

## Analyzing the response of economic growth to monetary policy instruments: The case of Algeria (1990–2024) using the QARDL approach

Salima Belhaoues <sup>1</sup>, Fenazi Fatima Zohra <sup>2</sup>, Cherif Mohamed <sup>3</sup>, Ali Abed <sup>4</sup>, Radhia Guessab <sup>5</sup>, Abdallah Bouzar <sup>6</sup>

<sup>1</sup> University of Elbayadh, Algeria. Email: [s.belhaoues@cu-elbayadh.dz](mailto:s.belhaoues@cu-elbayadh.dz)

<sup>2</sup> University of Skikda, Algeria. Email: [fz.fenazi@univ-skikda.dz](mailto:fz.fenazi@univ-skikda.dz)

<sup>3</sup> University of Tiaret, Algeria. Email: [mohamed.cherif@univ-tiaret.dz](mailto:mohamed.cherif@univ-tiaret.dz)

<sup>4</sup> University of Tiaret, Algeria. Email: [ali.abed@univ-tiaret.dz](mailto:ali.abed@univ-tiaret.dz)

<sup>5</sup> University of Tissemsilt, Algeria. Email: [guessab.radhia@univ-tissemsilt.dz](mailto:guessab.radhia@univ-tissemsilt.dz)

<sup>6</sup> University of Sidi Belabbes, Algeria. Email: [abdallah.bouzar@dl.univ-sba.dz](mailto:abdallah.bouzar@dl.univ-sba.dz)

**Abstract---**This study aims to analyze the response of economic growth to monetary policy instruments in Algeria during the period 1990–2024, focusing on heterogeneity across different growth states, using the quantile accelerated regression with distributed lag (QARDL) methodology. The study relies on quarterly data for a set of key monetary variables, including the exchange rate (tch), interest rate (ir), foreign reserves (cr), and broad money (m2). The results show clear nonlinear relationships in the long term between monetary policy instruments and economic growth, with the exchange rate having a negative and insignificant effect at the lower quantile (0.25) and more negative at the medium (0.50) and high (0.75) quantiles, reflecting the sensitivity of growth to exchange rate fluctuations in cases of medium and high economic performance. In contrast, the short-term results revealed limited positive effects of the exchange rate across different quantiles, indicating a degree of short-term flexibility. The study concludes that it is necessary to enhance the effectiveness of monetary policy instruments, improve the flexibility of the monetary framework, and develop financial markets, thereby supporting the ability of monetary policy to stimulate economic growth in Algeria.

**Keywords---**monetary policy, economic growth, quarterly data, QARDL model, Algeria.

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## Introduction

Given the increasing interdependence of global economies, the ability of monetary policy to influence real economic activity has become one of the key challenges to achieving macroeconomic stability and supporting sustainable economic growth, particularly in emerging economies that are dependent on natural resources. Algeria is a clear example of such an economy, as its economic performance is heavily dependent on oil and gas revenues, which account for more than 95% of exports, making economic growth vulnerable to external shocks, particularly energy price shocks in global markets.

Since the beginning of monetary reforms in the 1990s, the Bank of Algeria has worked to develop its monetary policy framework and expand the use of its instruments in an effort to enhance their effectiveness in managing liquidity, controlling inflation, and supporting economic growth. However, the effectiveness of these instruments does not depend solely on their nature, but is also linked to the mechanisms through which their effects are transmitted to the real economy, which are influenced by the structural characteristics of the national economy. In this context, the managed exchange rate regime adopted by the Algerian dinar limits exchange rate flexibility in the face of shocks, thereby affecting competitiveness and economic growth.

The Algerian economy underwent profound changes during the period 1990–2024, including the implementation of liberal reforms, exposure to a sharp decline in oil prices during the period 2014–2016, and the resulting external imbalances, as well as the economic repercussions of the COVID-19 pandemic in 2020, which caused a contraction in growth and increased economic instability. These developments revealed a clear divergence in the response of economic growth to monetary policy instruments, indicating asymmetric effects across different stages of the economic cycle.

In this context, the study focuses on the following question:

To what extent do economic growth rates in Algeria respond to monetary policy instruments, and does this response vary depending on the economic growth situation in the face of external shocks?

To answer this question, the study uses the quantitative autoregressive distributed lag (QARDL) methodology, which allows for the analysis of short- and long-term relationships while taking into account the asymmetry in the response of economic growth across its various distributions. The importance of this study lies in providing a nonlinear analytical framework that helps monetary policymakers design more appropriate policies to address periods of recession or boom. It also contributes to enriching the literature on rentier economies by applying the QARDL model to long-term time series data up to 2024.

## Literature Survey

Monetary policy refers to the set of measures adopted by the central bank to regulate the money supply and influence interest rates, with the aim of achieving price stability and supporting economic growth. The instruments of this policy are open market operations, discount rates, and reserve requirements, which affect the amount of liquidity available to the financial system, the cost of credit, and the level of economic activity (Mishkin, 2011, p. 5)

In theory, the success of monetary policy assumes price and wage flexibility and efficient financial markets. However, these assumptions are often not met in emerging economies, where heavy dependence on external shocks, such as commodity price fluctuations, complicates the transmission mechanisms of monetary policy. In this context, open economy models, such as the Mundell–Fleming model, highlight the importance of international interactions in explaining the effectiveness of monetary policy (Bernanke & Gertler, 1995, pp. 27–48) The literature also suggests that the limited development of financial markets weakens transmission channels, requiring additional interventions to enhance the economic response (Montiel, 1990, pp. 47–90).

The effects of monetary policy are transmitted to the real economy through several main channels, including the interest rate channel, which affects investment and consumption decisions; the credit channel, which controls the amount of financing available to the private sector; the price channel, which affects aggregate demand through inflation, and the exchange rate channel, which affects foreign trade and competitiveness (Obstfeld, 1996).

In open economies, these channels are highly interrelated, with changes in one affecting the others, particularly in the context of international capital flows (Mohanty & Klau, 2005, pp. 36–63). However, financial crises often weaken the effectiveness of these channels, requiring alternative strategies to ensure the continued impact of monetary policy in emerging economies (Cho, Kim, & Shin, 2015, pp. 281–300).

Monetary policy instruments, primarily the exchange rate, interest rates, foreign reserves, and broad money, affect GDP through multiple channels. In resource-dependent economies such as Algeria, changes in the exchange rate contribute to adjusting the competitiveness of exports, which is reflected in aggregate demand and economic growth. Studies indicate that a decline in the exchange rate can lead to an increase in GDP in the short term by supporting exports and reducing unnecessary imports.

However, exchange rate fluctuations may, in turn, lead to higher imported inflation, especially given the heavy dependence on food and capital goods imports, limiting the positive impact on long-term growth. Empirical studies on Algeria have shown that external shocks, such as oil price fluctuations or global health crises, lead to a decline in growth and increased economic instability (Khelifa & Bekkouche, 2021, pp. 130–135).

The Mundell–Fleming model provides a theoretical framework for explaining the relationship between monetary policy, exchange rates, and GDP in open economies. It shows that the effectiveness of monetary policy depends on the exchange rate regime, with it being more effective under a floating exchange rate regime than under a fixed regime (Mundell, 1971, pp. 475–485). In the case of Algeria, which has a managed exchange rate system that combines the characteristics of both systems, the effectiveness of monetary policy is relatively reduced, reinforcing the need for more flexible policies to achieve a better balance between stability and growth.

## Method

The Quantile Autoregressive Distributed Lag (QARDL) methodology is a powerful econometric framework that combines the Autoregressive Distributed Lag (ARDL) model with Quantile Regression analysis. It aims to analyze the dynamic relationships between time variables across their different conditional distributions, allowing for the study of short-term and long-term effects in asymmetric contexts. It was developed primarily in the work of researchers such as Cho et al. (2015), extending to include quantile cointegration analysis in (Cho, Kim, & Shin, 2015, pp. 281–300).

models Traditional ARDL developed by Pesaran and Shin (1998), which focuses on estimating long-run relationships and short-run dynamics using ordinary least squares (OLS), with a focus on the conditional mean of the dependent variable (Pesaran & Shin, 1998, pp. 2–3). However, this model assumes homogeneity of effects across the distribution, which may overlook differences in the lower and upper tails (e.g., effects in economic crises or boom periods).

This QARDL model extends it by making it quantile, where the model coefficients vary according to the quantile  $\tau$  (where  $0 < \tau < 1$ ), such as  $\tau = 0.05$  for the lower tail or  $\tau = 0.95$  for the upper tail. This allows for the analysis of quantile cointegration, i.e., long-term relationships that vary according to the level of distribution, while maintaining the ability to deal with integrated variables of degree zero or one (I(0) or I(1)). without prior unit root testing (Cho, Kim, & Shin, 2015, pp. 281–300).

Quantile regression (developed by Koenker and Bassett, 1978) is incorporated by replacing the loss function in ARDL with a quantile loss function, which relies on a weighted sum of absolute deviations rather than squares (Koenker & Bassett, 1978, pp. 35–36). This makes the model more resistant to outliers and non-normal distributions, and allows for the estimation of the conditional quantile

$Q_{-\{Y_{-t}\}}(\tau | F_{-\{t-1\}})$  of the dependent variable  $Y_{-t}$  based on prior information  $F_{-\{t-1\}}$  (Cho, Kim, & Shin, 2015, p. 285). The QARDL model takes the form:

$$Y_t = \alpha^*(\tau) + \sum_{j=1}^p \phi_j^*(\tau) Y_{t-j} + \sum_{j=0}^q \theta_j^*(\tau)' X_{t-j} + U_t(\tau)$$

where:

$\alpha^*(\tau)$  The constant according to the quantile  $\tau$ .

$\phi_j^*(\tau)$  Short-term autoregressive coefficients

$\theta_j^*(\tau)$  Distributed lag coefficients for independent variables  $X_{-t}$

$U_t(\tau) = Y_t - Q_{Y_t}(\tau | F_{t-1})$  Quantile error where:  $U_t(\tau)$  (Cho, Kim, & Shin, 2015, p. 286)

Long-run quantile Relationship:

$$Y_t = \mu^*(\tau) + X_t' \beta^*(\tau) + R_t(\tau)$$

Where  $\beta^*(\tau) = \gamma^*(\tau) \left[ 1 - \sum_{i=1}^p \phi_i^*(\tau) \right]^{-1}$  and  $\gamma^*(\tau) = \sum_{j=0}^q \theta_j^*(\tau)$  represent the long-term cumulative effect (Pesaran & Shin, 1998, p10).

Error Correction Model (ECM):

$$\Delta Y_t = \alpha^*(\tau) + \zeta^*(\tau) (Y_{t-1} - \beta^*(\tau)' X_{t-1}) + \sum_{j=1}^{p-1} \phi_j^*(\tau) \Delta Y_{t-j} + \sum_{j=0}^{q-1} \theta_j^*(\tau)' \Delta X_{t-j} + U_t(\tau)$$

Where:

$\zeta^*(\tau)$  Measures the speed of correction towards long-term equilibrium according to the quantile (Cho, Quantile cointegration in the autoregressive distributed-lag model, 2015, pp. 288-289).

These equations are estimated using the backward quantile method, with the loss function:

$$\tau \sum_{Y_i > \hat{Y}_i} |Y_i - \hat{Y}_i| + (1 - \tau) \sum_{Y_i < \hat{Y}_i} |Y_i - \hat{Y}_i|$$

(Koenker & Bassett, 1978, p36).

### Key assumptions

– The variables  $X_{-t}$  are integrated of order one, with  $\Delta X_t$  constant.

–  $U_t$  errors are independent and continuously distributed, with positive density at quantile  $\tau$ .

No simultaneous cointegration between the independent variables, and multiple roots outside the unit circle.

Independence between errors and changes in  $X_{-t}$  (Cho, Kim, & Shin, 2015, pp. 290-291)

### Study model:

– **GDP:** A measure of the total market value of all final goods and services produced within a country's borders during a specific period of time (usually a year or quarter). It is measured in US dollars or

Algerian dinars and includes industrial, agricultural, and service production, excluding unrecorded production. In the Algerian context, GDP is heavily dependent on the hydrocarbon sector and is derived from World Bank data (e.g., World Development Indicators database) and Bank of Algeria data (annual economic growth reports).

**\_Ir:** Refers to the nominal interest rate minus the inflation rate, reflecting the real cost of borrowing or the return on savings after adjusting for monetary erosion. In Algeria, it is calculated based on the Bank of Algeria's key interest rate (such as the discount rate) minus annual inflation, measured as a percentage, with data from the Bank of Algeria (monthly reports on prices and interest rates) and the World Bank (index FR.INR.RINR). It has a negative relationship; that is, a rise in the real interest rate increases the real cost of borrowing, which reduces investment and consumer spending, thereby slowing GDP growth. (Keynes, 1936)

**\_Cr:** Represents the total volume of loans provided by banks and financial institutions to economic sectors (private and public), whether short- or long-term, measured as a percentage of GDP or as an absolute volume in dinars in Algeria. It is monitored as an indicator of financing expansion, with data from the Bank of Algeria (annual reports on loan distribution). and the World Bank as indicators of total credit such as (FS.AST.PRVT.GD.ZS), it has a positive relationship; i.e., an increase in the volume of loans facilitates investment and production, which enhances GDP growth by improving financial intermediation and supporting economic activity (Schumpeter, 1934, pp. 70-100) .

**\_Tch:** Refers to the exchange rate of the Algerian dinar against major foreign currencies (such as the US dollar or the euro), determined in part by the Bank of Algeria in a managed floating system, measured as the number of dinars per foreign unit, with data from the Bank of Algeria (daily exchange rate reports) and the World Bank as an index (PA.NUS.FCRF) . It has a dual relationship, but one that is mostly positive in the short term; i.e., a decline in the value of the dinar (a rise in the exchange rate) boosts exports (especially hydrocarbons in Algeria), which raises GDP, while raising import costs (Mundell, 1971, pp. 160–170)

**\_M2:** Measures total currency in circulation plus bank deposits (current and savings), and expresses the money supply in the economy as a percentage of GDP or as an absolute amount in dinars. In Algeria, it is monitored as a monetary policy tool, with data from the Bank of Algeria (monthly reports on M2) and the World Bank as an indicator (FM.LBL.BMNY.GD.ZS). (It has a positive relationship; that is, an increase in M2 increases liquidity, which stimulates spending and investment, leading to higher GDP in the long run (Fisher & Brown, 1911, pp. 24–30).

The model takes the following form:

$$Q_{\tau}(GDP_t | F_{t-1}) = \alpha_{\tau} + \phi_{\tau} GDP_{t-1} + \sum_{j=1}^p \gamma_{j,\tau} \Delta GDP_{t-j} + \sum_{k=1}^4 \beta_{k,\tau} X_{k,t-1} + \sum_{k=1}^4 \sum_{l=0}^{q_k} \delta_{k,l,\tau} \Delta X_{k,t-l} + \dot{o}_{\tau,t}$$

## Results

### Analysis of the study results using the QARDL model

This part of the study uses the Quantile Autoregressive Distributed Lag (QARDL) model, developed by Cho et al. (2015) as an extension of the traditional ARDL model. This model allows for the estimation of conditional relationships for different quantiles ( $\tau \in (0-1)$ ), enabling the analysis of how independent variables affect GDP in cases of economic downturn (lower quantile, such as  $\tau=0.25$ ), average growth ( $\tau=0.50$ ), or boom upper quantile, such as ( $\tau=0.75$ ) . This approach goes beyond the linear assumptions of classical models and provides accurate insights into short- and long-term effects, focusing on cointegration and asymmetric shocks. The results are obtained using a combination of software packages depending on the test under consideration, namely stata19 and colab.

### Descriptive variables

Descriptive statistics are an essential tool for exploring data characteristics before diving into advanced analyses, providing a comprehensive view of the distribution, dispersion, and outliers of key variables,

which focus on analyzing the dynamics of economic growth in Algeria through a quantile distributed auto-regression model (QARDL). The results are shown in the following table:

**Table 1: Goodness-of-fit tests for study variables**

	gdp	ir	cr	tch	m2
count	6900000.e+01	69.000000	6900000.e+01	69.000000	6900000.e+01
mean	1.221467e+07	-0.734186	4.100802e+06	78.482509	8.286406e+06
std	9.944382e+06	9.658019	3.893414e+06	33.872172	7.635756e+06
min	5.558000e+05	-29.770000	2.202490e+05	8.957508	3.433240e+05
25%	2.959554e+06	-6.180000	9.937370e+05	61.873685	1.300303e+06
50%	9.872971e+06	0.000000	2205242.e+06	74.385983	5.994608e+06
75%	1.925376e+07	6.681997	7567356.e+06	107.048170	1.381631e+07
max	3.533909e+07	16.600000	1.125650e+07	141.990000	2.652894e+07

**Source:** Prepared by researchers based on the colab program

### Stationarity and causality of the Quantile ARDL model

The stationarity test is an essential step in ensuring the validity of predictive models, especially in the quantile autoregressive distributed lag (QARDL) model, which deals with non-normal distributions and heterogeneous shocks. We will focus on the QADF (Quantile Augmented Dickey-Fuller) test, the results of which are shown in the following table:

**Table 2: QADF test for study variables**

cv_01	cv_05	cv_10	t_stat	delta_sq	rho_ols	rho_tau	alpha_tau	Quantile	VARIABLE
-	-	-	0.9620	0.0930	1.0130	1.0040	53,619.8370	0.25	<b>GDP</b>
2.7844	2.1158	1.7525							
-	-	-	2.7870	0.1400	1.0130	1.0120	86,627.8560	0.	
2.8365	2.1815	1.8188							<b>CR</b>
-	-	-	4.0850	0.2810	1.0130	1.0300	82,122.9950	0.75	
3.0347	2.3767	2.0308							
-	-	-	-	0.1160	0.8840	0.9040	-0.9270	0.25	<b>IR</b>
2.8047	2.1414	1.7783	1.9990						
-	-	-	-	0.2470	0.8840	0.8780	0.2310	0.5	
2.9836	2.3354	1.9828	2.6990						<b>TCH</b>
-	-	-	-	0.2190	0.8840	0.8840	1.0960	0.75	
2.9420	2.3018	1.9437	1.6500						
-	-	-	-	0.2480	1.0030	0.9970	6,308.6730	0.25	<b>M2</b>
2.9856	2.3370	1.9847	0.7790						
-	-	-	4.6340	0.1720	1.0030	1.0120	21,428.5430	0.5	
2.8771	2.2327	1.8704							<b>TCH</b>
-	-	-	7.3940	0.1790	1.0030	1.0130	29,197.1560	0.75	
2.8868	2.2449	1.8827							
-	-	-	-	0.1380	0.9940	0.9930	-0.0500	0.25	<b>TCH</b>
2.8330	2.1771	1.8144	1.2410						
-	-	-	-	0.2710	0.9940	0.9980	0.2530	0.5	
3.0199	2.3647	2.0169	0.3160						<b>M2</b>
-	-	-	-	0.2870	0.9940	0.9970	1.4780	0.75	
3.0435	2.3839	2.0392	0.4400						
-	-	-	2.3760	0.1630	1.0150	1.0140	12,787.3790	0.25	<b>M2</b>
2.8666	2.2195	1.8571							

cv_01	cv_05	cv_10	t_stat	delta_sq	rho_ols	rho_tau	alpha_tau	Quantile	VARIABLE
-	-	-	4.6060	0.1300	1.0150	1.0170	14,091.4360	0.5	
2.8236	2.1652	1.8023							
-	-	-	3.9700	0.2260	1.0150	1.0180	34,362.9410	0.75	
2.9526	2.3103	1.9536							

Source: Prepared by researchers based on R STUDIO outputs

**At a quantile of 0.25:** GDP appears unstable where (  $t\text{-stat} > cv_{05}$ , and  $\rho_{\tau}=1.0040 > 1$ ) ( the series GDP(1); whereas CR is stable (  $t\text{-stat} < cv_{05}$ ,  $\rho_{\tau}=0.9040 < 1$ ) The series IR(1), TCH(1), M2(1), highlighting the sensitivity of output to negative shocks and the role of credit in recovery (Schumpeter J. A., 1934, pp. 70-100).

**At quantile 0.50:** GDP is unstable at the level where (  $t\text{-stat} > cv_{05}$ ),  $\rho_{\tau}=1.0120 > 1$ ). Therefore, the series GDP(1) is unstable, while CR is stable where (  $t\text{-stat} < cv_{05}$ ,  $\rho_{\tau}=0.8780$ ). The series IR(1), TCH(1), M2(1), confirming the financial causality of normal growth (Keynes J. M., 1936, pp. 69-74) .

**At quantile 0.75:** GDP is unstable (  $t\text{-stat} > cv_{05}$ , and  $\rho_{\tau}=1.0300 > 1$ ) The series GDP(1); whereas CR is in the first degree (  $t\text{-stat} > cv_{05}$ ,  $\rho_{\tau}=0.8840 < 1$ ) The series IR(1), TCH(1), M2(1), and it is possible to point to the risks of bubbles and the importance of regulation in prosperity (Fisher & Brown, 1911, pp. 19-23) .

#### Causality of the QARDL model

The quantile causality test in QARDL assesses the heterogeneous effects of variables on GDP through quantiles, and the results are shown in the following table:

Table 3: QARDL causality test for study variables

Brief explanation	Causality	P-value	T Statistic	Coefficient of X_lag	Quantile ( $\tau$ )	Independent Var
No effect.	No	1.0000	0.00	0.0000	0.25	Ir
No effect.	No	1.00	0.00	0.00	0.5	
Weak negative, inconclusive.	No	0.7966	-0.2588	-2531.2559	0.75	
Strong negative effect	Yes	0.0001	-4.2413	-0.2152	0.25	Cr
Moderate negative impact in the middle.	Yes	0.0392	-2.1045	-0.0856	0.50	
Weak negative, inconclusive.	No	0.4152	-0.8200	-0.0606	0.75	
Positive, not conclusive.	No	0.2517	1.1566	2216.5544	0.25	Tch
Strong positive impact in the middle	Yes	0.0035	3.0324	4828.8832	0.50	
Positive, not conclusive.	No	0.1474	1.4663	3345.5528	0.75	
Negative impact at low volumes	Yes	0.0472	-2.0229	-0.1021	0.25	m2
Negative impact in the middle.	Yes	0.0440	-2.0542	-0.0916	0.50	
Weak negative, not indicative.	No	0.5216	-0.6443	-0.0691	0.75	

Source: Prepared by researchers based on R STUDIO outputs

**At quantile 0.25:** Strong negative causality confirmed for CR ( $p=0.0001$ , coefficient=-0.2152) and M2 ( $p=0.0472$ , =-0.1021), with no evidence for IR ( $p=1.0000$ ) and TCH ( $p=0.2517$ ), reflecting the role of credit and money supply in exacerbating declines.

**At quantile 0.50:** a strong positive causality emerges for TCH ( $p=0.0035$ , with a coefficient=4828.8832, and a negative one for CR ( $p=0.0392$ ), =-0.0856) and M2 ( $p=0.0440$ ), and no effect for IR ( $p=1.0000$ ).

**At quantile 0.75:** no clear causal evidence for any variable (IR  $p=0.7966$ , CR  $p=0.4152$ , TCH  $p=0.1474$ , M2  $p=0.5216$ ), with weak negative signs for CR and M2, indicating independence of growth in prosperity.

**Optimal lags and simultaneous integration test**

**Optimal lags for the QARDL model** the selection of optimal lags in QARDL is determined by minimizing the QIC criterion, the heterogeneous dynamics of the exchange rate effect on economic growth, which is based on the following equation:

$$QIC(\tau) = \log \left[ \frac{1}{n} \sum_{t=1}^n \rho_{\tau}(y_t - \hat{Q}_{\tau}(x_t)) \right] + \frac{k}{n} \log n$$

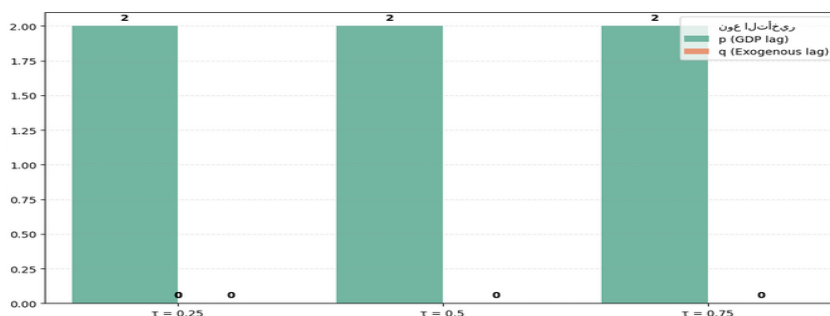
(Cho, Kim, & Shin, 2015, pp. 281–300)

**Table 4: Testing the optimal lags for the study model**

QIC (gdp)	q_ir	q_cr	q_tch	q_m2	Quantile	p
0.25	2	0	0	0	0	19.83
0.50	2	0	0	0	0	18.53
0.75	2	0	0	0	0	19.04

Source: Prepared by researchers based on Stata 19 outputs

The results show remarkable consistency at  $p=2$  for all quantiles, indicating a second-order effect of GDP, while all lags for the independent variables  $q_k=0$ , meaning that no lags are needed for the independent variables, which reinforces the simplicity of the model without losing statistical accuracy, as the QIC drops to its lowest level in the 0.5 quantile (18.53), highlighting the model's superiority in capturing normal dynamics, while rising slightly in the 0.25 quantile (19.83) and at the 0.75 quantile (19.04), reflecting higher sensitivity to shocks in recessions and booms, according to the theoretical framework of quantile regression. Economically, this suggests that the immediate (without delays) effect of TCH dominates the monetary channel, reinforcing short-term positive causality in the medium term (Mundell R. A., 1971, pp. 160-171) . He recommends expanding non-hydrocarbon investment to promote long-term stability in Algeria. The lags can be represented as follows:



**Figure 1: Distribution of model variable delays**

Source: Prepared by researchers based on colb outputs

### ▪ Quantile Bounds Test

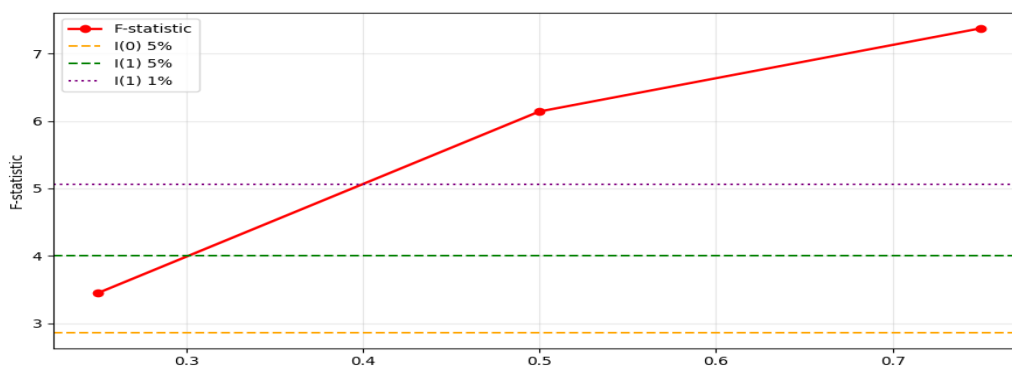
The quantile bounds test in QARDL assesses the joint equilibrium across quantiles ( $\tau$ ) by comparing F or t statistics with (Hsu, 2017, pp. 1-10), reinforcing the heterogeneous dynamics of monetary policy channels on Algerian growth. The results are as follows:

**Table 5: Quantile ARDL bound test**

Quantile	F-statistic	P-value	Result
0.25	3.4489	0.0094	Indeterminate
0.50	6.1414	0.0002	Long-term correlation (rejected at 5%)
0.75	7.3752	0.0000	Long-term correlation (rejected at 5%)

**Source:** Prepared by researchers based on Stata 19 outputs

The quantile frontier test table, which assesses the joint equilibrium between GDP and independent IR variables via quantiles  $\tau$ , compared to the Pesaran et al. (2001). At  $\tau=0.25$ , where the F-statistic was 3.4489 ( $p=0.0094$ ), it fell in the inconclusive zone, indicating no conclusive evidence of a long-term correlation during recessions, possibly due to hydrocarbon shocks. At the quantile  $\tau=0.50$ ,  $F=6.1414$  exceeds the upper limit ( $p=0.0002$ ), confirming the rejection of  $H_0$  and a strong long-term correlation in growth, supported by the positive TCH effect. At the quantile  $\tau=0.75$ ,  $F=7.3752$   $p=0.0000$ , which leads to a strong rejection, highlighting a common balance in prosperity with M2 flexibility, recommending diversification policies to enhance Algerian stability. This is illustrated in the following figure:



**Figure 2: Bound test for the QARDL model**

**Source:** Prepared by researchers based on colab

### Estimating the relationship in the long and short term

Estimating the dynamic relationships between exchange rates and economic growth is crucial, as the QARDL model reveals nonlinear effects in the short and long term, supporting economic stability policies

#### Estimating the long-term relationship for the QARDL model:

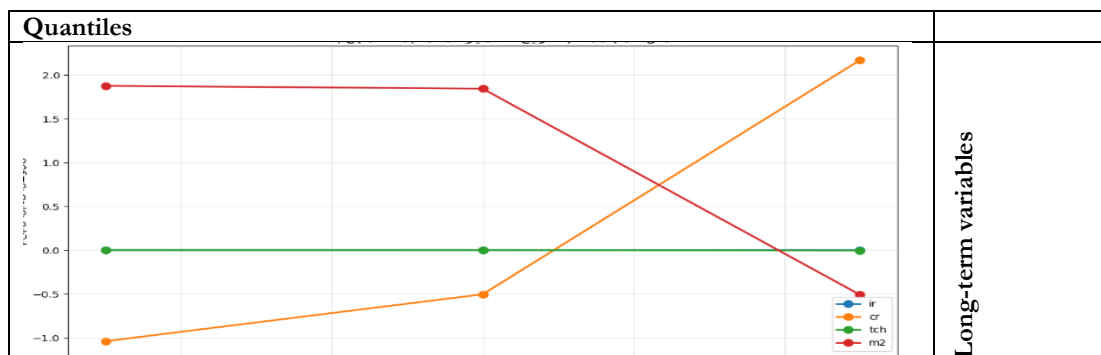
This estimation focuses on the long-run equilibrium coefficients in the QARDL model to explore the quantile effects of the exchange rate on growth, with a focus on differences across probability distributions.

**Table 6: Estimation of the long-run relationship for the model of the impact of the exchange rate on economic growth**

	ir	cr	tch	m2
0.25	-0.000397	-1.039963	-0.000021	1875340.
0.50	-0.000711	-0.504764	-0.000497	1843022.
0.75	-0.000281	2.167765	-0.005430	-0.509211

Source: Prepared by the researcher based on Colab outputs

The nonlinear results of the model show that: the tch coefficient is negative and insignificant in the lower quantile (0.25: -0.000021), indicating a weak effect on low growth, while in the middle quantile (0.50: -0.000497), it shows a slight negative effect, while it becomes more severe in the upper quantile (0.75: -0.005430), reflecting the worsening economic deterioration under the pressure of currency fluctuations. The ir (interest rate) coefficients show a stable negative sign across the quantiles, indicating their role in curbing growth, while cr (reserves) vary from strongly negative at 0.25 (-1.039963) to positive at 0.75 (2.167765), suggesting its regulatory role in different economic conditions. m2 (broad money) is positive in the lower and middle quantiles (1.875340 and 1.843022) but negative in the upper range (-0.509211), indicating the limits of monetary expansion in boom periods. The distribution of long-term coefficients can be illustrated in the following figure:



**Figure 3: Long-term coefficients via quantiles**

Source: Prepared by researchers based on Colab outputs

**Estimating the short-term relationship for the QARDL model**

We will estimate the short-term dynamics in QARDL to reveal the nonlinear effects of the exchange rate on growth via quantiles. The results are shown in the following table:

**Table 7: Estimation of the short-term relationship for the model of the impact of the exchange rate on economic growth**

	ir	cr	tch	m2	ir_lag1	cr_lag1	cr_lag2	cr_lag3	m2_lag1	m2_lag2
0.25	0.000222	-0.412421	0.000981	0.259555	0.000531	-0.009130	0.345136	-0.084772	-0.213262	0.001162
0.50	0.000295	-0.368461	0.003245	0.408230	-0.000080	-0.023918	0.361661	-0.035041	-0.536510	0.075725
0.75	-0.001376	-0.685113	0.002827	0.019844	-0.001185	0.833339	-0.779040	0.553788	0.238889	-0.355443

Source: Prepared by the researcher based on Colab outputs

The short-term estimates recorded the following equations:

**At quantile 0.25**

$$Q_{0.25}(y_t | F_{t-1}) = \alpha_{0.25} + 0.000222\Delta ir_t - 0.412421\Delta cr_t + 0.000981\Delta tch_t + 0.259555\Delta m2_t + 0.000531\Delta ir_{t-1} - 0.009130\Delta cr_{t-1} + 0.345136\Delta cr_{t-2} - 0.084772\Delta cr_{t-3} - 0.213262\Delta m2_{t-1} + 0.001162\Delta m2_{t-2} + \hat{\epsilon}_{0.25,t}$$

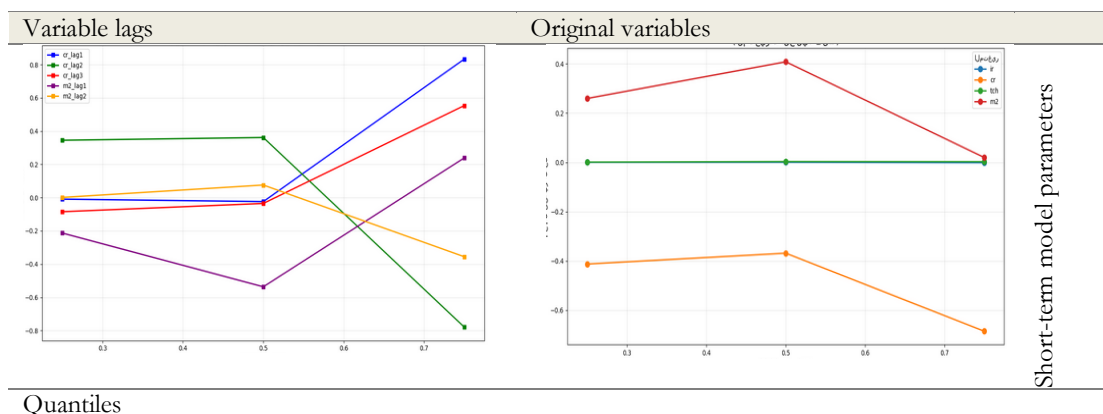
**At quantile 0.50**

$$Q_{0.50}(y_t | F_{t-1}) = \alpha_{0.50} + 0.000295\Delta ir_t - 0.368461\Delta cr_t + 0.003245\Delta tch_t + 0.408230\Delta m2_t - 0.000080\Delta ir_{t-1} - 0.023918\Delta cr_{t-1} + 0.361661\Delta cr_{t-2} - 0.035041\Delta cr_{t-3} - 0.536510\Delta m2_{t-1} + 0.075725\Delta m2_{t-2} + \hat{\alpha}_{0.50,t}$$

**At quantile 0.75**

$$Q_{0.75}(y_t | F_{t-1}) = \alpha_{0.75} - 0.001376\Delta ir_t - 0.685113\Delta cr_t + 0.002827\Delta tch_t + 0.019844\Delta m2_t - 0.001185\Delta ir_{t-1} + 0.833339\Delta cr_{t-1} - 0.779040\Delta cr_{t-2} + 0.553788\Delta cr_{t-3} + 0.238889\Delta m2_{t-1} - 0.355443\Delta m2_{t-2} + \hat{\alpha}_{0.75,t}$$

The table shows the dynamic variations: The tch coefficient is weakly positive at quantile 0.25 (0.000981) which reinforces low growth, and increases on average (0.003245) and at the upper end (0.002827), indicating short-term flexibility to currency fluctuations. while ir varies (positive in the lower, negative in the upper), indicating a regulatory role for interest rates, and cr shows a stable negative effect (-0.412 to -0.685) with positive lags in the upper (cr\_lag1: 0.833), reflecting the role of loans in stability, and m2 is positive in the lower and medium (0.259 to 0.408) but weak in the upper (0.019), with mostly negative lags, which limits monetary expansion. These results confirm the need for short-term policies tailored to different quantiles in the face of currency shocks. The distributions of short-term coefficients can be illustrated in the following figure:



**Figure 4: Long-term coefficients across quantiles**  
 Source: Prepared by researchers based on colab outputs

**QARDL model quality test**

**Ljung-Box Test**

Tests whether the residuals (errors) in the model follow a random pattern, or whether there is a correlation between errors over time (e.g., a previous effect influencing the current one), based on the

$$Q = n(n + 2) \sum_{k=1}^h \frac{\hat{\rho}_k^2}{n - k}$$

following equation:

(<https://uokerbala.edu.iq/wp-content/uploads/2022/06/Rp-Using-Box-Jenkins-models-for-analysis-Road-Accident-Fatalities-In-Holly-Karbala-for-the-period,p.60>) :

**Table 8: Ljung-Box Test**

Quantile	p-value	Result
0.25	0.179	Acceptable ( $p > 0.05$ ) $\rightarrow$ No serial correlation
0	0.063	Acceptable at 5% (but close to the limit)
0.	0.009	Rejected ( $p < 0.05$ ) $\rightarrow$ There is a serial correlation in the residuals

Source: Prepared by the researcher based on colab outputs

The model is good at low and medium quantiles, but at high quantiles (0.75) there is a problem with the residuals – the model may need additional lags or transformations.

#### **Heterogeneity test: (Breusch-Pagan Test)**

Tests whether the variance of the residuals is constant (homogeneity) or changes with the level of the variables and is based on the following equation:  $LM = n \cdot R^2 \sim \chi^2(k)$

**Table 9: Breusch-Pagan Test**

Quantile	p-value	Result
0.25	0.0009	Rejected → Heterogeneity
0.50	0.0085	Rejected → Heterogeneity
0.75	0.000	Rejected → Strong heterogeneity

**Source:** Prepared by the researcher based on colab outputs

The table shows that the model suffers from heterogeneity in all quantiles 0.25, 0.5, 0.75

#### **ARCH LM test for the QARDL model**

Tests for the presence of ARCH (time-varying variance) in the residuals – i.e., large shocks are followed by large shocks.

It is based on the following equation:  $LM = n \cdot R^2$  From the regression  $e_t^2 \quad e_{t-1}^2, \dots, e_{t-p}^2$   
(Wooldridge, 2009, pp. 433–435)

**Table 10: ARCH LM test for the QARDL model**

Quantile	p-value	Result
<b>0.25, 0.5, 0.75</b>	0.00	<b>Rejected → There is a very strong ARCH effect</b>

**Source:** Prepared by the researcher based on colab outputs

The table shows that the residuals exhibit clustered volatility

#### **Jarque–Bera normality test**

Tests whether the residuals follow a normal distribution and is based on the equation (Greene, 2017, pp. 78–79) :

**Table 11: Jarque–Bera test for the QARDL model**

Quantile	p-value	Result
0.25, 0.5, 0.75	0.00	Rejected → Residuals are not normal

**Source:** Prepared by the researcher based on colab outputs

The models do not follow a normal distribution, which does not pose a problem in quantile models

#### **Testing the shape and functional form of the model (RESET Test)**

Tests whether the model is correctly specified (no missing variables or neglected nonlinearities) and is based on the following equation:

**Table 12: RESET Test for the QARDL model**

Quantile	p-value	Result
<b>0.25</b>	0.5132	Acceptable
<b>0.50</b>	0.5092	Acceptable
<b>0.75</b>	0.5178	Acceptable

**Source:** Prepared by the researcher based on colab outputs

The table shows that the shape is correct and the estimate is accurate for all quantiles 0.25, 0.50, and 0.75.

### CUSUM and CUSUMSQ test:

This test examines the stability of QARDL coefficients over time, revealing nonlinear structural shocks.

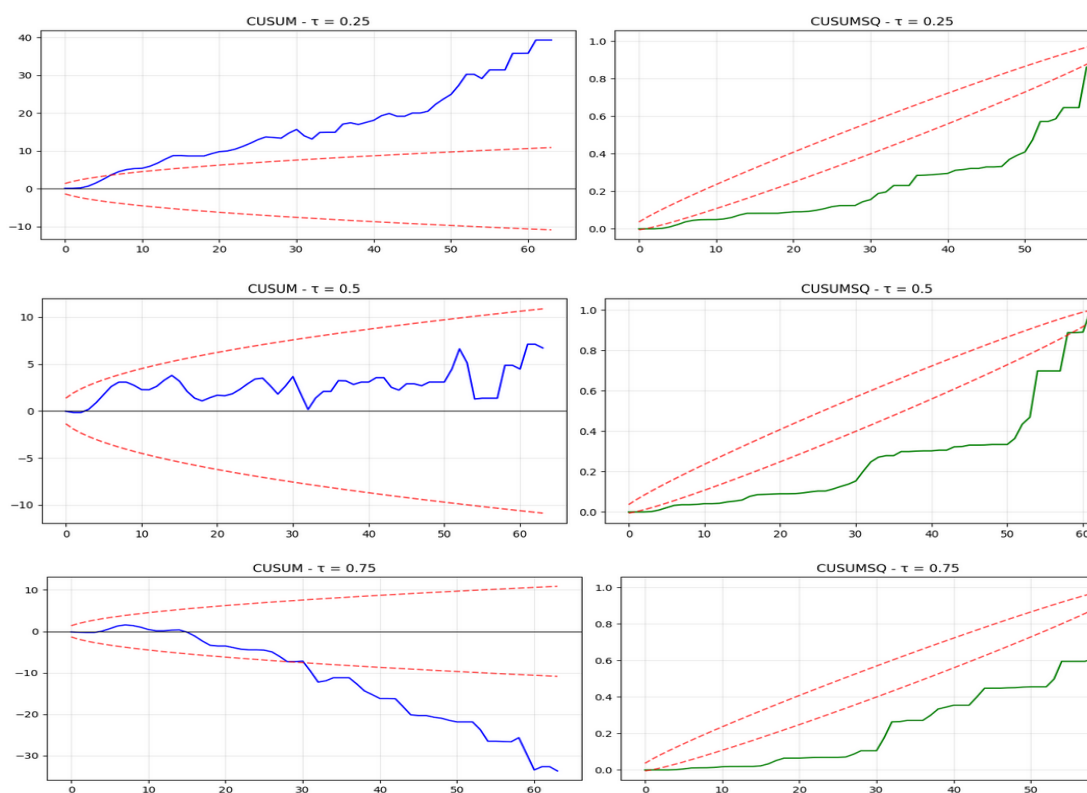
$$S_t = \frac{\sum_{i=1}^t w_i e_i}{\hat{\sigma}}, \quad w_i = \sqrt{\frac{i}{T}}$$

CUSUM is based on the following equation:

$$V_t = \frac{\sum_{i=1}^t \left( \frac{e_i^2}{\hat{\sigma}^2} - 1 \right)}{\sqrt{2T}}$$

on the equation:

. The results are shown in the following figures:



**Figure 5: CUSUM CUSUMSQ test for quantiles**

Source: Prepared by researchers based on COLAB outputs

The CUSUM and CUSUMSQ figures for quantiles 0.25 show stability in the mean and variance, with the blue line remaining within the red limits without exceeding them, and the green line remaining stable close to zero, reflecting the absence of structural shocks in low growth. For quantile 0.50, the blue line fluctuates slightly but returns within the limits, while the green line rises gradually without exceeding them, indicating moderate flexibility. For a quantile of 0.75, the blue line eventually falls within the limits, and the green line rises but remains conservative, confirming the stability of

transactions over time for upper growth. These results support the validity of the nonlinear QARDL model in the economic context.

### **Discussion**

This study sought to analyze the response of economic growth in Algeria to monetary policy instruments during the period 1990-2024, relying on the QARDL model, which allows for the observation of nonlinear variations across different growth situations. The results show that the effectiveness of monetary policy is not constant but varies according to the instrument used and the cyclical phase of the economy, whether in periods of recession, moderate growth, or boom. This reflects the nature of the Algerian economy, which is dependent on hydrocarbons and highly sensitive to external shocks and monetary fluctuations.

In the long term, the results showed a weak and asymmetric response to economic growth in relation to monetary policy instruments. The exchange rate channel had a negative and insignificant effect at the lower quantile of 0.25, with an exchange rate coefficient of 0.000021, which reflects its limited role in stimulating growth during periods of low economic performance, while the negative impact deepened in the medium quantile of 0.50 with a value of 0.000497, reaching its maximum in the high quantile of 0.75 with a value of 0.005430, indicating that exchange rate fluctuations weaken growth in periods of better economic performance. The interest rate channel also showed a stable negative effect across all quantiles, with real interest rate coefficients ranging between 0.000281 and 0.000711, reflecting its role in curbing investment and reducing the pace of growth in the long term. The results also showed that foreign reserves had a strong negative effect in the lower quantile of 1.039963, compared to a significant positive effect in the higher quantile of 2.167765. This highlights their regulatory role in supporting economic stability during periods of prosperity. Meanwhile, the money supply had a positive impact on the lower and medium quantiles, with values of 1.875340 and 1.843022, before turning negative in the high quantile with a value of 0.509211, indicating clear limits to monetary expansion in the long term.

In the short term, the results revealed greater flexibility for monetary policy instruments compared to the long term, with the exchange rate channel recording a positive effect across various quantiles, reaching 0.000981 in the 0.25 quantile, 0.003245 in the 0.50 quantile, and 0.002827 in the 0.75 quantile, reflecting the ability of exchange rate fluctuations to temporarily support growth by stimulating exports and reducing imports, with a pass-through of between 0.2 and 0.3 percent in non-crisis periods. Money supply also had a positive effect in the lower and middle quantiles, with values ranging between 0.259 and 0.408, confirming the role of expansionary monetary policy in mitigating the economic downturn in the short term, while its effect remained limited in the high quantile, not exceeding 0.019. The impact of loans was weak or negative in most short-term cases, reflecting the limited efficiency of the credit channel in supporting immediate growth.

In general, the results of the study confirm that the response of economic growth in Algeria to monetary policy instruments is characterized by temporal and structural asymmetry, with monetary policy being more effective in the short term, especially in periods of low growth, while its effectiveness declines in the long term due to dependence on oil shocks, exchange rate fluctuations, and the limited flexibility of the monetary framework. This calls for the adoption of monetary policies tailored to the state of economic growth, while strengthening the role of foreign reserves and developing financial markets, thereby allowing the growth rate to rise to between 3 and 4% in the medium term.

### **Conclusion**

The findings of this study indicate that the response of economic growth in Algeria to monetary policy instruments is inherently non-linear and asymmetric, reflecting a complex interaction between policy

tools, cyclical conditions, and structural characteristics of the economy. Monetary policy effectiveness is shown to be highly state-dependent, varying across different growth regimes, and remaining constrained in the long run by the economy's strong reliance on hydrocarbons and its exposure to external shocks. These structural features limit the ability of conventional monetary instruments to generate sustained growth effects over time. In this context, the results highlight the need for a more flexible and growth-contingent monetary policy framework, supported by stronger coordination with fiscal and structural policies. Enhancing the stabilizing role of foreign reserves, deepening financial markets, and improving the efficiency of monetary transmission channels appear essential to strengthening policy effectiveness. Furthermore, this study opens avenues for future research by encouraging the use of more advanced non-linear modeling approaches, the incorporation of institutional and structural variables, and comparative analyses with other resource-dependent economies, in order to develop a more comprehensive understanding of growth dynamics and macroeconomic stability in similar economic settings

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