increases production, investment, consumption, and taxable income, thereby broadening the tax base. It also indicates that tax revenue mobilization in Algeria is not determined solely by the size of the shadow economy, but is also associated with the capacity of the formal economy, particularly the non-hydrocarbon sector, to generate taxable economic activity.

This finding gains additional importance in light of the literature addressing the shadow economy and financial development. (Haruna, 2023) found that financial development can contribute to reducing the size of the shadow economy, while the present study shows that the expansion of non-hydrocarbon economic activity is itself associated with higher tax revenues. This suggests an important link between the expansion of the formal sector, growth outside the hydrocarbon sector, and improvements in the capacity to mobilize domestic revenues.

Another important point of this study is that, in the case of the Algerian economy, the significance of the findings goes beyond merely demonstrating the applicability of the NARDL model to Algeria. The main lesson provided by the Algerian case is that the relationship between the shadow economy and tax revenues is not simply a linear negative relationship, but rather a dynamic and asymmetric one. The results indicate that a contraction in the shadow economy is associated with stronger and more pronounced tax gains than the estimated effect of its expansion, and that these gains do not materialize immediately in the short run but become more evident in the long run.

This finding suggests that reducing the shadow economy can constitute a channel for strengthening non-hydrocarbon tax revenues, provided that the decline in informal activity is transformed into effective integration into the formal economy. A mere reduction in the size of informal activity does not automatically guarantee an increase in revenues; rather, the fiscal gains depend on the ability of institutions and the tax administration to register new activities, broaden the taxpayer base, improve compliance, and enhance reporting and collection.

Accordingly, the Algerian case indicates that addressing the shadow economy should not be limited to control and punitive measures. Instead, such measures should be accompanied by policies that encourage the transition of activities into the formal sector, reduce compliance costs, improve tax services and procedures, strengthen digitalization and information sharing, and enhance the integration of economic activities into the formal system. These policies should also be integrated with efforts to diversify the economy and promote growth outside the hydrocarbon sector, as the results indicate that an expansion of real gross domestic product excluding the hydrocarbon sector is positively associated with tax revenues.

Thus, the scientific contribution of the study lies not only in the use of the NARDL model, but also in providing evidence specific to Algeria that the direction of change in the shadow economy and the time horizon are important elements in understanding the relationship between informal activity and tax revenue mobilization. The findings

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highlight that policies aimed at reducing the shadow economy may generate greater fiscal gains in the long run than suggested by their short-run effects, and that the success of such policies depends on the ability of the economy and tax institutions to transform formalization into a sustainable base for non-hydrocarbon revenues.

Diagnostic Tests

Following the estimation of the Error Correction Model (ECM) within the NARDL framework, it is essential to verify that the estimated model satisfies the standard econometric assumptions. Accordingly, a battery of diagnostic tests was conducted to assess the adequacy and robustness of the estimated model. The results are summarized in Table 10.

Table 10: Results of the Diagnostic Tests

Panel A: Breusch–Godfrey Serial Correlation LM Test			
F-statistic	Prob. F(2,32)	Obs*R^2	Prob. χ^2
1.533	0.230	4.46	0.107
Panel B: ARCH Heteroskedasticity Test			
F-statistic	Prob. F(1,48)	Obs*R^2	Prob. χ^2
0.0002	0.980	0.0002	0.980
Panel C:Ramsey RESET Specification Test			
Test Statistic	Value	D.F	Probability
F-statistic	2.75	(1,33)	0.106
Panel D:Jarque–Bera Normality Test			
JB Statistic	1.13	Probability	0.56
Panel E:CUSUM and CUSUMSQ Stability Tests			
CUSUM	Stable	CUSUMSQ	stable

Source: Prepared by the author.

The results of the Breusch–Godfrey LM test reported in Panel A indicate that both the probability associated with the χ^2 statistic (0.107) and the probability corresponding to the F-statistic (0.230) exceed the 10% significance level. Therefore, the null hypothesis of no serial correlation cannot be rejected, indicating that the residuals are free from autocorrelation.

The ARCH heteroskedasticity test presented in Panel B also supports the adequacy of the estimated model. Both the χ^2 probability (0.980) and the F-statistic probability (0.980) are well above the conventional significance levels, implying acceptance of the null hypothesis of homoskedasticity. Consequently, the variance of the error term remains constant over the sample period.

Regarding the Ramsey RESET specification test reported in Panel C, the probability associated with the F-statistic (0.106) exceeds the 10% significance level, suggesting that the model does not suffer from functional form misspecification.

The Jarque–Bera normality test shown in Panel D yields a probability value of 0.56, which is substantially higher than the conventional significance levels. Accordingly, the null hypothesis of normally distributed residuals cannot be rejected, indicating that the model residuals satisfy the normality assumption.

Finally, the CUSUM and CUSUMSQ stability tests presented in Panel E confirm the structural stability of the estimated model. The cumulative sums of recursive residuals, as well as their squared values, remain within the 5% critical bounds throughout the sample period. This finding indicates the absence of structural instability and confirms the stability of both the short-run and long-run parameter estimates.

Overall, the diagnostic tests demonstrate that the estimated NARDL model, which relates non-hydrocarbon tax revenues (NHTR) to positive and negative shocks in the shadow economy (SE) and real gross domestic product excluding the hydrocarbon sector (RGDPNH), is statistically adequate and does not exhibit any major econometric problems.

Furthermore, the recursive and rolling-window estimates of the long-run NARDL coefficients (Figures A1 and A2 in Appendix A) reveal considerable variation in the temporal stability of the long-run coefficients of the NARDL model over the study period. Specifically, the coefficients

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associated with positive shocks to SE exhibit pronounced fluctuations during the initial estimation periods. These fluctuations gradually subside, however, with the coefficients converging towards zero in subsequent periods. By contrast, the coefficients associated with negative shocks remain relatively close to zero throughout the sample period. Regarding RGDPNH, its long-run coefficient displays substantial fluctuations during the initial stages of estimation, before gradually converging towards a more stable positive value of approximately 0.65–0.70 towards the end of the sample period. This finding suggests the existence of a positive long-run relationship between RGDPNH and the dependent variable. Overall, these results highlight the sensitivity of certain long-run coefficients to variations in the estimation period and sample size. Accordingly, they should be interpreted with caution, particularly in view of the relatively small number of observations available within each rolling window.

Robustness Checks and Data Limitations

To assess the robustness of the findings obtained from the baseline NARDL model, estimated using 56 semi-annual observations derived by interpolating the annual data, the model was re-estimated using the original annual data, comprising 28 observations over the period 1993–2020. This step is methodologically important, given that although interpolation provides a higher data frequency, it does not necessarily generate additional independent economic information. Furthermore, it may affect the dynamic properties of the time series, as well as the estimated coefficients and their levels of statistical significance. Accordingly, this robustness test aims to assess whether the main findings remain consistent when using the original annual frequency and to examine their sensitivity to the method used to construct the data. The results of the NARDL estimation using the original 28 annual observations are presented in Table 11.

Regarding the bounds test for cointegration, and given the relatively small sample size of 28 observations, the critical values developed by (Kripfganz & Schneider, 2020) were employed. The F-statistic was approximately 4.365, while the t-statistic was -3.724. A comparison of these statistics with the corresponding critical values reported by (Kripfganz & Schneider, 2020) indicates that both statistics exceed the upper bound at the 10% significance level, whereas they fall within the inconclusive region at the 5% level. Accordingly, the results provide limited and inconclusive evidence of a long-run relationship between non-hydrocarbon tax revenues, shadow economy shocks, and real gross domestic product excluding the hydrocarbon sector. However, this evidence does not reach the conventional 5% significance level. This finding suggests that the evidence supporting a long-run equilibrium relationship is weaker in the annual estimation than in the semi-annual model.

The estimated long-run coefficients reveal varying degrees of stability between the semi-annual model and the annual model used for the robustness test. The positive component of the shadow economy (LSE^{+}) retains its negative sign in both estimations; however, it remains statistically insignificant, indicating insufficient statistical evidence to establish a long-run effect of this component on non-hydrocarbon tax revenues. Conversely, the negative component of the shadow economy (LSE^{-}) retains its positive sign and statistical significance in both estimations, suggesting stability in the direction and statistical significance of this effect. Nevertheless, it should be noted that the bounds-test evidence in the annual model remains limited to the 10% significance level, as the test fails to confirm a long-run equilibrium relationship at the 5% level. Regarding non-hydrocarbon GDP (LRGDPNH), its coefficient remains positive in both models, although its statistical significance in the semi-annual estimation is not maintained in the annual estimation.

In the short run, the annual model results reveal a negative and statistically significant effect, at the 5% level, of changes in the positive shocks to the shadow economy. This indicates that an increase in this component is associated with a decline in non-hydrocarbon tax revenues in the short run. By contrast, changes in negative shocks carry a positive sign but are statistically insignificant at conventional significance levels, precluding a definitive conclusion regarding their short-run effect.

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Table 11: NARDL Estimation Results Using Annual Data (1993–2020)

Panel A: Bounds Test for Cointegration									
Test Statistic	**Value**	**Significance Level 10%**		**Significance Level 5%**		**Significance Level 1%**		**Prob Value**	
		I(0)	**I(1)**	**I(0)**	**I(1)**	**I(0)**	**I(1)**	**I(0)**	**I(1)**
F-statistic	4.365	2.735	3.842	3.401	4.699	5.125	6.901	0.020	0.065
T-statistic	-3.724	-2.541	-3.456	-2.937	-3.918	-3.779	-4.898	0.011	0.067
Panel B: Short-Run Coefficient									
Variables		**Coefficient**		**t-statistic**		**Probability**			
ΔLNHTR(-1)		0.382		1.92		0.072			
ΔLRGDPNH(-1)		-0.46		-2.06		0.056			
$\Delta LSE^{+}(-1)$		-15.08		-2.18		0.043			
$\Delta LSE^{-}(-1)$		4.27		1.70		0.108			
ECT(-1)		-0.733		-3.72		0.002			
Panel C: Long-Run Coefficient									
LSE^{+}		-0.630		-0.28		0.782			
LSE^{-}		1.868		2.54		0.021			
LRGDPNH		0.090		0.40		0.695			
C		8.122		2.51		0.023			
Panel D: Asymmetry Tests									
Variable		**Test Statistic**		**Value**		**Probability**			
Long-Run : LSE		F-statistic		4.37		0.0519			
Short-Run :LSE		F-statistic		6.21		0.023			
Panel E: Diagnostic Tests									
Tests		**F / χ^2 Values**				**F / χ^2 Probability**		**DF**	
Breusch–Godfrey Serial Correlation LM Test		1.592				0.207		1	
ARCH Heteroskedasticity Test		2.544				0.110		1	
Ramsey RESET Specification Test		1.76				0.201		(3.14)	
Jarque–Bera Normality Test		0.66				0.71			
CUSUM		Stable				CUSUMSQ		stable	

Source: Prepared by the author.

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With regard to the error correction term (ECT), its coefficient is negative and statistically significant, amounting to -0.733, with a p-value of 0.002. This result is consistent with the convergence condition towards the long-run equilibrium and indicates that approximately 73.3% of the disequilibrium arising in the previous period is corrected in the current period. In other words, the model exhibits a relatively high speed of adjustment towards its equilibrium path. The negative and statistically significant ECT coefficient provides supporting evidence of an adjustment mechanism through which the dependent variable returns towards equilibrium following short-run shocks. However, the significance of this coefficient alone is insufficient to establish cointegration. It should instead be interpreted in conjunction with the bounds test, which provides no conclusive evidence at the 5% significance level in the annual model, but rather indicates evidence of a long-run relationship at the 10% level only.

Regarding the asymmetry tests, the results indicate the presence of short-run asymmetry, with an F-statistic of approximately 6.21 and a p-value of 0.023. This allows the null hypothesis of symmetric effects of increases and decreases in the shadow economy to be rejected at the 5% significance level. This implies that the response of non-hydrocarbon tax revenues to positive shocks differs statistically from their response to negative shocks in the short run. In the long run, however, the p-value of the asymmetry test is 0.0519, which is close to the 5% significance threshold but does not allow the null hypothesis of symmetry to be rejected at this level, although it provides borderline evidence of asymmetry at the 10% level. Regarding the long-run coefficients, positive shocks to the shadow

economy exhibit a negative and statistically insignificant coefficient, whereas the coefficient associated with negative shocks is positive and statistically significant. These findings may suggest that the effect of shadow economy expansion on tax revenues differs from that of its contraction. Nevertheless, the available statistical evidence is insufficient to confirm this difference at the 5% significance level. By comparison, short-run asymmetry appears more pronounced and robust when moving to annual data, whereas the evidence of long-run asymmetry remains only marginal at the 10% level.

Furthermore, the diagnostic tests support the statistical adequacy of the annual model. The Breusch–Godfrey test reveals no evidence of serial correlation in the residuals, while the ARCH test provides no evidence of conditional heteroskedasticity. Likewise, the Ramsey RESET test does not indicate functional form misspecification, and the Jarque–Bera test fails to reject the null hypothesis of normality of the residuals. In addition, the CUSUM and CUSUMSQ tests indicate that the model parameters remain stable throughout the study period. Thus, the diagnostic tests considered do not reveal any major statistical problems at the 5% significance level.

Overall, the robustness test results based on annual data provide partial support for the findings of the semi-annual model, particularly with regard to the stability of the sign and statistical significance of negative shadow economy shocks, especially in the long run. However, some differences emerge in the statistical significance of the effect of non-hydrocarbon GDP. The short-run results also reveal a significant negative effect of positive shadow economy shocks, while the error correction coefficient confirms the presence of an adjustment mechanism towards equilibrium. Nevertheless, caution is warranted when asserting the existence of cointegration in light of the bounds-test results.

On the other hand, several considerations should be taken into account when assessing the robustness of the empirical findings. First, the use of semi-annual data provides a larger number of observations for estimating the NARDL model and identifying short- and long-run dynamics. Nevertheless, temporal disaggregation may introduce a degree of uncertainty and generate within-year movements that do not fully reflect actual changes in the shadow economy. Second, the shadow economy is inherently unobservable, and differences in measurement methodologies, such as those based on MIMIC and DGE models, may affect the magnitude of the estimated relationship. Third, ARIMA forecasts could be used to extend the shadow economy series over the period 2021–2024, for example. However, these values would be model-generated rather than actual observations. Treating them as genuine observations could therefore introduce an additional degree of forecast-related uncertainty. Accordingly, such alternative specifications are left for future research.

Finally, caution should be exercised when interpreting the evidence concerning long-run asymmetry in the first and second models. The Wald test yielded p-values of 0.082 and 0.051 for the F-statistic, respectively, indicating limited evidence of long-run asymmetry at the 10% significance level, without reaching the conventional 5% significance threshold. Therefore, this finding should be regarded as suggestive rather than conclusive. Nevertheless, the estimated asymmetric coefficients provide useful evidence that non-hydrocarbon tax revenues may respond differently depending on the direction of changes in the shadow economy.

CONCLUSION

The shadow economy is not a phenomenon unique to Algeria; rather, it exists in both developed and developing economies. Consequently, its presence is not necessarily indicative of the quality or performance of a country's economy. Instead, the emergence and rapid expansion of the shadow economy stem from a variety of economic, institutional, and social factors. For some individuals, it serves as a means of escaping unemployment and poverty, whereas for others it provides opportunities to engage in illegal or unreported economic activities. Moreover, weaknesses in tax systems, including legal loopholes and ineffective tax administration, constitute major drivers of the shadow economy by enabling economic agents to appropriate financial resources that would otherwise accrue to the government. This has prompted many governments to reform their tax systems with the objective of increasing tax revenues and mitigating the adverse consequences associated with the expansion of the shadow economy.

Although the relationship between the shadow economy and tax revenues is generally regarded as straightforward, empirical evidence for Algeria

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remains limited. Existing econometric studies have produced inconclusive findings regarding the nature of this relationship. To address this gap, the present study employed the Nonlinear Autoregressive Distributed Lag (NARDL) model to examine the asymmetric effects of positive and negative shocks in the shadow economy on non-hydrocarbon tax revenues (NHTR) in Algeria using semiannual data covering the period 1993–2020.

The empirical findings can be summarized as follows:

- The Zivot–Andrews (ZA) unit root test with one structural break and the Lee–Strazicich (LS) test with two structural breaks indicate that all variables are stationary at first differences and, therefore, integrated of order one, I(1). These results support the application of the NARDL model**.**
- The Bounds cointegration test confirmed the existence of a long-run equilibrium relationship among positive and negative shocks in the shadow economy (SE), real gross domestic product excluding the hydrocarbon sector (RGDPNH), and non-hydrocarbon tax revenues (NHTR).
- The short-run estimation results indicate that the error correction term (ECT = −0.2389) is negative and statistically significant, providing further evidence of cointegration among the variables. The estimated adjustment coefficient implies that approximately 23.89% of any short-run disequilibrium in non-hydrocarbon tax revenues is corrected during the subsequent semi-annual period. Equivalently, the system requires approximately 4.18 semi-annual periods (around two years) to return to its long-run equilibrium following a shock in either the shadow economy or real non-hydrocarbon GDP.
- The long-run estimates reveal that both positive and negative shocks in the shadow economy exert an inverse effect on non-hydrocarbon tax revenues, although the magnitude and statistical significance differ substantially. A 1% increase in the size of the shadow economy reduces non-hydrocarbon tax revenues by approximately 0.58%; however, this effect is statistically insignificant. This finding suggests that the expansion of the shadow economy shifts part of economic activity outside the formal sector, thereby reducing the taxable base and limiting the tax administration's capacity to collect revenues. Conversely, a 1% decrease in the size of the shadow economy increases non-hydrocarbon tax revenues by approximately 1.74%, and this effect is statistically significant. The transfer of economic activities may explain this result from the informal to the formal sector, which broadens the tax base, improves tax compliance, and enhances the government's tax collection capacity. Consequently, non-hydrocarbon tax revenues appear to be considerably more responsive to contractions in the shadow economy than to its expansion. Moreover, the elasticity associated with negative shocks is substantially larger than that associated with positive shocks, providing strong evidence of long-run asymmetry.
- Real gross domestic product excluding the hydrocarbon sector (RGDPNH) exerts a positive and statistically significant impact on non-hydrocarbon tax revenues. Specifically, a 1% increase in RGDPNH raises non-hydrocarbon tax revenues by approximately 0.32%. This positive relationship reflects the fact that stronger economic activity outside the hydrocarbon sector expands production, investment, and consumption, thereby enlarging the tax base. Conversely, higher tax revenues enable the government to increase public expenditure, infrastructure investment, and economic support programs, which in turn stimulate further non-hydrocarbon economic growth.

In the short run, the results of the NARDL model indicate that neither positive nor negative shocks to the shadow economy have a statistically significant effect on non-hydrocarbon tax revenues. Moreover, the Wald test does not reveal significant differences between the response of revenues to positive and negative shocks, indicating that there is no statistical evidence of asymmetry in the relationship in the short run. This result can be explained by the fact that short-run changes in the size of the shadow economy do not immediately translate into changes in tax revenues, given the time lag between changes in informal economic activity and the ability of the tax administration to detect such changes and incorporate them into the tax base. In addition, short-run tax revenues may be more strongly influenced by other factors, such as developments in formal economic activity, fiscal policy, tax rates, and collection efficiency, which may limit the emergence of a direct effect of short-run changes in the shadow economy. Therefore, the statistical insignificance of both positive and negative shocks suggests that the fiscal effects of changes in the shadow economy do not materialize immediately

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but require a certain period of time to develop. In contrast, the long-run results reveal statistically significant asymmetry in the effect of the shadow economy on non-hydrocarbon tax revenues at the 10% significance level, with the response of tax revenues differing according to the direction of the shock. The results indicate an inverse relationship between shocks to the shadow economy and tax revenues: a decline in the size of the shadow economy leads to a significant increase in non-hydrocarbon tax revenues, whereas an increase in the size of the shadow economy does not result in a statistically significant corresponding decline in tax revenues. This finding suggests that a contraction in the shadow economy is associated with stronger fiscal effects than its expansion. This may be explained by the transition of part of informal activities into the formal sector, which gradually broadens the tax base, improves compliance, and enhances the tax administration's capacity to collect revenues. Accordingly, the long-run asymmetric effect indicates that the revenue gains associated with a contraction in the shadow economy may be more pronounced than the tax revenue losses resulting from its expansion. Taken together, these findings indicate that the fiscal effects of changes in the shadow economy do not materialize immediately but emerge gradually over time. This explains the absence of significant effects and asymmetry in the short run, compared with the emergence of significant asymmetry in the long run.

The empirical findings are of particular importance in light of Algeria's efforts to modernize tax administration and integrate economic activities into the formal sector. The NARDL model results show that a reduction in the size of the shadow economy is associated with a statistically significant increase of 1.74% in non-hydrocarbon tax revenues in the long run, whereas no statistically significant effects of positive or negative shocks were observed in the short run. This finding suggests that the tax gains resulting from a contraction of the shadow economy do not materialize immediately; rather, they require time for activities to transition into the formal sector, be registered, and incorporated into the tax base. In this context, the digitalization of tax administration can support the transition toward the formal economy by improving taxpayer identification and monitoring of their activities, facilitating information exchange, and strengthening tax compliance. Over the past five years, Algeria has introduced a number of tools aimed at simplifying procedures, reducing compliance costs, and improving the tax administration's capacity to process tax-related information. These mechanisms include the establishment of the electronic Tax Identification Number (TIN), the Tax Management System, and the "Jibayatic" and "Moussahamatic" portals for remote filing and payment. Algeria has also introduced mechanisms to expand electronic payments, such as the "Tabaoukom" platform, which aims to enhance the traceability of transactions and reduce reliance on paper-based procedures. Although the present study does not directly test the effects of these digital tools, they represent institutional mechanisms that may help explain how a contraction of informal activity can translate into higher tax revenues over the long term. These findings also suggest that reducing the shadow economy should not rely solely on monitoring and sanctions, but should be accompanied by measures that facilitate the transition to the formal sector. The registration of economic activities, the simplification of filing and payment procedures, and the provision of accessible and transparent electronic services can reduce compliance costs and encourage firms to integrate into the formal system. Furthermore, improving transparency and integrating databases can strengthen taxpayers' confidence and enhance the tax administration's capacity to monitor activities and collect revenues.

The effects of integrating informal activities extend beyond tax revenues to the broader business environment. The formalization of informal activities can reduce cost differentials between formal and informal firms, thereby improving competitive conditions and encouraging formal firms to invest and expand. This issue becomes even more important in light of the finding that a 1% increase in real gross domestic product excluding the hydrocarbon sector is associated with an approximately 0.32% increase in non-hydrocarbon tax revenues. Accordingly, expanding the formal non-hydrocarbon sector can simultaneously broaden the tax base, support economic growth, and contribute to economic diversification. Therefore, the study's findings indicate that strengthening tax revenues in Algeria requires an integrated approach combining the reduction of the shadow economy, the facilitation of economic activities' integration into the formal sector, the continued digitalization of tax administration, the expansion of electronic payment systems, improved transparency and information sharing, and, in parallel, the promotion of growth in the non-hydrocarbon sector. The importance of these policies stems directly from the

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empirical findings, which indicate that the tax gains associated with a contraction of the shadow economy become more pronounced over the long term.

One limitation of this study concerns the temporal frequency of the data used. Since the original data are available on an annual basis, the semi-annual observations employed in the NARDL framework were obtained through temporal disaggregation rather than from directly observed semi-annual data. Therefore, the estimated within-year dynamics and the timing of potential structural changes should be interpreted with caution, as they may partly reflect the interpolation procedure used to construct the semi-annual series. Accordingly, the interpolated semi-annual series should not be regarded as equivalent to originally observed semi-annual data. This limitation should be taken into consideration when interpreting the empirical findings.

It should also be noted that the results of this study are limited to the period 1993–2020 and therefore do not capture developments that occurred after 2020 in tax administration, digitalization, policies aimed at formalizing economic activity, or changes in the post-COVID-19 economic environment. Accordingly, the findings should be interpreted within the temporal context covered by the study, and caution should be exercised when generalizing them to periods after 2020, given the possibility of institutional, policy, and economic changes that may affect the relationship between SE and NHTR.

Future research could extend the analysis of the relationship between SE and NHTR in several directions. First, NHTR could be disaggregated into its main components, particularly direct and indirect taxes, in order to examine whether SE shocks generate asymmetric effects that differ according to the type of tax. Second, future studies could investigate the role of digitalization and the quality of tax administration in moderating the relationship between SE and NHTR, by examining whether greater use of digital tools and enhanced tax-administration capabilities can mitigate the adverse effects of SE shocks. Third, future research could re-examine this relationship using more recent data and directly observed semi-annual or quarterly data, whenever such data become available, while applying alternative nonlinear models to assess the robustness of the findings obtained using the NARDL approach. Future research could also focus on how this relationship varies across periods of economic crises, oil price fluctuations, and tax reforms. Incorporating additional control variables, such as oil prices, the exchange rate, government expenditure, and financial development, could provide a clearer picture of the relationship between shadow economy shocks and non-hydrocarbon tax revenues. This would allow for a deeper understanding of the conditions under which the asymmetric effects of the shadow economy on non-hydrocarbon tax revenues are strengthened or weakened.

With regard to policy implications, previous empirical studies emphasize the crucial role of technological innovation and institutional quality in reducing the size of the shadow economy. Digitalization significantly improves tax administration, reduces opportunities for tax evasion, and enhances revenue collection (Yamen et al., 2023). Likewise, the adoption of electronic payment systems facilitates transaction traceability and contributes to higher tax revenues (Zhang et al., 2019). Furthermore, strengthening digital transparency represents an effective strategy for protecting public resources from revenue leakage (Tychyna et al., 2026). Evidence from computable general equilibrium models for Italy and Spain also suggests that reducing tax rates while simultaneously strengthening tax enforcement may ultimately increase total tax revenues (Herranz & Turino, 2023; Orsi et al., 2014). Finally, improving tax awareness and reinforcing the social contract between taxpayers and the government can encourage voluntary tax compliance and reduce reliance on the shadow economy (Sebele-Mpofu, 2023).

In the Algerian context, policies aimed at reducing the shadow economy and enhancing tax compliance are particularly important given the structure of the national economy and its heavy reliance on hydrocarbons, which accounted for approximately 83% of Algeria's total exports and 47% of budget revenues over the period 2019–202**3**. This situation highlights the need to diversify public revenue sources and expand the contribution of non-hydrocarbon activities to budget financing. In this regard, the non-hydrocarbon tax revenue gap has been estimated at between 2% and 4% of GDP. Furthermore, (Vellutini, 2025) found that average value-added tax (VAT) revenues amounted to 3.3% of GDP in Algeria over the period 2018–2024, compared with 6.5% in emerging economies exporting non-fuel commodities. Similarly, corporate income tax revenues stood at 1.8% of GDP, compared with 3.4% in the comparator group.

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These indicators suggest that there is considerable scope for improving tax revenue mobilization. However, the observed differences should not be attributed solely to tax evasion, as they may also reflect tax exemptions and structural differences across economies.

Against this backdrop, tax policies in Algeria should focus on improving collection efficiency and broadening the non-hydrocarbon tax base through practical measures tailored to the specific characteristics of each tax. Regarding value-added tax (VAT), electronic invoicing and digital transaction reporting could be strengthened, alongside improved cross-checking of sales and purchase invoices against tax returns and wider adoption of electronic payment methods. These measures could help reduce the underreporting of turnover and the concealment of taxable transactions. Their importance is further underscored by the expansion of electronic payments in Algeria: their total value increased from DZD 332.6 billion in 2023 to DZD 643.8 billion in 2024, reaching DZD 939 billion in 2025, according to data published by the Economic Interest Grouping for Electronic Payments**.** However, the extent to which this expansion translates into higher tax revenues depends on the effective use of commercial transaction data to improve invoicing, tax reporting, and collection. An increase in electronic payments does not necessarily imply a proportionate increase in tax revenues.

With regard to personal income tax, priority should be given to improving the reporting of income derived from self-employment, liberal professions, trade, and services. This could be achieved by strengthening information exchange between the tax administration and relevant administrative authorities, subject to appropriate legal safeguards for data protection, while simplifying registration and filing procedures for small taxpayers. Such measures could encourage voluntary compliance and reduce income concealment. As for corporate income tax, risk-based auditing should be further developed, and the reconciliation of tax returns with accounting records and commercial data should be strengthened. Particular attention should be paid to activities linked to hydrocarbon supply chains, services, and subcontracting, as well as to non-hydrocarbon sectors with significant productive and growth potential. These measures could help reduce the underreporting of corporate profits while ensuring a clear distinction between tax evasion and legitimate accounting practices and maintaining clarity and stability in tax rules.

In parallel, integrating informal activities into the formal economy requires simplifying business registration, tax registration, bookkeeping, and tax filing procedures, while adapting compliance costs to the scale of business activity and the characteristics of taxpayers. This would encourage a gradual transition to formality without imposing disproportionate administrative or tax burdens on small enterprises, traders, and artisans. Such facilitation measures should be complemented by more effective enforcement against deliberate non-compliance, improvements in the quality of digital tax administration services, and greater transparency and public trust in the use of government revenues.

Therefore, reducing the shadow economy in Algeria cannot be achieved through digitalization or stricter enforcement in isolation. Rather, it requires an integrated approach combining improved collection of VAT, personal income tax, and corporate income tax; expansion of the tax base beyond the hydrocarbon sector; and lower barriers to formalization. Such an approach could strengthen the sustainability of public revenues and reduce their vulnerability to fluctuations in hydrocarbon prices, while taking into account the economic and social dimensions of informal activities.

DECLARATION OF GENERATIVE AI AND AI-ASSISTED TECHNOLOGIES IN THE WRITING PROCESS

During the preparation of this manuscript, the authors used ChatGPT (OpenAI, GPT-5) solely as an assistive tool for language editing and improving the clarity of the text. The authors reviewed and verified all AI-assisted content and accept full responsibility for the final version of the manuscript.

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APPENDIX

Appendix A: Additional Results of Rolling and Recursive NARDL Estimations

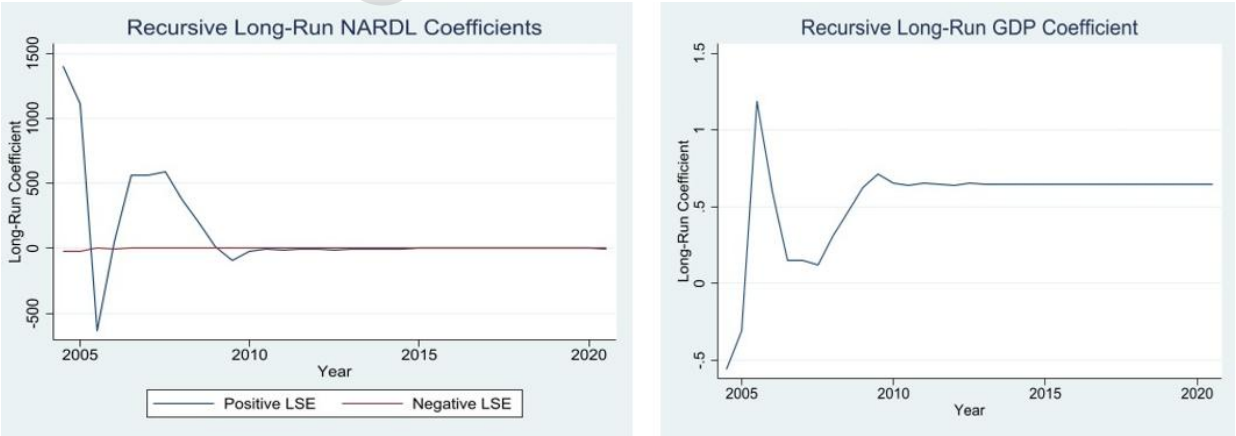

Figure A1: Recursive estimates of long-run NARDL coefficients

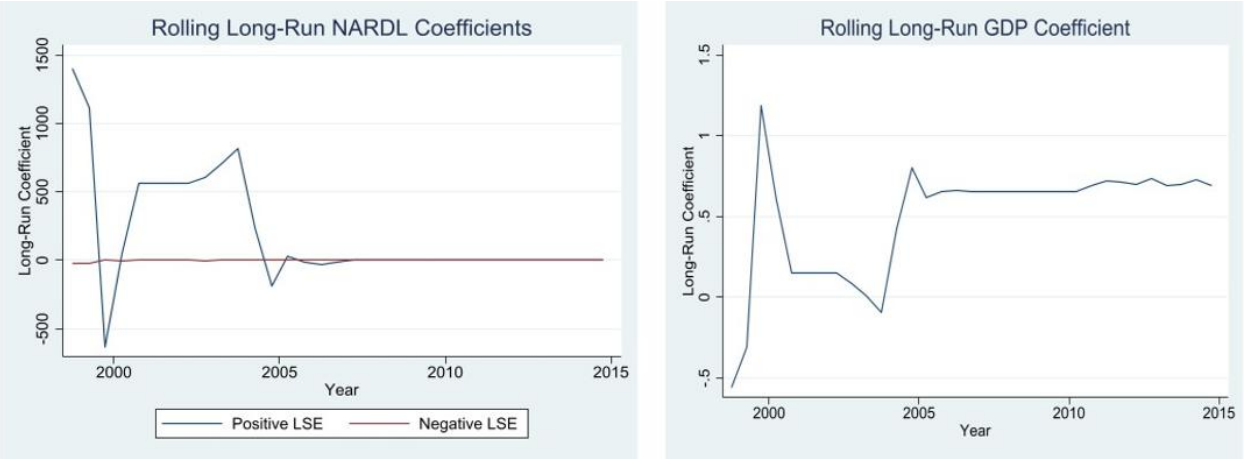

Figure A2: Rolling-window estimates of long-run NARDL coefficients

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DA LI ŠOKOVI SIVE EKONOMIJE IMAJU SIMETRIČAN ILI ASIMETRIČAN UTICAJ NA PORESKE PRIHODE IZ NEUGLJOVODONIČNOG SEKTORA U ALŽIRU?

Cilj ovog istraživanja je ispitivanje uticaja pozitivnih i negativnih šokova sive ekonomije na poreske prihode iz neugljovodoničnog sektora u Alžiru, korišćenjem polugodišnjih podataka za period od 1993. do 2020. godine. U analizi je primenjen nelinearni autoregresioni model sa distribuiranim docnjama (NARDL). Rezultati testova jediničnog korena koji uzimaju u obzir strukturne prekide, Zivot–Andrews (ZA) i Lee–Strazicich (LS), pokazuju da sve promenljive postaju stacionarne nakon prvog diferenciranja. Ekonometrijski rezultati ukazuju na postojanje dugoročne ravnotežne veze između posmatranih promenljivih. Waldov test takođe pruža slabe dokaze o dugoročnoj asimetriji uticaja šokova sive ekonomije na poreske prihode iz neugljovodoničnog sektora. Rezultat je statistički značajan na nivou od 10%, ali ne i na uobičajenom nivou od 5%. Pokazalo se da su poreski prihodi iz neugljovodoničnog sektora osetljiviji na negativne nego na pozitivne šokove. Dugoročno posmatrano, negativan šok sive ekonomije dovodi do povećanja poreskih prihoda iz neugljovodoničnog sektora za 1,7424%, dok pozitivan šok dovodi do njihovog smanjenja za 0,58%. Kratkoročno posmatrano, rezultati ukazuju na simetrične efekte pozitivnih i negativnih šokova sive ekonomije na poreske prihode iz neugljovodoničnog sektora.

Ključne reči: Siva ekonomija; Poreski prihodi iz neugljovodoničnog sektora; Realni bruto domaći proizvod bez sektora ugljovodonika; NARDL; Asimetrija.