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Modelling Non-Linearities and Asymmetries in Algerian Monetary Policy: Evidence from Extended Taylor Rules

Abstract. *This study investigates the determinants of the Money Market Rate (MMR) in Algeria, examining the role of the real exchange rate (RER), output gap, and consumer price index (CPI) within a nonlinear framework. Employing unit root tests, cointegration analysis, causality tests, quantile autoregressive distributed lag (QARDL) modelling, and multi-threshold nonlinear autoregressive distributed lag (MTNARDL) modelling, we analyse quarterly data from 2000 to 2021. The results indicate that while traditional Taylor Rule variables show limited influence on the MMR, the RER has a significant, heterogeneous, and asymmetric impact. Specifically, large changes in the RER positively affect the MMR in the long run, and both small-to-medium and large RER shocks influence the MMR in the short run. QARDL results also point to a nuanced monetary policy response, with inflation having a significant impact only when it is low and the output gap having a more significant effect at lower quantiles. Our findings underscore the need for Algerian monetary policy to focus on the magnitude of exchange rate fluctuations and to move beyond linear policy models. This study provides insights into the complex dynamics of monetary policy in a developing economy, highlighting the importance of considering asymmetries and nonlinearities.*

Keywords: *monetary policy, Taylor rule, exchange rate, nonlinearity, asymmetric effects, emerging economies, Algeria, QARDL, MTNARDL*

JEL Classification: C22, E17, E43, E52, E58.

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1. Introduction

Due to various economic and financial constraints, traditional models struggle to adequately depict emerging economy central banks. John Taylor (1993) developed the Taylor Rule to describe how central banks adjust interest rates in response to inflation and production gaps. This approach emphasises that inflation and output should influence policy interest rates and is commonly used to study central bank

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monetary policy. Furthermore, many central banks now target inflation, which has significantly impacted monetary policy in industrialised nations (Clarida et al., 1998).

However, the Taylor Rule was created for closed economies and does not account for the influence of exchange rates on inflation and production in open economies. To address this limitation, several researchers have expanded the Taylor Rule to include currency rates in monetary policy, particularly in emerging economies (Svensson, 2000). Add to that Exchange rate variations in open economies affect inflation, exports, and investment through import prices and competitiveness. For instance, Garcia et al. (2011) demonstrated that including exchange rates in monetary policy frameworks improves the mitigation of risk premium shocks. Empirical studies suggest that central bank policy reactions to inflation and production may be unequal. Bec et al. (2002) observed asymmetric monetary policy responses in the US, France, and Germany, indicating that central banks may react more strongly to positive deviations in inflation or production than to negative ones. To explore such nonlinearity, threshold models allow policy responses to vary depending on the magnitude of deviations (Caporale et al., 2018). Emerging economies, including Indonesia, South Korea, Israel, Thailand, and Turkey, have studied both linear and nonlinear applications of the Taylor Rule. Research in this area highlights that monetary policy responses differ depending on the inflation regime. As emerging nations adopt inflation-targeting strategies and integrate into the global financial system, Taylor Rule analysis has gained prominence.

Studies on the Taylor Rule in emerging economies are crucial for understanding how central banks respond to economic shocks and how their monetary policies influence macroeconomic stability. In Algeria's case, assessing the central bank's compliance with the Taylor Rule must consider the country's economic conditions and currency rate fluctuations. This study applies linear and nonlinear extended Taylor Rules to Algeria's monetary policy, with the exchange rate serving as a key variable (CHEDDAD & MEKIDICHE, 2024). The empirical findings will shed light on the central bank’s response function and its implications for macroeconomic stability.

2. Literature review

The Taylor Rule has been a fundamental tool for monetary policy since its introduction in 1993, offering a systematic framework for central banks to adjust interest rates based on inflation deviations and output gaps. Its simplicity and effectiveness have led to widespread adoption, particularly in stable economic environments (Orphanides, 2001). However, as economic conditions evolve, especially in open economies, modifications incorporating forward-looking elements and exchange rate variables have become necessary to address external shocks and financial instability. Empirical studies confirm the limitations of the traditional Taylor Rule, particularly in economies subject to exchange rate volatility.

Research has demonstrated that exchange rate-inclusive modifications enhance the rule's explanatory power in Mongolia, Indonesia, South Korea, Israel, and Thailand (Taguchi & Khishigjargal, 2018; Caporale et al., 2018).

Furthermore, hybrid approaches integrating forward- and backward-looking elements have proven helpful in capturing the dynamic interactions between past trends and future expectations in monetary policy decision-making (Taguchi & Wanasilp, 2018; Paranavithana et al., 2020). Despite these advancements, challenges remain, as some economies, such as Tunisia, do not conform to Taylor Rule predictions even when modified to include exchange rates (Lamia & Djelassi, 2020). These findings underscore the need for more tailored, nonlinear models to address different economies' diverse monetary policy challenges.

Research Gap

While the Taylor Rule remains a key benchmark for monetary policy, its traditional linear specification often fails to capture the complexities of developing economies, particularly those with structural characteristics such as oil dependence and managed exchange rates. While acknowledging the importance of exchange rates, existing research frequently overlooks their dynamic and asymmetric impact on monetary policy instruments. In the case of Algeria, there is a notable gap in empirical analysis using advanced econometric techniques, such as QARDL and MTNARDL, to fully assess central bank policy responses. This study fills this gap by moving beyond standard linear models, providing a nuanced analysis of the Algerian money market rate's nonlinear response to exchange rate fluctuations, and offering tailored policy recommendations suited to Algeria's specific economic context.

3. Model, data, and methodology

3.1 Data

We estimate the extended Taylor rule (forward-looking) in Algeria. The data were analysed from the first quarter of 2000 to the fourth quarter of 2021. Data on the Consumer Price Index (CPI) were collected, and the Money Market Rate (MMR) was used as a proxy for the interest rate. Additionally, nominal GDP (NGDP) was obtained from the World Bank and further processed into the output gap using the Hodrick-Prescott (HP) filter. The actual exchange rate was also included. All variables are described in Table 1.

Table 1. Sources of variables

	Variables	Data source (IMF/WB)
MMR	The money market rate	WB
CPI	General Consumer Price Index	WB
NGDP	nominal GDP	The GDP gap, or output gap, is further analysed using the Hodrick-Prescott filter.
rer_{t+k}	Real exchange rate	(IFS)

Source: Computed by the authors.

3.2 Methodology

The original Taylor Rule takes into account inflation's deviation from its target. Nevertheless, in practice, central banks tend not to target past or current inflation but rather expected inflation. Therefore, researchers (Clarida et al., 2000; Clarida et al., 1998) have proposed a forward-looking version of the Taylor Rule. This version allows the central bank to consider various relevant variables when calculating inflation expectations. The model proposed by Clarida et al. (2000) and Clarida et al. (1998) is expressed as follows:

$$MMR_t = \alpha_1 + \beta(\text{CPI}) + \delta(\text{OUTPUTGAP}) + \lambda(\text{RER}) + \mathcal{E}_t \quad (1)$$

- MMR_t: Short-term interest rate. (CPI) : Consumer Price Index. OUTPUTGAP: Output gap in period t. RER : Real exchange rate. $\mathcal{E}_t$: Error term.

4. Empirical findings

4.1 Descriptive statistics

The descriptive analysis highlights significant variability in key economic indicators during the observed period. While the positive mean output gap reflects an economy operating above potential, its high standard deviation points to cyclical fluctuations. The stability of the real exchange rate suggests effective exchange rate management, whereas the notable skewness and variability of the (MMR) imply interest rate volatility. Furthermore, the CPI statistics indicate moderate inflationary trends. These findings underscore the need for further analysis to understand these observed patterns' underlying dynamics and policy implications, shown in Table 2.

Table 2. Descriptive statistics

	MMR	CPI	OUTPUTGAP	RER
Mean	2,743141	108,9969	4,36E-09	101.113
Median	2,38613	101,8572	101,0885	100.396
Maximum	9,99346	172,2675	6102,005	125.712
Minimum	0,3125	69,53683	-10286,75	85.175
Std, Dev,	1,882781	29,80809	2764,619	8.694
Skewness	2,215867	0,414861	-0,597295	1014315
Kurtosis	8,905517	1,845483	4,872231	4.197
Jarque-Bera	199,8898	7,411613	18,08508	21.274
Probability	0	0,02458	0,000118	0.0000024
CV	68,6359542	27,3476493	6,34E+13	93.3655
Sum	241,3964	9591,73	3,84E-07	6.58E-85
Sum Sq, Dev,	308,4033	77301,45	6,65E+08	6879.075
Observations	92	92	92	92

Source: Computed by the authors.

Figure 1 shows the correlation matrix which reveals several key relationships among the variables studied. A strong negative correlation between (RER) and (CPI) suggests that inflationary pressures tend to weaken the currency. Similarly, a moderate negative correlation between the (MMR) and the CPI supports the effectiveness of higher interest rates in curbing inflation. Although there is a weak positive correlation between RER and the output gap, it suggests that other factors beyond domestic output fluctuations drive the real exchange rate. Despite these observations, the relationships are not causal, and further analysis is necessary to disentangle the underlying drivers and evaluate their policy implications.

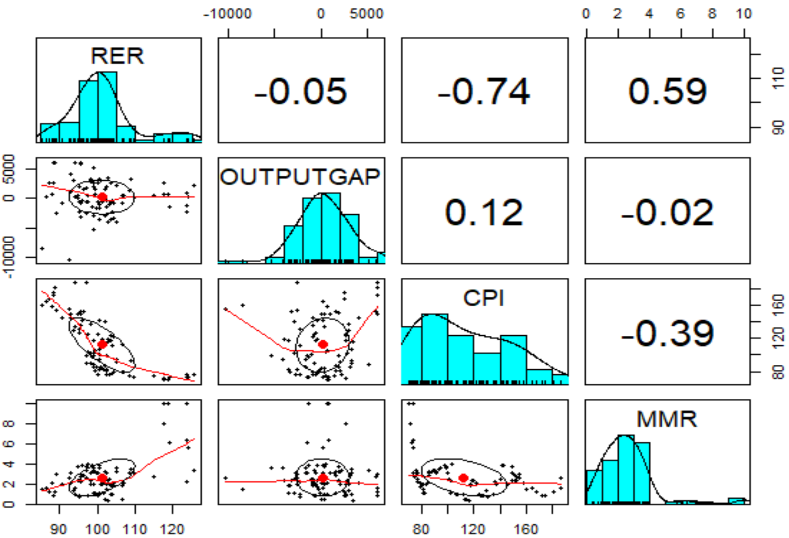

Figure 1. Correlation matrix
Source: Computed by the authors.

To address the potential issue of multicollinearity among independent variables, the Variance Inflation Factor (VIF) test was employed. The VIF values, as summarised in Table 3, indicate the degree of correlation among explanatory variables in the dataset. A VIF value of 1 denotes no multicollinearity, values between 1 and 5 indicate weak correlation, and values exceeding five signal a high degree of multicollinearity, which could undermine the robustness of the estimation results. The test results reveal that all variables exhibit VIF values below 5, indicating an absence of severe multicollinearity. This finding ensures the reliability of the regression analysis, as the independent variables are sufficiently uncorrelated to provide robust and unbiased estimates. Consequently, the dataset satisfies the multicollinearity diagnostic criteria, supporting the validity of subsequent econometric analyses.

Table 3. VIF test findings

Variables	VIF	1/VIF
CPI	2.23	0.449
RER	2.20	0.454
OUTPUTGAP	1.02	0.981
Mean VIF		1.81

Source: Computed by the authors.

4.2 Unit root test

Unit roots in time-series data pose significant challenges in econometric analysis, notably leading to spurious regression issues. Unit root tests are widely used to determine whether time series are stationary by examining the existence of unit roots. This study employs unit root test to ascertain the integration order of variables, with particular attention to structural breaks due to the inclusion of the 2008 financial crisis and the COVID-19 period in the analysis. The test utilises four distinct statistics, compared against asymptotic critical values. The results, summarised in Table 4, reveal mixed outcomes, with some series exhibiting unit roots. Nevertheless, all variables were found to become stationary at first differences. This finding supports the application of difference-stationary models in the econometric analysis while highlighting the importance of accounting for structural breaks during periods of economic turbulence.

Table 4. Unit root test results

VARIABLES	MZa	MZt	MSB	MPT
MMR	-0.770(0)	-0.497	0.645	22.878
$\Delta\ MMR$	-44.944 ***	-4.694 ***	0.104***	0.668***
CPI	3.019(4)	4.613	1.527	1.780
$\Delta\ CPI$	-21.544**	-3.914**	0.114**	3.914 **
OUTPUTGAP	-12.777(5)	-2.479	0.194	7.401
$\Delta\ OUTPUTGAP$	-24.223 ***	-3.889 ***	0.109 ***	1.099 **
RER	-17.323 (1)	-2.850	0.164	5.823
$\Delta\ RER$	-27.431 ***	-3.617 ***	0.131 ***	1.170 ***

Notes: (*) (**) (***) Significant at the 10%, 05%, 01%

Source: Computed by the authors.

4.3 Cointegration tests

Granger and Yoon (2002) introduce a nuanced definition of cointegration, describing it as the simultaneous response of data components to shocks, even when the variables do not exhibit direct cointegration. This special case of cointegration, illustrated through practical examples, underscores the potential for more accurate and holistic economic modelling. By analysing the cointegration of components, economists can uncover more profound insights into dynamic relationships between variables, thus enhancing forecasting capabilities. To empirically investigate cointegration in the presence of structural breaks, the Gregory and Hansen (1996) test was employed. The analysis, summarised in Table 05, examines four scenarios:

- Intercept changes (Break(level)): The ADF, Z_a, and Z_t statistics reveal no evidence of cointegration as the calculated values exceed the critical values.
- Trend changes (Break(trend)): The results indicate no cointegration under this scenario.
- Independent variable changes (Break(regime)): When structural breaks are introduced in the independent variables, the absence of cointegration persists.
- Changes in all parameters (Break(regime/trend)): Similarly, no cointegration is detected when all parameters, including the intercept, trend, and explanatory variables, exhibit structural breaks.

The findings highlight that no cointegration relationships exist across the tested scenarios, even when structural breaks are accounted for. These results suggest that dynamic interactions between the variables are not robust enough to establish a stable long-term equilibrium under the given conditions. Further analysis may require alternative models or data segmentation to capture potential relationships better.

Table 5. Cointegration tests

Model	Test	Statistic Value	Time Break
Break(level)	ADF	-5.54	2010Q03
	Z_t	-4.38	2011Q01
	Z_a	-26.10	2011Q01
Break(trend)	ADF	-4.51	2002Q01
	Z_t	-4.64	2002Q01
	Z_a	-31.31	2002Q01
Break(regime)	ADF	-4.51	2010Q01
	Z_t	-4.77	2003Q02
	Z_a	-34.22	2003Q02
Break(regime/trend)	ADF	-4.59	2008Q04
	Z_t	-4.39	2005Q02
	Z_a	-32.08	2005Q02

Source: Computed by the authors.

4.4 Causality test

Causality is a fundamental concept in economic analysis, essential for econometric modelling and policy evaluation. It investigates how changes in one variable influence another, emphasising the distinction between correlation and authentic causal relationships. Counterfactual analysis (Holland, 1986) provides a key framework for identifying causality by comparing observed outcomes with hypothetical scenarios. However, confounding variables often pose challenges by creating spurious correlations (Pearl, 2000). To address this, economists utilise various methodologies to isolate causal effects, including randomised experiments, statistical controls, and natural experiments. Despite these approaches, the identification problem persists due to the difficulty of directly observing counterfactuals, necessitating rigorous empirical techniques. This study employs the Hacker and Hatemi-J (2010) causality test, which improves causal inference through bootstrap techniques, providing robust estimations of critical values. This methodology enables a comprehensive examination of the dynamic causal relationships within the dataset, ensuring more reliable and statistically sound conclusions.

Table 6. Causality test

Hypothesis	Wald Test Statistic	Bootstrap critical Values		
		1 %	5 %	10 %
RER ---MMR	0.413	12.019	6.865	4.941
Outputgap ---MMR	0.333	9.066	4.366	2.679
CPI --- MMR	1.314	13.729	7.688	6.221

Source: Computed by the authors.

The results of the Wald test, summarised in Table 6, provide insight into the potential causal relationships among key variables. The null hypothesis of no causality from one variable to another cannot be rejected in any of the tested relationships:

- From the real exchange rate (RER) to the money market rate (MMR), the test statistic (0.413) does not reach significance, indicating no evidence of causality.
- From the output gap to MMR, the test statistic (0.333) similarly shows no evidence of a causal link.
- From the consumer price index (CPI) to MMR, the test statistic (1.314) also does not indicate causality.

The absence of causality in these tests suggests limited direct interactions among these variables within the tested framework. However, the findings highlight the need for deeper exploration, as causal dynamics may be sensitive to model specifications, underlying assumptions, and potential asymmetries in economic relationships.Additional causality tests, particularly those accounting for asymmetries, will be employed to advance the analysis. This approach will help investigate whether directional or nonlinear causal effects exist. In addition, including the economic context and theoretical frameworks will provide a more robust foundation for interpreting the mechanisms driving potential causal relationships. The statistical analysis presented in Table 07 investigates the causal effects of key economic variables on the (MMR) using the Wald test. The results highlight nuanced causal dynamics based on the direction of changes in the independent variables:

- (RER): Causality is identified from positive RER changes to positive MMR changes. However, adverse changes in the RER do not exhibit a causal relationship with either positive or negative changes in the MMR.

- Output Gap: A positive output gap demonstrates causality toward the MMR and positive changes in the MMR. Conversely, no causality is found from the output gap toward negative changes in the MMR.
- (CPI): The results do not show evidence of causality from CPI to MMR, regardless of the direction of changes.

These findings underscore the asymmetric nature of causal relationships among economic variables, where positive and negative changes yield distinct outcomes. The absence of causality from CPI to MMR may reflect a lack of direct interaction under the tested framework. At the same time, the directional influence of RER and Output Gap suggests that specific economic conditions amplify their impact on monetary policy dynamics. Further investigation is warranted to explore the underlying mechanisms driving these asymmetries.

Table 7. Findings from the test for asymmetric causality

Hypothesis	Wald Test Statistic	Bootstrap critical Values		
		1 %	5 %	10 %
RER (-) ---MMR	3.901	15.686	10.422	8.030
RER (+) ---MMR (+)	24.079***	21.457	13.540	10.480
RER (-) ---MMR (+)	14.631**	16.808	11.078	8.197
RER (+) ---MMR (-)	3.420	12.737	9.008	7.021
RER (-) ---MMR (-)	1.001	15.124	10.327	7.897
Outputgap (+) ---MMR	4.375	11.798	6.230	4.707
Outputgap (-) ---MMR	11.157**	14.048	8.327	6.501
Outputgap (+) ---MMR (+)	9.240**	10.165	6.338	4.888
Outputgap (-) ---MMR (+)	16.949**	17.252	10.486	7.739
Outputgap (+) ---MMR (-)	0.412	15.926	11.184	8.959
Outputgap (-) ---MMR (-)	0.707	15.615	10.072	7.823
CPI (+) --- MMR	2.474	18.512	11.859	9.755
CPI (-) --- MMR	4.288	13.554	8.834	7.274
CPI (-) --- MMR (+)	9.344	19.112	11.874	9.412
CPI (+) --- MMR (-)	2.338	13.651	8.979	6.908
CPI (-) --- MMR (-)	11.331	17.733	11.323	8.371

Notes: (*) (**) (***) Significant at the 10%, 05%, 01%

Source: Computed by the authors.

4.5 QARDL model

(QARDL) the model enhances the traditional ARDL approach by analysing the entire conditional distribution of the dependent variable rather than focusing solely on mean relationships (Kim & Shin, 2015). QARDL captures heterogeneous and nonlinear dynamics by estimating quantile-specific coefficients, making it particularly useful for economic data with outliers and skewness (Koenker & Bassett Jr., 1978). This methodology is essential for studying complex economic relationships where explanatory variables and shocks exert asymmetric effects across different quantiles.

$$Q_Y(\tau \mid X) = \beta_0(\tau) + \beta_1(\tau)X \quad (2)$$

Where: τ\tauτ represents the quantile level (0<τ<1).$Q_Y(\tau \mid X)$indicates the effect of Xon quantile Y. And $\beta_0(\tau), \beta_1(\tau)$ are quantile-specific coefficients.
Study Model Using Traditional ARDL:

$$MMR_t = \alpha_1 + \beta(\text{CPI}) + \delta(\text{OUTPUTGAP}) + \lambda(\text{RER}) + \varepsilon_t \quad (3)$$

Where: $\alpha_1 = r_t + \pi_t$ (4)

QARDL Model (Kwanbo et al., 2022):

$$MMR_t = \beta_0(\tau) + \beta_1(\tau)MMR_{t-1} + \beta_2(\tau)CPI_t + \beta_3(\tau)OUTPUTGAP_t + \beta_4(\tau)RER_t + \lambda_1(\tau)CPI_{t-1} + \lambda_2(\tau)OUTPUTGAP_{t-1} + \lambda_3(\tau)RER_{t-1} + \varepsilon_t \quad (5)$$

Where:β: Coefficients for current values of explanatory variables at quantile τ\tauτ. λ: Coefficients for lagged values of explanatory variables at quantile τ\tauτ.Ɛ: Error term at time t.

The QARDL model results (Table 08) reveal how the relationships between the Money Market Rate (MMR) and key variables – Consumer Price Index (CPI), Output Gap, and Real Exchange Rate (RER) – vary across the MMR distribution. Lagged MMR .$\boldsymbol{\beta_1(\tau)}$ is positive and significant across all quantiles, indicating consistent policy rate adjustments for stability. CPI $\boldsymbol{\beta_1(\tau)}$has a negative effect, significant only at lower quantiles (τ=0.25\tau = 0.25τ=0.25), reflecting the nuanced response of monetary policy to inflation. The Output Gap ($\boldsymbol{\beta_3(\tau)}$)shows a positive effect, significant at the lower quantile (τ=0.10\tau = 0.10τ=0.10), consistent with more substantial rate reductions during recessions. RER ($\boldsymbol{\beta_4(\tau)}$) is positively significant across all quantiles, suggesting its robust influence on MMR through exchange rate stabilisation or demand for domestic assets. Lagged CPI (λ1(τ)\lambda_1(\tau)λ1(τ)) is significant at lower quantiles, while lagged Output Gap and RER are insignificant throughout. These findings highlight the asymmetric effects of variables on MMR, emphasising stronger monetary responses during downturns and the critical role of exchange rate dynamics in policy adjustments.

Table 8. QARDL estimation results

Quantiles	τ 0.10	τ 0.25	τ 0.50	τ 0.75	τ 0.9
$\boldsymbol{\beta_0(\tau)}$	0.857 (0.270)	-7.229 (-2.010) **	-3.808 (-0.930)	-9.120 (-1.630)	-23.147 (-3.090) ***
$\boldsymbol{\beta_1(\tau)}$	0.735 (6.170) ***	0.815 (13.770) ***	0.917 (16.990) ***	0.924 (19.630) ***	0.906 (6.830) ***
$\boldsymbol{\beta_2(\tau)}$	-0.004 (-0.590)	0.008 (1.120) **	-0.003 (-0.380)	-0.000 (-0.040)	0.016 (1.000)
$\boldsymbol{\beta_3(\tau)}$	--1.650 (-0.030) **	-0.000 (-0.710)	-0.000 (-0.350)	-0.000 (-0.120)	-0.000 (-0.710)
$\boldsymbol{\beta_4(\tau)}$	0.005 (0.220)	0.079 (2.76) ***	0.065 (2.010) **	0.1266 (2.810) ***	0.257 (4.300) ***

Quantiles	τ 0.10	τ 0.25	τ 0.50	τ 0.75	τ 0.9
$\lambda_1(\tau)$	0.248 (1.710) *	0.131 (1.850) *	0.033 (0.510)	0.071 (1.250)	0.115 (0.710)
$\lambda_2(\tau)$	-0.000 (-0.590)	-8.492 (-0.260)	-0.000 (-0.710)	-2.585 (-0.100)	-0.000 (-0.740)
$\lambda_3(\tau)$	0.020 (0.280)	0.006 (0.170)	0.009 (0.280)	-0.014 (-0.520)	-0.032 (-0.400)
Note: Table shows quantile estimation findings. The t-statistics are bracketed. *, **, and *** show significance at 1%, 5%, and 10%.					

Notes: (*) (**) (***) Significant at the 10%, 05%, 01%

Source: Computed by the authors.

4.6 MTNARDL model

The methodology is closely related to the Nonlinear Autoregressive Distributed Lag (NARDL) model. Still, unlike the latter, which includes a single threshold of 0, the Multi-Threshold Nonlinear Autoregressive Distributed Lag (MTNARDL) model incorporates multiple thresholds that are calculated and integrated into the standard methodology. Developed by Pal and Mitra (2015), the MTNARDL model allows for the inclusion of various thresholds; in this study, we use three thresholds: 0.25, 0.5, and 0.75, selected based on sample size.For instance, in the relationship between exchange rates and economic growth, the NARDL model can only capture a single regime, assuming a positive or negative relationship. However, the MTNARDL model accommodates varying relationships, depending on the magnitude of the exchange rate. For example, a depreciation in the exchange rate may benefit growth up to a certain point, beyond which further depreciation becomes harmful. The MTNARDL model captures this nuanced relationship by identifying multiple regimes and estimating separate coefficients. Overall, the MTNARDL model provides a robust framework for analysing dynamic relationships between variables that exhibit nonlinearity or regime shifts (Pal & Mitra, 2016). It allows for the identification of multiple thresholds and captures varying responses of the dependent variable based on the magnitude of the independent variable. This makes the MTNARDL model particularly relevant for studying various economic phenomena, including policy interventions, structural changes, or other factors.

This study chose the real exchange rate (RER) variable for analysis across thresholds due to its substantial and statistically significant positive effect on the Money Market Rate (MMR), as revealed in the QARDL results. The impact of RER on MMR varies significantly across quantiles , indicating the potential for substantial effects on MMR. By analysing RER across thresholds, a deeper understanding of the RER-MMR relationship can be achieved, allowing for the identification of specific types of RER changes likely to influence MMR.

The key reasons for selecting RER for threshold analysis include:

- Asymmetric Effects: RER may have asymmetric effects on MMR. For example, a sudden increase in RER could reduce investment and production, indirectly influencing MMR. Conversely, prolonged increases in RER might have the opposite effect.
- Threshold Effects: The impact of RER on MMR may be nonlinear, with threshold effects indicating varying implications at different levels of RER.
- Period Effects: The effect of RER on MMR may differ across periods, requiring a segmented analysis.

This study aims to understand asymmetric effects, threshold impacts, and time-lagged influences by analysing RER across thresholds. Thus, the objective is to examine the asymmetric impacts of RER on MMR by decomposing RER into its positive and negative changes for further analysis.

$$RER_t^+ = \sum_{j=1}^{t} \Delta RER_t^+ = \sum_{j=1}^{t} MAX\ (\Delta RER_j, 0) \quad (6)$$

$$RER_t^+ = \sum_{j=1}^{t} \Delta RER_t^+ = \sum_{j=1}^{t} MAX\ (\Delta RER_j, 0) \quad (7)$$

$$RER_t = RER_0 + RER_t^+ + RER_t^- \quad (8)$$

We will use (MTNARDL) model with three thresholds corresponding to τ=0.25, τ=0.50, and τ=0.75, to obtain partial sum series (quantiles) at the 25th, 50th, and 75th percentiles, respectively, given that:

$$RER_t^i = RER_0^i + RER_t^i(\omega_1) + RER_t^i(\omega_2) + RER_t^i(\omega_3) + RER_t^i(\omega_4) \quad (9)$$

Calculated as follows:

$$RER_t^i(\omega_1) = \sum_{j=1}^{t} \Delta RER_j^i(\omega_1) = \sum_{j=1}^{t} \Delta RER_j^i\ I\left\{\Delta RER_j^i\ < \tau 25\right\} \quad (10)$$

$$RER_t^i(\omega_2) = \sum_{j=1}^{t} \Delta RER_j^i(\omega_2) = \sum_{j=1}^{t} \Delta RER_j^i\ I\left\{\tau 25\ < \Delta Q_j^i\ < \tau 50\right\} \quad (11)$$

$$RER_t^i(\omega_3) = \sum_{j=1}^{t} \Delta RER_j^i(\omega_3) = \sum_{j=1}^{t} \Delta RER_j^i\ I\left\{\tau 50\ < \Delta Q_j^i\ < \tau 75\right\} \quad (12)$$

$$RER_t^i(\omega_1) = \sum_{j=1}^{t} \Delta RER_j^i(\omega_1) = \sum_{j=1}^{t} \Delta RER_j^i\ I\left\{\Delta Q_j^i\ \geq \tau 75\right\} \quad (13)$$

- $\left\{\Delta RER_j^i\ < \tau 25\right\}$: This indicates that changes smaller than 0.25 are considered minor, representing the set of accumulations of less than 0.25 (25%).
- $\left\{\tau 25\ < \Delta Q_j^i\ < \tau 50\right\}$: Changes in the real exchange rate are greater than 0.25 but less than 0.50, representing moderately small changes.
- $\left\{\tau 50\ < \Delta Q_j^i\ < \tau 75\right\}$: Changes in the real exchange rate are greater than 0.50 but less than 0.75, representing moderate changes.
- $\left\{\Delta Q_j^i\ \geq \tau 75\right\}$: Changes in the real exchange rate are more significant than 0.75, representing large changes.

The MTNARDL model can be expressed as follows:

$$\Delta MMR_t = \varphi + \beta_1 MMR_{t-1} + \beta_2 CPI_{t-1} + \beta_3(\tau) OUTPUTGAP_{t-1} + \sum_{l=1}^{4} \beta_K\, RER_{t-1}^{i}(\omega_l) + \sum_{i=1}^{p} \gamma_{1i}\, \Delta MMR_{t-i} + \sum_{i=0}^{p} \gamma_{2i}\, \Delta CPI_{t-i} + \sum_{i=0}^{p} \gamma_{3i}\, \Delta OUTPUTGAP_{t-i} + \sum_{l=0}^{4} \sum_{i=0}^{p} \gamma_{ki}\, RER_{t-i}^{i}(\omega_l) + \varepsilon_t \quad (14)$$

This is evaluated using standard critical values, as proposed by Pesaran et al. (2001), with the null hypothesis defined as follows:

$$H_0: \beta_1 = \beta_2 = \beta_3 = \beta_4 = \beta_5 = \beta_6 = \beta_7 = 0 \quad (15)$$

Table 09 presents the long-run results of the MTNARDL. We observe a CPI effect of 0.025, which is statistically insignificant. Similarly, OUTPUTGAP has no short-run impact. Regarding RER, small and medium changes have no effect. However, large changes have a positive effect of 0.148

Table 9. Long-run results of the MTNARDL

Variables	**CPI**	**OUTPUTGA**	**RER (ω_1)**	**RER (ω_2)**	**RER (ω_3)**	**RER (ω_4)**
	0.027	0.000	-0.085	0.149	0.447	0.148*

Notes: (*) (**) (***) Significant at the 10%, 05%, 01%

Source: Computed by the authors.

The analysis confirms a cointegrating relationship between the real exchange rate (RER) and the money market rate (MMR), indicating their long-term interdependence. The Wald test reveals asymmetric effects, where both small and significant changes in RER positively influence MMR, with a stronger impact observed in the short run. Notably, a 1% increase in significant RER changes leads to a 0.148% rise in MMR in the long run, while small-to-medium RER changes have a larger short-run effect of 0.587%. These findings highlight the necessity of considering asymmetric dynamics when assessing monetary policy responses to exchange rate fluctuations.

Table 10. Short-run results of the MTNARDL

Variables	
$\Delta(CPI)$	-0.171***
$\Delta(outputgap)$	-0.045
$\Delta(outputgap) - 1$	-0.014***
$\Delta(RER(\omega_2))$	0.587**
$\Delta(RER(\omega_4))$	0.084*
Constant	-0.047
Fisher Bound test	5.602***
Student Bound test	-6.501***
LM test	1.047
ARCH test	0.331
CUSUM	S
CUSUM of Squares	S

Notes: (*) (**) (***) Significant at the 10%, 05%, 01%

Source: Computed by the authors.

5. Discussion

This study provides an in-depth analysis of the determinants of the Money Market Rate (MMR) in Algeria, emphasising the critical role of the real exchange rate (RER) alongside the output gap and consumer price index (CPI). By employing advanced econometric methodologies – including unit root tests, cointegration analysis, causality tests, quantile autoregressive distributed lag (QARDL) modelling, and multi-threshold nonlinear autoregressive distributed lag (MTNARDL) modelling – this research captures the nonlinear and asymmetric dynamics influencing Algerian monetary policy. The findings challenge the conventional application of the Taylor Rule in Algeria, as traditional variables such as the output gap and CPI exhibit a limited impact on the MMR. In contrast, the RER emerges as a key determinant, exerting significant and asymmetric effects. The absence of a robust long-term equilibrium among the variables suggests that Algeria's monetary environment is highly susceptible to external shocks, necessitating a more flexible and dynamic policy approach. Asymmetric causality tests confirm that positive RER and output gap fluctuations influence the MMR, reinforcing the need for models that account for nonlinear interactions. QARDL analysis further reveals heterogeneity in the monetary policy response across quantiles, with the RER consistently exerting a significant effect, while the CPI's influence is confined to low-inflation environments. The MTNARDL model underscores the importance of the magnitude of RER fluctuations, demonstrating that only substantial long-term changes significantly impact the MMR. In contrast, both moderate and significant short-term changes also play a role.

These results align with previous findings in the literature, notably those of Lamia and Djelassi (2020), who similarly argue that a linear Taylor Rule framework is insufficient to capture the complexities of monetary policy in Tunisia. The prominence of the RER as a determinant of the MMR is consistent with studies on open economies (Manogaran & Sek, 2016; Tawadros, 2020; Paranavithana et al., 2020), emphasising the need for policymakers to incorporate exchange rate dynamics into monetary decision-making. The asymmetric response of the Algerian central bank to inflation and the output gap further highlights the necessity of adaptive policy measures that consider both the magnitude and direction of economic shocks.In conclusion, this study underscores the importance of adopting nonlinear and dynamic approaches to monetary policy in Algeria. By integrating exchange rate considerations and accounting for asymmetric responses to inflation and economic fluctuations, policymakers can enhance the effectiveness of monetary interventions and mitigate vulnerabilities to external shocks.

Summary of Findings and Policy Implications

The findings of this study have significant implications for Algerian monetary policy, particularly in highlighting the critical role of exchange rate fluctuations. The results indicate that the money market rate is susceptible to exchange rate movements, both in magnitude and direction, suggesting that conventional models excluding exchange rate variables may be inadequate. Additionally, nonlinearities and asymmetries challenge the applicability of standard Taylor Rule frameworks, emphasising the need for policymakers to adopt dynamic models that account for these complexities. The study further underscores the limited impact of traditional determinants, such as inflation, in shaping monetary policy, reinforcing the necessity of incorporating external variables, especially exchange rate dynamics. Advanced econometric models, such as QARDL and MTNARDL, are recommended to enhance policy precision, refine monetary policy calibration, and ensure more targeted responses to economic fluctuations. Moreover, the evidence that positive output gap shocks lead to increases in the money market rate suggests that the Algerian central bank may actively adjust its policies to mitigate inflationary pressures during periods of economic expansion.

Limitations of the Study

While this study provides robust insights, we acknowledge some limitations:

- Data Period: Our analysis focused on a specific period (2000-2021). Recent structural changes or policy changes may have altered the dynamic relationships.
- Specific Country Context: Algeria is a unique economy relying on oil revenues and a complex exchange rate system. These findings may not be generalisable to other developing nations, thus highlighting the need to examine each country individually.

Future research could not address the potential issue of endogeneity. Directions Building on our findings, future research should explore the following:

- Longer and More Recent Data: Incorporating more recent data could capture possible changes after the COVID-19 pandemic and any new policy adjustments.
- Additional Macroeconomic Variables: Investigating the role of other relevant macroeconomic variables, such as fiscal policy measures or commodity prices.
- Alternative Model Specifications: Employing other nonlinear models, such as regime-switching or time-varying parameter models, could provide a deeper understanding of the relationships.

6. Conclusions

This study examined the determinants of the Money Market Rate (MMR) in Algeria, focusing on the real exchange rate (RER), output gap, and consumer price index (CPI) within a nonlinear and asymmetric framework. Utilising advanced econometric models such as QARDL and MTNARDL, the findings indicate that traditional Taylor Rule variables exert limited influence, while the RER emerges as a key driver of MMR fluctuations. Notably, no strong long-run equilibrium was identified, underscoring the Algerian economy’s vulnerability to external shocks.

The study highlights the importance of accounting for nonlinear and asymmetric relationships, particularly in the short run, where both moderate and substantial RER changes influence MMR, while only significant changes matter in the long run. These results challenge the applicability of a linear Taylor Rule in Algeria, aligning with previous findings from Tunisia. The study's key contribution lies in demonstrating that Algerian monetary policy is highly sensitive to exchange rate fluctuations, necessitating a more dynamic and adaptive policy approach. The asymmetric response of the central bank to inflation and the output gap further reinforces the need for models that capture the complexities of policy reactions. From a policy perspective, the findings suggest that Algerian monetary authorities should incorporate exchange rate dynamics into their decision-making process and reconsider reliance on standard linear frameworks. Additionally, addressing external shocks and refining policy calibration through a nuanced approach to the output gap could enhance inflation control. Despite its contributions, this study is subject to certain limitations, including the sample period (2000-2021) and unresolved endogeneity concerns. Future research should extend the dataset, account for potential endogeneity, explore additional macroeconomic variables, and adopt models that capture various forms of nonlinearity. Such advancements would further enhance the understanding of monetary policy dynamics in Algeria and similar developing economies, contributing to more effective macroeconomic stability strategies.

References

[1] Bec, F., Salem, M.B., Collard, F. (2002), *Asymmetries in monetary policy reaction function: evidence for US French and German central banks. Studies in Nonlinear Dynamics & Econometrics*, 6(2), https://doi.org/10.2202/1558-3708.1006.

[2] Beju, D-.G., Ciupac-Ulici, M.-L. (2015), *Taylor rule in emerging countries. Romanian case. Procedia Economics and Finance*, 32, 1122-1130, https://doi.org/10.1016/S2212-5671(15)01577-4.

[3] Caporale, G.M., Helmi, M.H., Çatık, A.N., Ali, F.M., Akdeniz, C. (2018), *Monetary policy rules in emerging countries: is there an augmented nonlinear TAYLOR rule? Economic Modelling*, 72, 306-319, https://doi.org/10.1016/j.econmod.2018.02.006.

[4] Castro, V. (2011), *Can central banks' monetary policy be described by a linear (augmented) Taylor rule or by a nonlinear rule? Journal of Financial Stability*, 7(4), 228-246, https://doi.org/10.1016/j.jfs.2010.06.002.

[5] Cheddad, A., Mekidiche, M. (2024), *Inflation targeting in Algeria: obstacles and opportunities. Economy of Ukraine*, 67(11), https://doi.org/10.15407/economyukr.2024.11.029.

[6] Clarida, R., Galı, J., Gertler, M. (1998), *Monetary policy rules in practice: Some international evidence. European Economic Review*, 42(6), 1033-1067, https://doi.org/10.1016/S0014-2921(98)00016-6.

[7] Garcia, C.J., Restrepo, J.E., Roger, S. (2011), *How much should inflation targeters care about the exchange rate? Journal of International Money and Finance*, 30(7), 1590-1617, https://doi.org/10.1016/j.jimonfin.2011.06.017.

[8] Granger C.W., Yoon G. (2002) *Hidden cointegration*. SSRN J, https://doi.org/10.2139/ssrn.313831.

[9] Holland, P.W. (1986), *Statistics and causal inference. Journal of the American statistical Association*, 81(396), 945-960, https://doi/abs/10.1080/01621459.1986. 10478354.

[10] Koenker, R., Bassett Jr, G. (1978), *Regression quantiles. Econometrica: Journal of the Econometric Society*, 33-50, https://doi.org/10.2307/1913643.

[11] Kwanbo, M.L., Ayuba, A., Tanko, M. (2022), *The moderating role of internal control system on the impact of tax revenue on economic growth in Nigeria [Article]. International Journal of Business and Globalisation*, 30(3-4), 429-443, https://doi.org/10.1504/IJBG.2022.123620.

[12] Lamia, B., Djelassi, M. (2020), *Is the Tunisian Central Bank following a Linear or a Nonlinear Augmented Taylor Rule? International Journal of Economics and Financial Issues*, 10(3), 69.

[13] Manogaran, L., Sek, S.K. (2016), *Can Taylor Rule be a Good Representation of Monetary Policy Function for ASEAN5. Indian Journal of Science and Technology*, 9(48), 1-9, doi: 10.17485/ijst/2016/v9i48/109305.

[14] Orphanides, A. (2001), *Monetary policy rules based on real-time data. American Economic Review*, 91(4), 964-98, https://doi.org/10.1257/aer.91.4.964.

[15] Pal, D., Mitra, S.K. (2015), *Asymmetric impact of crude price on oil product pricing in the United States: An application of multiple threshold nonlinear autoregressive distributed lag model. Economic Modelling*, 51, 436-443, https://doi.org/10.1016/j.econmod.2015.08.026.

[16] Paranavithana, H., Magnusson, L., Tyers, R. (2020), *Transitions to inflation targeting: panel evidence. Applied Economics*, 52(59), 6468-6481, https://doi.org/10.1080/00036846.2020.1796919.

[17] Pearl, J. (2000), *Causality: Models, reasoning, and inference*. Cambridge University Press, https://doi.org/10.1017/CBO9780511803161.

[18] Pesaran, M.H., Shin, Y., Smith, R.J. (2001), *Bounds testing approaches to the analysis of level relationships. Journal of Applied Econometrics*, 16(3), 289-326, https://doi.org/10.1002/jae.616.

[19] Svensson, L.E. (2000), *Open-economy inflation targeting. Journal of International Economics*, 50(1), 155-183, https://doi.org/10.1016/S0022-1996(98)00078-6.

[20] Svensson, L.E. (2003), *What is wrong with Taylor rules? Using judgment in monetary policy through targeting rules. Journal of Economic Literature*, 41(2), 426-477, https://doi.org/10.1257/002205103765762734.

[21] Taguchi, H., Khishigjargal, E. (2018), *Monetary policy rule under inflation targeting in Mongolia. East Asian Economic Review*, 22(4), 531-555, doi:10.11644/KIEP.EAER.2018.22.4.353.

[22] Taguchi, H., Tamegawa, K., Wanasilp, M. (2020), *Taylor principle under inflation targeting in emerging ASEAN economies: GMM and DSGE approaches. Bulletin of Applied Economics*, 7(2), 35-47, https://doi.org/10.47260/bae/723.

[23] Tawadros, G.B. (2020), *Does the Reserve Bank of Australia follow a forward-looking nonlinear monetary policy rule? Applied Economics*, 52(12), 1395-1408, https://doi.org/10.1080/00036846.2019.1673302.

[24] Taylor, J.B. (1993, December). *Discretion versus policy rules in practice*. In *Carnegie-Rochester conference series on public policy* (Vol. 39, pp. 195-214). North-Holland, https://doi.org/10.1016/0167-2231(93)90009-L.