



Simulating Banking Sector Dynamics in North Africa: Methodological Insights from DSGE Models

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ABSTRACT

North African economies face a structural policy paradox, in which bank-centric financial systems and persistent public-sector dominance complicate coordinating the monetary and fiscal instruments needed for price and debt stability. This study examines how fiscal-monetary interactions shape inflation, output, and debt dynamics in the region, and evaluates which Taylor rule specification best supports stability. We develop a small-scale open-economy DSGE model, extending the Galí and Monacelli (2008) framework with Calvo price rigidities, household heterogeneity, and a monopolistically competitive banking sector subject to capital and liquidity constraints, estimated using Bayesian methods on five macroeconomic observables for North Africa spanning 2000–2022, and compare a standard output-gap Taylor rule (Model 1) with a growth-augmented rule (Model 2). Posterior estimates indicate moderate price rigidity, averaging four quarters, and confirm a monetary dominance regime with active, inflation-responsive rates and substantial interest rate smoothing, while fiscal authorities remain passive and debt-focused. Contractionary monetary shocks generate persistent negative output gaps and crowd out government spending, whereas fiscal shocks produce procyclical, debt-sensitive responses depending on the prevailing monetary rule. The growth-augmented Taylor rule delivers stronger debt stabilization and smoother adjustment, indicating that anchoring policy to output growth improves fiscal-monetary coordination in North Africa.

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1 Introduction

North African economies are characterized by a complex interplay of structural rigidities: a pervasive public sector, bank-centric financial systems, and an inherent vulnerability to global volatility (IMF, 2023; Boughzala & Rouis, 2017). Within this context, the synergy between fiscal and monetary authorities is not merely a policy choice but a necessity for safeguarding price stability and debt sustainability (Leeper, 2021). While many regional frameworks have transitioned toward greater monetary flexibility, fiscal policy often remains the dominant stabilization lever, creating an asymmetrical policy mix frequently hampered by financial market frictions (Minea & Tapsoba, 2020).

Despite institutional reforms targeting central bank autonomy, the specter of "fiscal dominance" persists (Bianchi & Melosi, 2017). This creates a policy paradox: expansionary fiscal measures may jeopardize inflation targets, while aggressive monetary tightening risks inflating the cost of sovereign debt (Sargent & Wallace, 1981). Such misalignments often lead to "zero-sum" outcomes where the actions of one authority inadvertently neutralize the other (Acosta-Ormaechea et al., 2022).

Dynamic Stochastic General Equilibrium (DSGE) models provide the micro-founded rigor necessary to untangle these interdependencies (Smets & Wouters, 2003). For North Africa, these models are particularly vital for capturing the nuances of price stickiness and underdeveloped financial deepening (Ben Salem et al., 2024). Yet, the existing literature remains fragmented, often isolating fiscal or monetary tools rather than examining their combined equilibrium.

This study addresses this void by developing a tailored DSGE framework that internalizes the structural realities of North Africa. Our research aims to achieve four primary objectives:

1. **Examine** how the interactions between fiscal and monetary authorities dictate inflation and output dynamics.
2. **Evaluate** the efficacy of monetary policy when operating under divergent fiscal stances.
3. **Assess** the specific contribution of fiscal instruments to long-term debt sustainability.
4. **Analyze** the transmission mechanisms of exogenous shocks across the regional economy.

By focusing on the coordination dimension, this paper provides methodological insights into designing a policy mix that enhances macroeconomic resilience.

The remainder of this paper is organized as follows: **Section 2** details the model's structural components and the behavior of agents. **Section 3** outlines the Bayesian estimation procedure and data properties. **Section 4** presents the empirical findings and impulse response analysis, and **Section 5** concludes with policy implications and future research directions.

2. Stylized Facts and Literature Review

2.1. Macroeconomic Dynamics in North Africa

The North African economic landscape is defined by a heterogeneous mix of exchange rate regimes, spanning from managed pegs to nascent transitions toward inflation targeting (IMF, 2022). Within this framework, the Real Effective Exchange Rate (REER) emerges as a pivotal barometer of external competitiveness. Empirical evidence suggests that regional currencies exhibit heightened sensitivity to commodity price fluctuations and the volatility of the Euro-Dollar axis (World Bank, 2022). Such REER misalignments, often triggered by external shocks, create a precarious environment where fiscal and monetary policies must be tightly synchronized to prevent inflationary spirals and ensure sovereign debt sustainability (Leeper, 2021).

2.2. DSGE Frameworks and Financial Frictions

Early DSGE benchmarks (Smets & Wouters, 2003; Christiano et al., 2005) were primarily calibrated for advanced economies with mature financial markets. However, the unique challenges of emerging markets have necessitated the integration of financial frictions into the structural modeling process. In North Africa, where the financial system is predominantly bank-based, modeling the banking sector as an active intermediary—rather than a passive conduit—is indispensable (Gertler & Karadi, 2011). Recent regional studies (Ben Salem et al., 2024) underscore that banking frictions, specifically capital adequacy requirements and liquidity constraints, act as critical filters that fundamentally reshape the transmission mechanisms of monetary policy.

2.3. Identifying the Research Gap

A critical review of the existing literature reveals that most DSGE applications in the North African context are fragmented and country-specific, focusing on idiosyncratic cases like Algeria or Egypt in isolation. These studies often overlook the broader

methodological implications of the fiscal-monetary "nexus" and the shared structural vulnerabilities of the region. This paper bridges this gap by offering a unified and flexible open-economy framework. By internalizing banking sector dynamics and the nuances of policy coordination, our model provides a more robust lens through which to analyze the structural idiosyncrasies of North African economies.

3. The Model

- Households

The household sector in the model is composed of a continuum of agents, divided into **patient (savers)** and **impatient (borrowers)** households, reflecting heterogeneity in intertemporal preferences and access to credit.

Patient households

Patient households maximize expected lifetime utility from non-durable consumption c_t^P , housing h_t^P , and labor l_t^P , accounting for habit persistence and stochastic shocks:

$$\max E_0 \sum_{t=0}^{\infty} \beta_p^t \varepsilon_t^z \left[\log(c_t^P(i) - a^P c_{t-1}^P) + \varepsilon_t^h \log h_t^P(i) - \frac{(l_t^P(i))^{1+\varphi}}{1+\varphi} \right] \tag{1}$$

Their budget constraint is:

$$c_t^P(i) + q_t^h \Delta h_t^P(i) + d_t^P(i) \leq W_t^P l_t^P(i) \frac{(1+r_{t-1}^d)^{d_{t-1}^P(i)}}{\pi_t} + J_t^R + (1 - \omega^b) \frac{J_{t-1}^b}{\pi_t} + U_t(i) \tag{2}$$

where households allocate income between consumption, housing accumulation, and bank deposits, receiving wages, dividends, and other sources of income.

Impatient households

Impatient households value current consumption more than future consumption, and maximize:

$$\max E_0 \sum_{t=0}^{\infty} \beta_i^t \varepsilon_t^z \left[a^I \log(c_t^I(i) - a^I c_{t-1}^I) + \varepsilon_t^h \log h_t^I(i) - \frac{(l_t^I)^{1+\varphi}}{1+\varphi} \right] \tag{3}$$

subject to the budget constraint:

$$c_t^l(i) + q_t^h \Delta h_t^l(i) + (1 + r_t^{bH}) \frac{b_{t-1}^l(i)}{\pi_t} \leq W_t^l l_t^l(i) + b_t^{bH}(i) + T_t^l + U(i)_t \quad (4)$$

and borrowing limit:

$$\pi_{t+1} h_{t+1}^l q_{t+1}^h [E_t m_t^l] \leq i (b_t^l) r_t^{bH} (1 + \quad (5)$$

where credit is constrained by housing collateral (LTV ratio), linking household borrowing behavior to macro-prudential regulation.

Entrepreneurs

Entrepreneurs are a continuum of agents producing intermediate goods under perfect competition. They maximize lifetime utility from consumption c_t^E with habit formation:

$$E_0 \sum_{t=1}^{\infty} \beta_t^E \log(c_t^E(i) - a^E c_{t-1}^E) \quad (6)$$

They produce using capital k_{t-1}^E , labor l_t^E , and capital utilization u_t :

$$y_t^E(i) = a_t^E (k_{t-1}^E(i) u_t(i))^{\alpha E} l_t^E(i)^{1-\alpha E} \quad (7)$$

Their budget constraint is:

$$c_t^E(i) + W_t^P l_t^P + W_t^l l_t^l + \frac{(1 + i_{t-1}^{bE}) b_{t-1}^E(i)}{\pi_t} + q_t^k k_t^E(i) + \psi (u_t(i) k_{t-1}^E(i) = \frac{y_t^E(i)}{x_t} + b_t^E(i) + q_t^k (1 - \delta) k_{t-1}^E(i) \quad (8)$$

and borrowing is constrained by expected capital value:

$$(1 + r_t^{bE}) b_t^E \leq m_t^E E_t [q_{t+1}^k \pi_{t+1} (1 - \delta) k_t^E(i)] \quad (9)$$

Production depends on capital stock, labor input, and capital utilization, linking micro-level investment decisions to aggregate output.

Labor Market

The labor demand curve for a given type of labor is:

$$l_t^s(m) = \left(\frac{W_t^s(m)}{W_t^s} \right)^{-\varepsilon^l} l_t^s, \tag{10}$$

The aggregate wage is given by:

$$W_t^s = \left[\int_0^1 W_t^s(m)^{1-\varepsilon^l} d_m \right]^{\frac{1}{1-\varepsilon^l}} \tag{11}$$

Each union maximizes expected nominal wage utility:

$$E_0 \sum_{t=0}^{\infty} \beta_s^t \left\{ \left[u_{c_t^s(i,m)} \frac{W_t^s(m)}{P_t} l_t^s(i,m) - \frac{\kappa_w}{2} \left(\frac{W_t^s(m)}{W_{t-1}^s(m)} - \pi^{1-l_w} \right)^2 \frac{W_t^s}{P_t} \right] - \frac{i_t^s(i,m)^{1+\varphi}}{1+\varphi} \right\} \tag{12}$$

In equilibrium, labor supply follows a non-linear Phillips curve:

$$\kappa_w (\pi_t^{w^s} - \pi_{t-1}^{l_w} \pi^{1-l_w}) \pi_t^{w^s} = \beta_s E_t \left[\frac{\lambda_t^s + 1}{\lambda_t^s} \kappa_w (\pi_{t+1}^{w^s} - \pi_t^{l_w} \pi^{1-l_w}) \frac{(\pi_{t+1}^{w^s})^2}{\pi_{t+1}} \right] + (1 - \varepsilon^l) l_t^s + \frac{\varepsilon^l (l_t^s)^{1+\varphi}}{\omega_t^s \lambda_t^s} \tag{13}$$

This equation captures the dynamics of wage determination under unions, balancing current and expected wage adjustments, labor supply costs, and demand conditions.

Capital Goods Producers

Entrepreneurs also operate capital goods producing firms in a perfectly competitive market. These firms acquire previously installed capital at price Q_t^k and final goods at

price P_t to produce new capital for sale to entrepreneurs. The market price of capital is crucial for determining collateral values in entrepreneurial loans. Capital goods producers choose investment i_t to maximize expected profits:

$$E_0 \sum_{t=0}^{\infty} \Lambda_{0,t}^E (q_t^k (k_t - (1 - \delta)k_{t-1}) - i_t) \tag{14}$$

The transformation of final goods into new capital incurs quadratic adjustment costs:

$$k_t - (1 - \delta)k_{t-1} = \left[1 - \frac{\kappa_i}{2} \left(\frac{i_t \varepsilon_t^{qk(j)}}{i_{t-1}(j)} - 1 \right)^2 \right] i_t(j) \tag{15}$$

The first-order condition yields the real capital price equilibrium:

$$q_t^k \left[1 - \left(\frac{\kappa_i}{2} \frac{i_t \varepsilon_t^{qk}}{i_{t-1}} - 1 \right)^2 - \kappa_i \left(\frac{i_t \varepsilon_t^{qk}}{i_{t-1}} - 1 \right) \frac{i_t \varepsilon_t^{qk}}{i_{t-1}} \right] + \beta_E E_t \left[\frac{\lambda_{t+1}^E}{\lambda_t^E} q_{t+1}^k \varepsilon_t^{qk} + 1^{\kappa_i} \left(\frac{i_{t+1} \varepsilon_{t+1}^{qk}}{i_t} - 1 \right) \left(\frac{i_{t+1}}{i_t} \right)^2 \right] = 1 \tag{16}$$

This condition reflects dynamic investment decisions, considering current and expected future states of the economy, adjustment costs, and real capital values.

Loans and Demand Deposits of Households and Entrepreneurs

Deposit and loan contracts for households and entrepreneurs are assumed to consist of a range of differentiated financial products, each with a fixed substitution elasticity at the branch level.

Individual Loan Demand of Entrepreneurs

Consider an entrepreneur i who seeks a loan $b_t^E(i, j)$ from bank j . The total repayment due across all banks is:

$$\int_0^1 r_t^{bE}(j) b_t^E(i, j) dj \tag{17}$$

Aggregate Loan Demand

Using the Dixit-Stiglitz aggregation with elasticity $\varepsilon_t^{bE} > 1$, the total loan demand of entrepreneur i is:

$$\bar{b}_t^E(i) \leq \left[\int_0^1 b_t^E(i, j)^{\frac{\varepsilon_t^{bE}-1}{\varepsilon_t^{bE}}} dj \right]^{\frac{\varepsilon_t^{bE}}{\varepsilon_t^{bE}-1}} \quad (18)$$

where $\bar{b}_t^E(i)$ represents the **maximum total loan** required by entrepreneur i at time t , and ε_t^{bE} is the substitution elasticity across different banks.

Bank-Level Loan Allocation

Applying the first-order conditions across all entrepreneurs, the loan demand allocated to bank j is:

$$b_t^E(j) = \left(\frac{r_t^{bE}(j)}{r_t^{bE}} \right)^{-\varepsilon_t^{bE}} b_t^E \quad (19)$$

where r_t^{bE} is the average interest rate across banks.

Here, r_t^{bE} represents the average interest rate facing entrepreneurs, which is calculated by weighting the individual bank rates according to a constant elasticity of substitution (CES) specification:

$$r_t^{bE} = \left[\int_0^1 r_t^{bE}(j)^{1-\varepsilon_t^{bE}} dj \right]^{\frac{1}{1-\varepsilon_t^{bE}}} \quad (20)$$

Similarly, for impatient households, the demand for a specific loan product j is determined by:

$$b_t^I(j) = \left(\frac{r_t^{bH}(j)}{r_t^{bH}} \right)^{-\varepsilon_t^{bH}} b_t^I \quad (21)$$

with the corresponding average interest rate given by:

$$r_t^{bH} = \left[\int_0^1 dj \right]^{\frac{1}{1-\varepsilon_t^{bH}}} r_t^{bH} (j)^{1-\varepsilon_t^{bH}} \tag{22}$$

In this framework, the distribution of loan demand reflects the relative attractiveness of lenders and the ease with which borrowers can switch between them, as captured by the substitution elasticity ε_t^{bH} :

$$d_t^P(j) = \left(\frac{r_t^d(j)}{r_t^d} \right)^{-\varepsilon_t^d} d_t \tag{23}$$

denotes the deposit interest rate index, calculated as: r_t^d where

$$r_t^d = \left[\int_0^1 r_t^d(j)^{1-\varepsilon_t^d} dj \right]^{\frac{1}{1-\varepsilon_t^d}} \tag{24}$$

Producers of the Final Good

The problem of a firm producing final good $j \in (0,1)$ is to choose $P_t(j)$ in order to maximize expected profits:

$$E_0 \left[\sum_{t=0}^{\infty} \Lambda_{0,t}^P (P_t(j)y_t(j) - P_t^W(j)y_t^E(j) - \frac{\kappa_P}{2} \left(\frac{P_t(j)}{P_{t-1}(j)} - \pi_{t-1}^{1-\varphi} \right)^2) P_t y_t \right] \tag{25}$$

Consumer demand determines output for firm j :

$$y_t(j) = \left(\frac{P_t(j)}{P_t} \right)^{-\varepsilon_t^Y} y_t \tag{26}$$

Under symmetric equilibrium, the nonlinear Phillips curve is derived from the first-order conditions:

$$1 - \varepsilon_t^Y + \frac{\varepsilon_t^Y}{x_t} - \kappa_P (\pi_t - \pi_{t-1}^{1-\varphi}) \pi_t + \beta_P \left[\frac{\lambda_{t+1}^P}{\lambda_t^P} \kappa_P (\pi_{t+1} - \pi_t^{1-\varphi}) \frac{y_{t+1}}{y_t} \pi_{t+1} \right] = 0 \tag{26}$$

Finally, **profits of final goods producers** are given by:

$$\Pi_t^F = y_t \int_0^1 y_t(j) \frac{\varepsilon^y - 1}{\varepsilon^y} \frac{\varepsilon^y - 1}{\varepsilon^y} d_j - \int_0^1 p_t(j) y_t d_j \quad (27)$$

Π_t^F : net profits of final goods producers.

- ε^y : elasticity of substitution between intermediate and final goods.

Financial Intermediation

Banks operate in a monopolistically competitive environment, where their market power allows them to set prices below those dictated by monetary policy.

Capital Management

We assume bank capital is fixed in the short run, subject to depreciation at rate δ_b , and can only be accumulated through retained earnings from the previous period. In real terms, capital evolves as:

$$\pi_t K_t^b = (1 - \delta_b) K_{t-1}^b + J_{t-1}^b \quad (28)$$

Banks must also comply with **loan-to-value (LTV) constraints** and maintain high-liquidity assets (LCR_t). Loans granted to households and firms (B_t) are financed from bank capital (K_t^b) and household deposits (D_t):

$$B_t + LCR_t = K_t^b + D_t \quad (29)$$

This equality ensures that **total loans plus liquid assets** match the bank's **funding sources**.

The liquidity coverage ratio is determined as a fraction of deposits:

$$LCR_t = \tau_t^{LGR} D_t \quad (30)$$

- τ_t^{LCR} : regulatory fraction of deposits held as high-liquidity assets.

The **capital adjustment cost** is given by:

$$\frac{\kappa_{Kb}}{2} \left(\frac{K_t^b}{w_t B_t} - v^b \right)^2 K_t^b, \tag{31}$$

This term penalizes deviations of the bank’s actual capital ratio from the regulatory target, reflecting higher costs for larger deviations.

Dynamic Risk Sensitivity

Risk-sensitive factors can be incorporated dynamically, conditional on changes in a macroeconomic variable X_t :

$$W_t = (1 - \rho_\omega)w + \rho_\omega w_{t-1} + (1 - \rho_\omega)\chi_\omega (\log X_t - \log X_{t-4}) \tag{32}$$

Consequently, the bank’s problem in managing its capital structure involves choosing the optimal levels of loans B_t and deposits D_t to maximize the expected present value of its future cash flows, taking into account the stochastic discount factor of patient households $\Lambda_{0,t}^p$:

$$E_0 \sum_{t=0}^{\infty} \Lambda_{0,t}^p \left[(1 + R_t^b)B_t - B_{t+1} \pi_{t+1} + (1 + R_t^{LCR})LCR_t - \pi_{t+1} + D_{t+1} \pi_{t+1} - (1 + R_t^d)D_t + K_{t+1}^b \pi_{t+1} - K_t^b - \frac{\kappa_{Kb}}{2} \left(\frac{K_t^b}{w_t B_t} - v^b \right)^2 K_t^b \right] \tag{33}$$

Under the balance sheet constraints in equation (3.34) and given the applied from the capital management matrices and R_t^b , including the capture of R_t interest rates and t , substituting these returns evaluated at R_t^{LCR} the reward rate for high-liquid assets into the objective function leads to a concise matrix problem:

$$\max_{\{B_t, D_t\}} \left[R_t^b B_t + R_t^{LCR} LCR_t - R_t^d D_t - \frac{\kappa_{Kb}}{2} \left(\frac{K_t^b}{w_t B_t} - v^b \right)^2 K_t^b \right] \tag{34}$$

According to the deposits equation, total deposits can be expressed as:

$$D_t = \frac{B_t - K_t^b}{1 - \tau_t^{LCR}} \quad (35)$$

The first-order condition with respect to B_t , assuming a given K_t^b , provides the interest rate on bank assets in relation to deposits, LCR, and capital adjustments:

$$R_t^b = \frac{R_t^d - R_t^{LCR} \tau_t^{LCR}}{1 - \tau_t^{LCR}} - \frac{\kappa_{Kb}}{w_t} \left(\frac{K_t^b}{w_t B_t} - \nu^b \right) \left(\frac{K_t^b}{B_t} \right)^2 \quad (36)$$

Equation (3.37) illustrates how the lending rate R_t^b is determined by the interplay between deposit rates, returns on liquid assets, regulatory liquidity requirements, and the bank's deviation from its target capital ratio, reflecting the optimization of financial intermediation within a DSGE framework.

, the r_t Assuming that banks have unrestricted funding at the policy tool rate relationship can be expressed as:

$$R_t^b = \frac{r_t - R_t^{LCR} \tau_t^{LCR}}{1 - \tau_t^{LCR}} - \frac{\kappa_{Kb}}{w_t} \left(\frac{K_t^b}{w_t B_t} - \nu^b \right) \left(\frac{K_t^b}{B_t} \right)^2 \quad (37)$$

Equation (3.38) thus formalizes how banks' lending rates are determined by the policy rate, returns on liquid assets, taxation on LCR income, capital management costs, and capital utilization efficiency, within a DSGE framework.

If we assume that high-liquid assets earn a return equal to the policy rate ($r_t = R_t^{LCR}$), the equation simplifies to:

$$R_t^b = r_t - \frac{\kappa_{Kb}}{w_t} \left(\frac{K_t^b}{w_t B_t} - \nu^b \right) \left(\frac{K_t^b}{B_t} \right)^2 \quad (38)$$

Deposit Agreements

Banks are responsible for deposit pricing, collecting deposits from patient households $d_t^p(j)$ at interest rate $r_t^d(j)$ and converting these resources into returns r_t . Banks also face a quadratic adjustment cost on changes in deposit rates, represented by the parameter κ_d . The deposit problem for bank j can be expressed as:

$$\max_{\{r_t^d(j)\}} E_0 \sum_{t=0}^{\infty} \Lambda_{0,t}^p \left[r_t D_t(j) - r_t^d(j) d_t^p(j) - \frac{\kappa_d}{2} \left(\frac{r_t^d(j)}{r_{t-1}^d(j)} - 1 \right)^2 r_t d_t \right] \quad (39)$$

The **first-order condition** with respect to deposit rates is:

$$-1 + \epsilon_t^d - \epsilon_t^d r_t r_t^d - \kappa_d \left(\frac{r_t^d}{r_{t-1}^d} - 1 \right) \frac{r_t^d}{r_{t-1}^d} + \beta^p E_t \left[\frac{\lambda_{t+1}^p}{\lambda_t^p} \kappa_d \left(\frac{r_{t+1}^d}{r_t^d} - 1 \right) \left(\frac{r_{t+1}^d}{r_t^d} \right)^2 \frac{d_{t+1}}{d_t} \right] = 0 \quad (41)$$

Optimal Deposit Rate

Equation (3.42) represents the first-order condition for the optimal deposit rate in the model. It balances the expected change in the deposit rate, penalties for deviations from past rates, and the discounting of future periods. The linearized version is given by:

$$\hat{r}_t^d = \frac{\kappa_d \hat{r}_{t-1}^d}{\epsilon_d - 1 + (1 + \beta_p) \kappa_d} + \frac{\beta_p \kappa_d E_t [\hat{r}_{t+1}^d]}{\epsilon_d - 1 + (1 + \beta_p) \kappa_d} + \frac{(\epsilon^d - 1) \bar{R}_t^d}{\epsilon_d - 1 + (1 + \beta_p) \kappa_d} - \frac{\hat{\epsilon}_t^d}{\epsilon_d - 1 + (1 + \beta_p) \kappa_d} \quad (40)$$

Banks determine deposit rates based on current conditions and future expectations, including the policy rate $R_t^d = r_t$, while balancing adjustment costs and competitive pressure among deposit branches. In the steady state, higher competition (lower ϵ^d) leads to more flexible rates, whereas with zero adjustment costs ($\kappa_d = 0$), rates fully adjust to market conditions.

Deposit Rates and Monetary Policy

Equation (3.43) illustrates the relationship between deposit rates and the policy rate set by the central bank. It shows how banks determine deposit rates within a broader economic context, specifically based on the policy rate:

$$r_t^d = \frac{\epsilon_t^d}{\epsilon_t^d - 1} r_t \quad (41)$$

Loan Agreements

Loan agreements refer to contracts between banks and impatient households (b_t^I) and entrepreneurs (b_t^E). Banks collect resources B_t at a cost R_t^b and act as intermediaries, setting loan rates for both households and entrepreneurs. For bank branch j , the optimization problem is:

$$E_0 \sum_{t=0}^{\infty} \Lambda_{0,t}^p \left[r_t^{bH}(j) b_t^I(j) + r_t^{bE}(j) b_t^E(j) - R_t^b B_t(j) - \frac{\kappa_{bH}}{2} \left(\frac{r_t^{bH}(j)}{r_{t-1}^{bH}(j)} - 1 \right)^2 r_t^{bH} b_t^I - \frac{\kappa_{bE}}{2} \left(\frac{r_t^{bE}(j)}{r_{t-1}^{bE}(j)} - 1 \right)^2 r_t^{bE} b_t^E \right] \quad (42)$$

The **first-order condition** for the household loan rate is given by:

$$-1 + \varepsilon_t^{bH} - \varepsilon_t^{bH} \frac{R_t^b}{r_t^{bH}} - \kappa_{bH} \left(\frac{r_t^{bH}}{r_{t-1}^{bH}} - 1 \right) \frac{r_t^{bH}}{r_{t-1}^{bH}} \beta^p E_t \left\{ \frac{\lambda_{t+1}^p}{\lambda_{t+1}^p} \kappa_{bH} \left(\frac{r_{t+1}^{bH}}{r_t^{bH}} - 1 \right) \left(\frac{r_{t+1}^{bH}}{r_t^{bH}} \right)^2 \frac{b_{t+1}^I}{b_t^I} \right\} = 0 \quad (43)$$

The equation balances the marginal revenue from increasing loans with the costs of adjustment and future expectations, reflecting optimal loan pricing in a DSGE framework.

Loan Rate Dynamics

The evolution of loan rates in the banking sector reflects the expected discounted future changes in interest rates for impatient households, incorporating marginal utility of consumption, quadratic adjustment costs, and the ratio of future to current real interest rates, as well as households' borrowing behavior. The linearized version of the household loan rate is given by:

$$\hat{r}_t^{bH} = \frac{\kappa_{bH} \hat{r}_{t-1}^{bH}}{\varepsilon_{bH} - 1 + (1 + \beta_p) \kappa_{bH}} + \frac{\beta_p \kappa_{bH} E_t [\hat{r}_{t+1}^{bH}]}{\varepsilon_{bH} - 1 + (1 + \beta_p) \kappa_{bH}} + \frac{(\varepsilon_{bH} - 1) \hat{R}_t^b}{\varepsilon_{bH} - 1 + (1 + \beta_p) \kappa_{bH}} - \frac{\hat{\varepsilon}_t^{bH}}{\varepsilon_{bH} - 1 + (1 + \beta_p) \kappa_{bH}} \quad (44)$$

Loan amounts are determined by collateral values and current expectations of shocks, while profit margins are influenced by the monetary policy rate and capital adjustment costs. Adjustments in loan rates are inversely proportional to the adjustment cost (κ_{bH})

and positively related to competition among banks for impatient households ($1/\epsilon_t^{bH}$). In the case of flexible rates ($\kappa_{bH} = 0$), the household loan rate simplifies to:

$$r_t^{bH} = \frac{\epsilon_t^{bH}}{\epsilon_t^{bH} - 1} R_t^b \quad (45)$$

Similarly, for entrepreneurs, the linearized loan rate dynamics are:

$$\hat{r}_t^{bE} = \frac{\kappa_{bE} \hat{r}_{t-1}^{bE}}{\epsilon_{bE} - 1 + (1 + \beta_p) \kappa_{bE}} + \frac{\beta_p \kappa_{bE} E_t [\hat{r}_{t+1}^{bE}]}{\epsilon_{bE} - 1 + (1 + \beta_p) \kappa_{bE}} + \frac{(\epsilon_{bE} - 1) \hat{R}_t^b}{\epsilon_{bE} - 1 + (1 + \beta_p) \kappa_{bE}} - \frac{\hat{\epsilon}_t^{bE}}{\epsilon_{bE} - 1 + (1 + \beta_p) \kappa_{bE}} \quad (46)$$

Which reduces to the steady-state form under flexible rates ($\kappa_{bE} = 0$):

$$r_t^{bE} = \frac{\epsilon_t^{bE}}{\epsilon_t^{bE} - 1} R_t^b \quad (47)$$

Bank Profits

Bank profits are determined by the difference between asset and liability operations, net of capital adjustment costs and other adjustment costs related to changes in deposit and loan rates A_j^B . The profit of bank j at time t is defined as:

$$J_t^b = r_t^{bH} b_t^H + r_t^{bE} - r_t^d dt - A_j^B \quad (50)$$

Equation (3.50) captures bank profits by considering interest income from loans, subtracting interest expenses on deposits, and incorporating the effect of banking lending activities on overall economic activity.

External Shocks

External shocks represent factors outside the model that impact the economy but are exogenous to the model dynamics. These shocks are modeled as stochastic processes around a steady-state value:

$$\varepsilon_t^s = (1 - \rho_s) \varepsilon_t^s + \rho_s \varepsilon_{t-1}^s + \zeta_t^s \quad (48)$$

Market Equilibrium

The equilibrium in the final goods market is defined by the following equation:

$$y_t = c_t + q_t^k [k_t - (1 - \delta)k_{t-1}] + \psi(u_t)k_{t-1} + \delta^b K_{t-1}^b \pi_t + A j_t, \quad (49)$$

Equation (3.52) represents the market-clearing condition where total output equals the sum of consumption, net investment in capital, adjustment costs from capital utilization, and other adjustment costs. This ensures that all produced goods are fully accounted for in their uses and costs.

Monetary Policy

Monetary policy is modeled using a Taylor-type rule, specifying how the nominal interest rate set by the central bank responds to deviations in inflation and output:

$$(1 + r_t) = (1 + r) (1 - \phi_R) \left(\frac{\pi_t}{\pi}\right)^{\phi_\pi (1 - \phi_R)} \left(\frac{y_t}{y_{t-1}}\right)^{\phi_y (1 - \phi_R)} (1 + r_{t-1})^{\phi_R} \varepsilon_t^r \quad (50)$$

4. Empirical Strategy: Bayesian Estimation

4.1. The Bayesian Approach

To bridge the gap between theoretical abstraction and empirical reality, this study employs Bayesian estimation. This methodology is particularly advantageous in the context of North African economies, as it effectively addresses the constraints of relatively short data samples while allowing for the integration of "prior" regional knowledge to sharpen posterior inferences. Unlike traditional frequentist methods, the Bayesian approach provides a robust framework for reconciling the model's micro-foundations with the observed volatility of the region.

4.2. Data Transformation and Stationarity

The model is estimated using five key macroeconomic observables (2000–2022) reflecting the North African structural context: GDP growth, inflation, nominal interest rates, the debt-to-GDP ratio, and the output gap. To ensure stationarity and alignment with the DSGE framework’s requirements, all non-stationary series were transformed using first-differences or the Hodrick-Prescott (HP) filter where appropriate.

Table 1: Prior Distribution of Structural Parameters and Shock Variances

Parameter	Description	Mean	Distribution	Std. Dev.
β_a	AR coefficient of technology	0.80	Beta	0.10
β_c	AR coefficient of foreign consumption	0.30	Beta	0.05
θ	Degree of price rigidity	0.50	Beta	0.10
ψ	Risk aversion coefficient	1.00	Normal	0.75
ϑ	Inverse of labor supply elasticity	2.50	Gamma	0.50
φ_π	Taylor rule coefficient for inflation	1.50	Gamma	0.50
φ_y	Taylor rule coefficient for output gap	0.30	Gamma	0.10
η	Price adjustment lag (Calvo)	0.75	Beta	0.02
φ_r	Interest rate smoothing	0.70	Beta	0.10
γ_r	Government expenditure smoothing	0.50	Beta	0.10
γ_τ	Tax rate smoothing	0.50	Beta	0.10
g_y	Coefficient on lagged output gap	0.10	Normal	0.10
g_b	Government debt feedback coefficient	-0.02	Normal	0.10
τ_r	Tax coefficient on lagged output gap	0.10	Normal	0.10
τ_b	Tax coefficient on government debt	0.04	Normal	0.03
r_t	Standard deviation of nominal interest rate	0.20	Inverse Gamma	Inf
g_t	Standard deviation of government spending	0.30	Inverse Gamma	Inf
τ_t	Standard deviation of government tax revenue	0.50	Inverse Gamma	Inf
a_t	Standard deviation of technology shock	0.45	Inverse Gamma	Inf
c_t	Standard deviation of foreign consumption shock	0.25	Inverse Gamma	Inf
π_{Dt}	Standard deviation of domestic inflation	0.25	Inverse Gamma	Inf

source: Own elaboration.

Note: Std. Dev. = Standard Deviation; Inf = theoretically unbounded for inverse gamma parameters

The structural parameters are calibrated to reflect the average macroeconomic ratios in North African economies (2000–2024). The discount factor β is set at 0.99, and the degree of openness φ_y is 0.30, matching the region's import-to-GDP average. Price rigidities follow the Calvo (1983) mechanism, with $\eta = 0.75$, implying an average contract duration of four quarters.

5. Results and Discussion

5.1. MCMC Diagnostics and Convergence

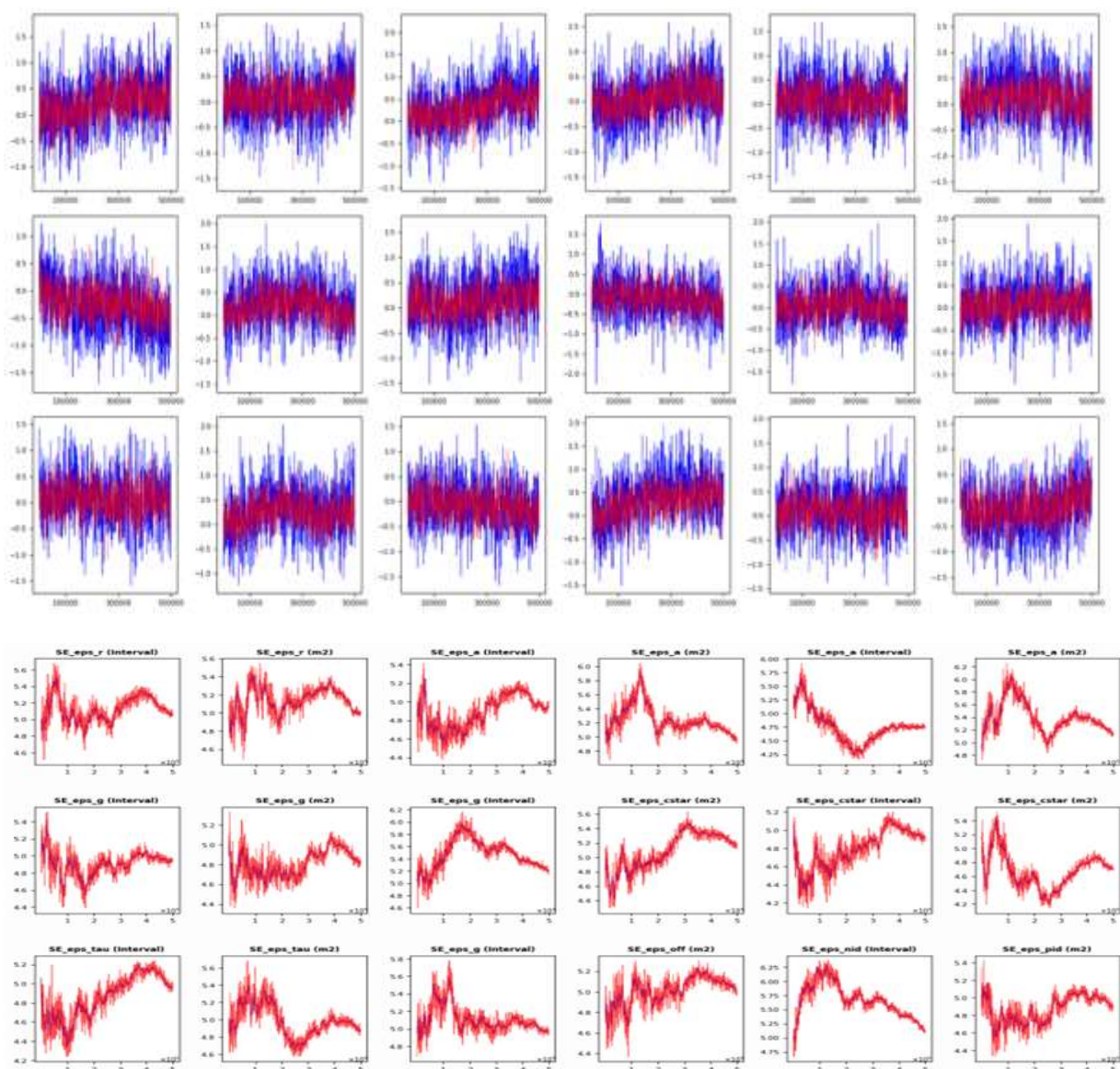
Before analyzing the model's economic implications, we evaluate the reliability of the Bayesian estimation through Markov Chain Monte Carlo (MCMC) diagnostics. Figure 1 presents the univariate MCMC trace plots, while Figure 2 displays the Brooks and Gelman (1998) convergence diagnostics.

As illustrated in **Figure 1**, the convergence of the red and blue lines (representing within-chain and pooled variances) toward a stable, horizontal plane indicates that the MCMC chains have successfully explored the posterior distribution. This stability ensures that the posterior mean estimates are reliable and not sensitive to initial conditions.

5.1.1. Historical and Smoothed Variables

Figure 1 illustrates the historical and smoothed series for the observed variables. The smoothed estimates represent the optimal inference of the latent state variables given the full information set of the sample, computed via the Kalman Smoother evaluated at the posterior mean. In this estimation, the observed and smoothed trajectories align closely, a result that underscores the model's structural integrity. By omitting measurement errors in the observation equations, the model's structural shocks effectively capture the historical dynamics of North African economies, ensuring the state-space representation honors the empirical data without the need for residual noise adjustments.

Figure 1 Univariate MCMC Diagnostics for Model 1



Source: Author's estimation based on Dynare simulation results.

The choice of Inverse Gamma distributions for the shock variances ensures positivity and reflects our prior uncertainty regarding the magnitude of structural shocks in a volatile regional environment.

5.1.2 Estimation Results and Model Fit

The Bayesian estimation of Model 1 demonstrates high data informativeness, with posterior distributions significantly more concentrated than their priors. The Metropolis-Hastings acceptance rate of 0.28 falls within the optimal 0.20–0.40 range, ensuring efficient subspace exploration.

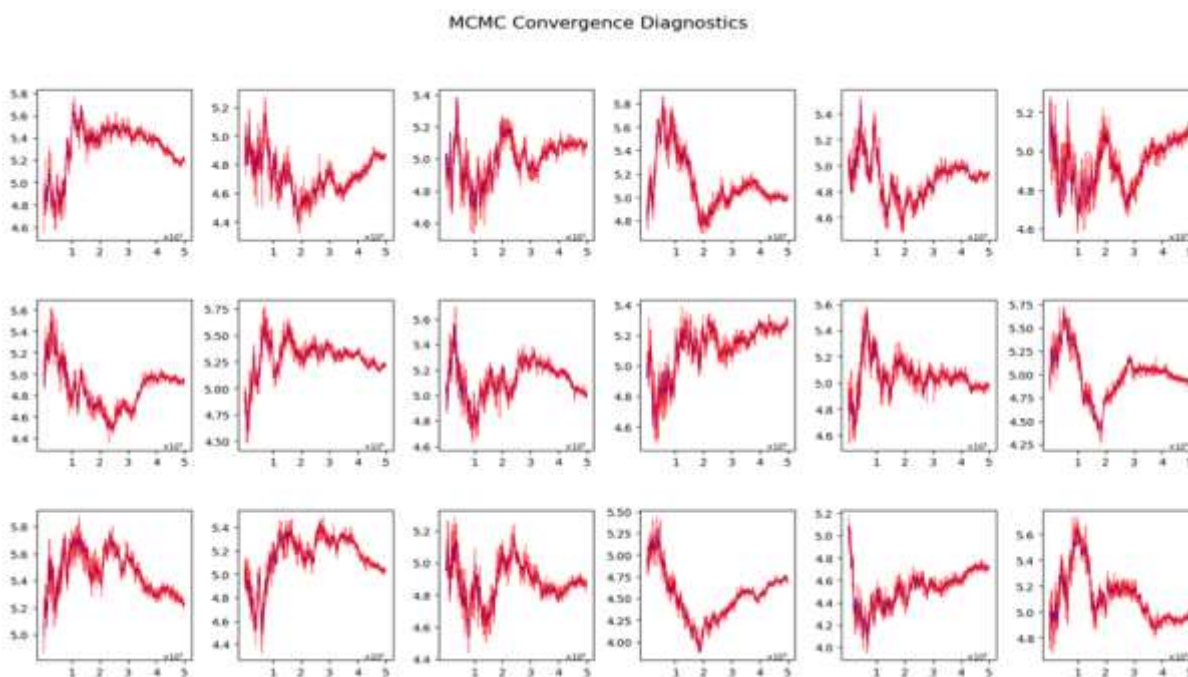
5.1.3 Structural Parameters and Policy Rules

The results reveal moderate price rigidity in North Africa. The Calvo parameter ($\theta = 0.48$) suggests an average price duration of four quarters, while high indexation ($\eta = 0.74$) reflects a significant backward-looking component in inflation. The estimates confirm a "Monetary Dominance" regime, where the authority follows an active rule with high interest rate smoothing ($\varphi_{\pi} = 0.77$) and a strong inflation response ($\varphi_{\pi} = 1.46$). Conversely, fiscal policy is "passive," primarily focused on debt stabilization.

5.1.4 MCMC Convergence Diagnostics

To ensure robustness, the model was estimated using 500,000 MH draws. Following Brooks and Gelman (1998), convergence was confirmed by monitoring within-chain and between-chain variances.

Figure 2: Univariate MCMC Diagnostics (Brooks-Gelman)



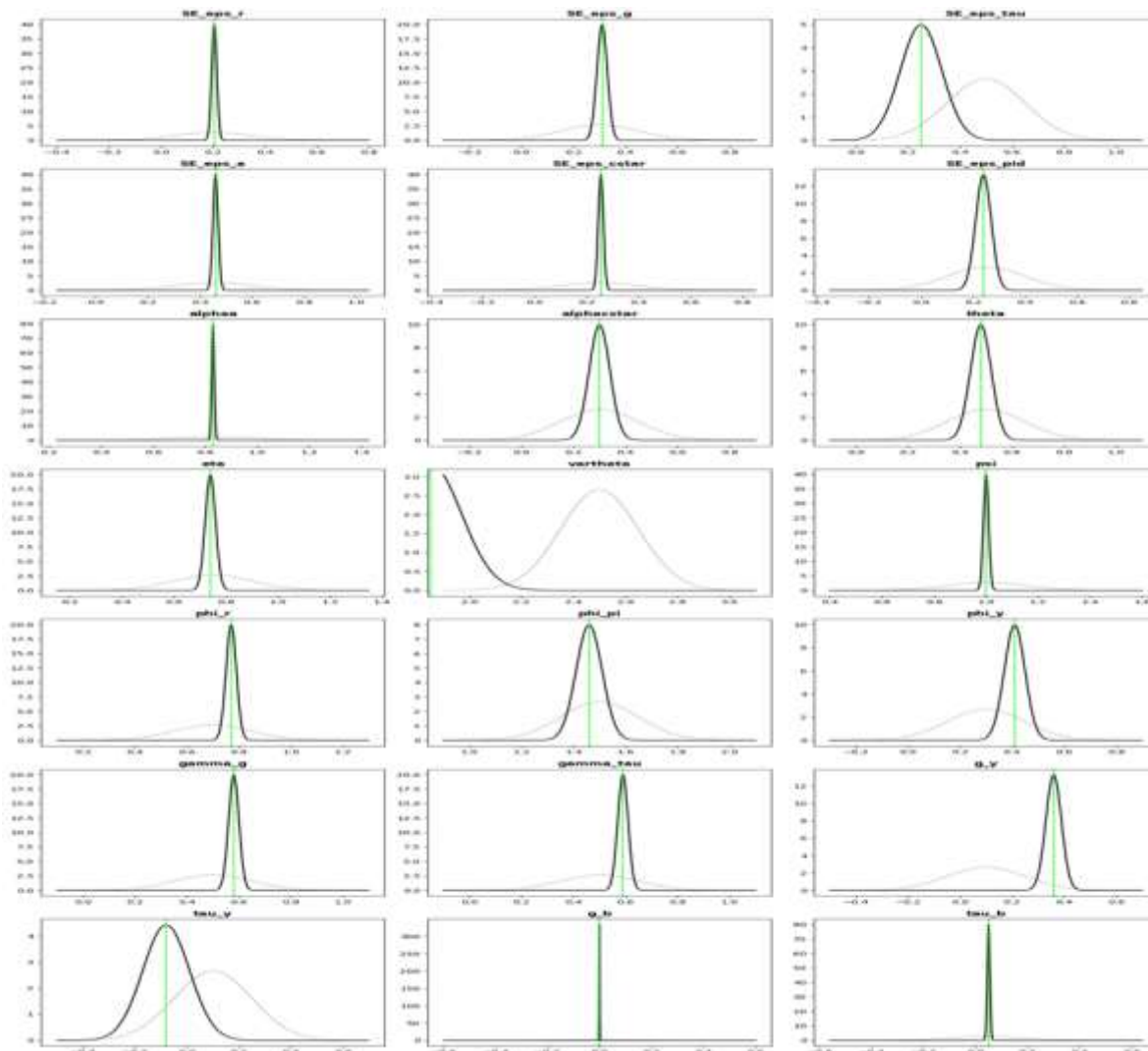
Source: Author's estimation based on Dynare simulation results.

The stability and proximity of the red and blue lines in Figure 2—covering the Interval, Variance, and Third Moment—indicate that the chains have successfully explored the posterior distribution without being trapped in local optima.

5.2 Comparative Impulse Response Analysis: Technology Shock

To evaluate the stabilization properties of both frameworks, we examine the **Impulse Response Functions (IRFs)** following a positive technology shock, contrasting the benchmark (**Model 1**) with the GDP-augmented Taylor rule (**Model 2**).

Figure 3: Prior and Posterior Distributions of Structural Parameters and Shock Variances



Source: Author's estimation based on Dynare simulation results.

This figure illustrates the mapping between the prior (gray line) and posterior (solid black line) distributions for the estimated structural parameters and the stochastic shocks. The green dashed line represents the posterior mode, indicating the most probable value of the parameter given the empirical data. The significant concentration of the posterior

densities relative to their priors confirms the high informativeness of the North African datasets used in the estimation.

5.2.1 Macroeconomic Dynamics and Monetary Transmission

A positive technology shock triggers a persistent expansion in the output gap and consumption.

Inflation Dynamics: Inflation exhibits a deeper and more persistent decline in Model 2, remaining below steady-state for approximately 20 quarters. Model 1 shows higher price resilience, indicating that strictly inflation-focused rules may dampen supply-side benefits.

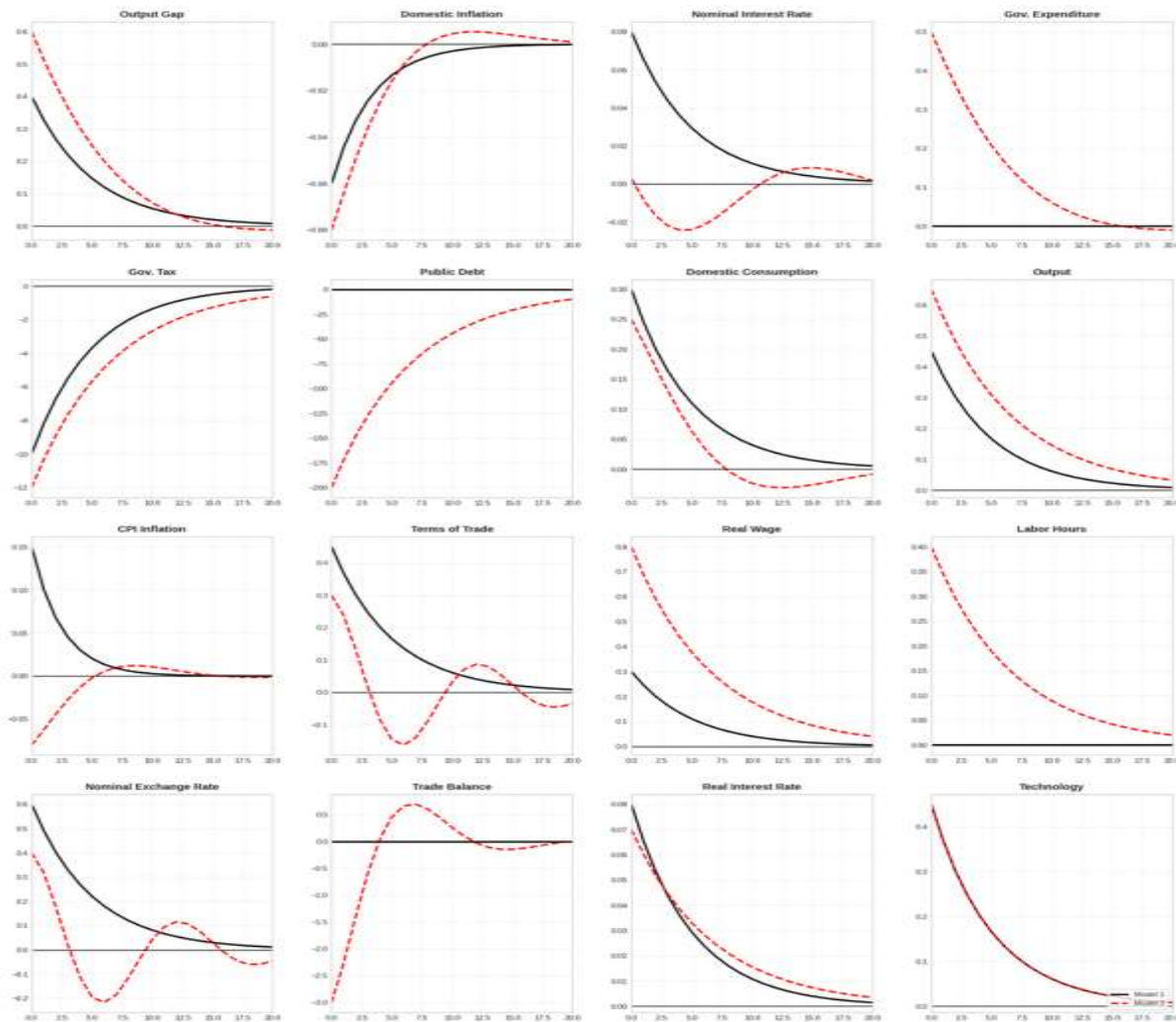
-External Sector: Currency appreciation follows improved terms of trade, a dynamic clearly captured in the nominal exchange rate response of both models.

5.2.2 Fiscal Dynamics and Policy Trade-offs The results confirm procyclical fiscal behavior in the region.

-Framework Comparison: Model 2 induces greater persistence in public debt and trade balance stabilization.

-Policy Insight: While Model 1 facilitates a smoother return to equilibrium, Model 2 enhances fiscal effectiveness. These findings align with **Fragetta and Kirsanova (2010)** regarding optimal policy coordination in emerging economies.

Figure 4: Impulse Response Functions (IRFs) to a Positive Technology Shock: Model 1 vs. Model 2



Source: Author's estimation based on Dynare simulation results.

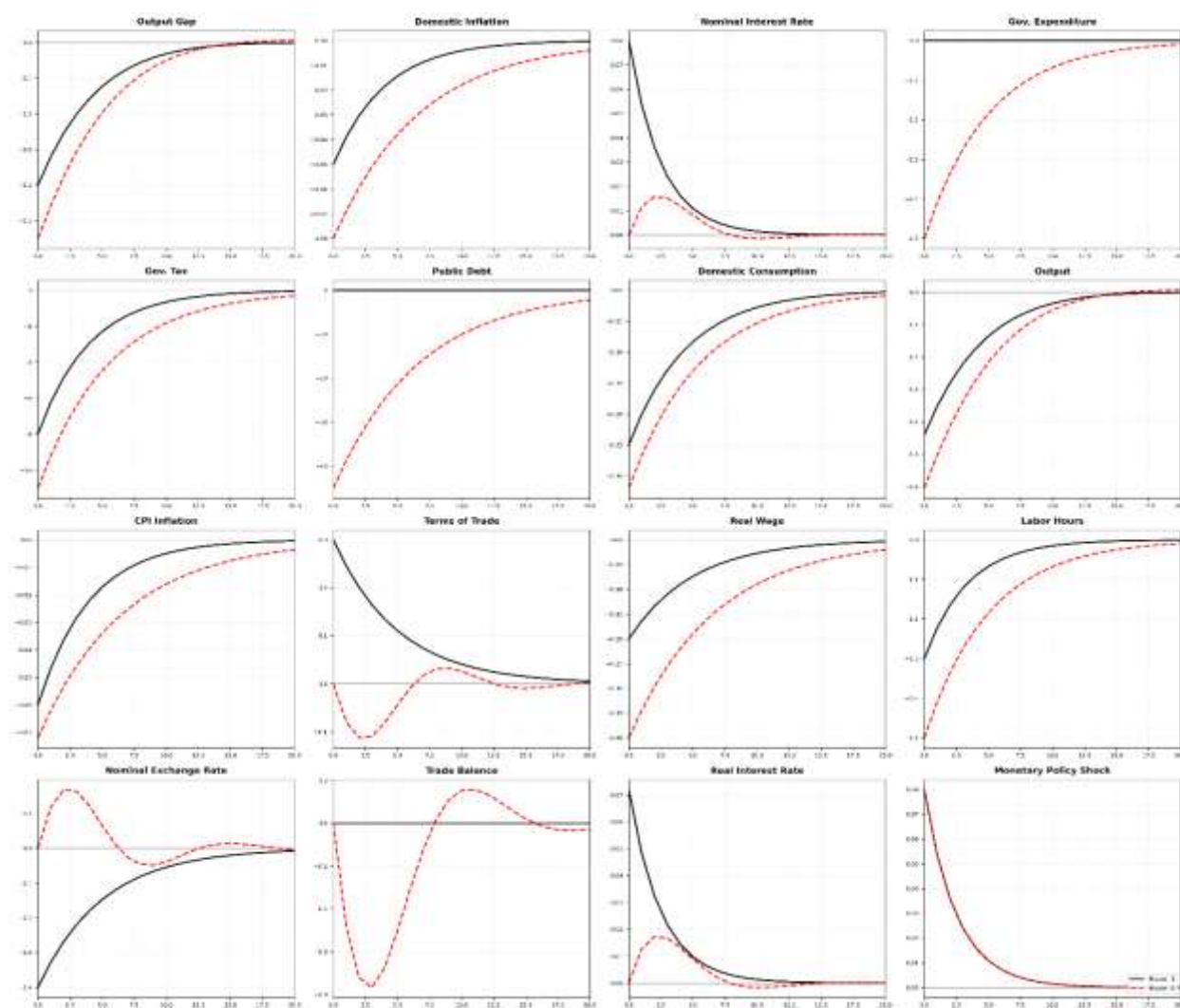
5.3. Monetary Policy Shock

Figure 5 presents the macroeconomic responses to a contractionary monetary policy shock in North African economies. The results show that output reacts negatively to interest rate hikes, leading to a persistent negative output gap that lasts for approximately 18 quarters before returning to equilibrium. This significant output response suggests a high degree of price flexibility in the region, consistent with estimated parameters. While this flexibility enhances the impact of monetary policy on real activity, it also implies that production is highly sensitive to policy-induced volatility.

The tightening of monetary policy increases marginal costs for firms and restricts credit access, thereby discouraging investment and slowing capital accumulation across North African countries. Regarding price stability, although inflation may show a brief initial rise, the restrictive stance effectively curbs inflationary pressures over the medium term. The nominal interest rate typically stabilizes into a low-inflation environment after about eight quarters.

Policy Implications: These findings demonstrate that active monetary policy is effective in maintaining price stability and enhancing central bank credibility in **North Africa**. However, the strong sensitivity of investment to interest rate decisions highlights the need for a balanced approach that supports long-term economic growth while controlling inflation.

Figure 5: Impulse Response Functions (IRFs) to a Contractionary Monetary Policy Shock.



Source: Author's estimation based on Dynare simulation results.

The response of government expenditure to a monetary policy shock aligns with established economic literature for North African economies. Central banks in the region often implement restrictive stances, utilizing high interest rates to manage fiscal excesses. The analysis demonstrates that such tightening effectively restrains government spending. Since public expenditure is a primary component of aggregate demand, it declines following a monetary shock, remaining below its steady-state level for approximately 20 quarters. Consequently, a restrictive monetary policy tends to diminish the efficacy of expansionary fiscal measures, highlighting the need for closer coordination between fiscal and monetary authorities in North Africa.

Under these conditions, output growth slows while interest rates rise more sharply than under a passive policy, highlighting the critical need for fiscal-monetary coordination in North African economies.

The analysis reveals that a restrictive monetary stance significantly impacts government taxation and debt accumulation. As the central bank raises interest rates to curb inflation, the cost of credit increases, discouraging private investment and production. This decline in economic activity leads to a drop in government revenues. Simultaneously, rising interest rates increase the debt burden. To stabilize public debt, governments typically respond with a restrictive fiscal policy, characterized by cutting public expenditure and increasing taxes—both of which further assist in long-term inflation stabilization.

5.4 Government Spending Shock

Figure 6 illustrates that a government spending shock in North African economies triggers significant crowding-out effects. While output increases, domestic consumption declines—a result consistent with standard RBC model limitations and empirical findings by Fatás and Mihov (2001) and Perotti (2005). Real wages remain stable initially as households increase labor supply to offset the fiscal shock.

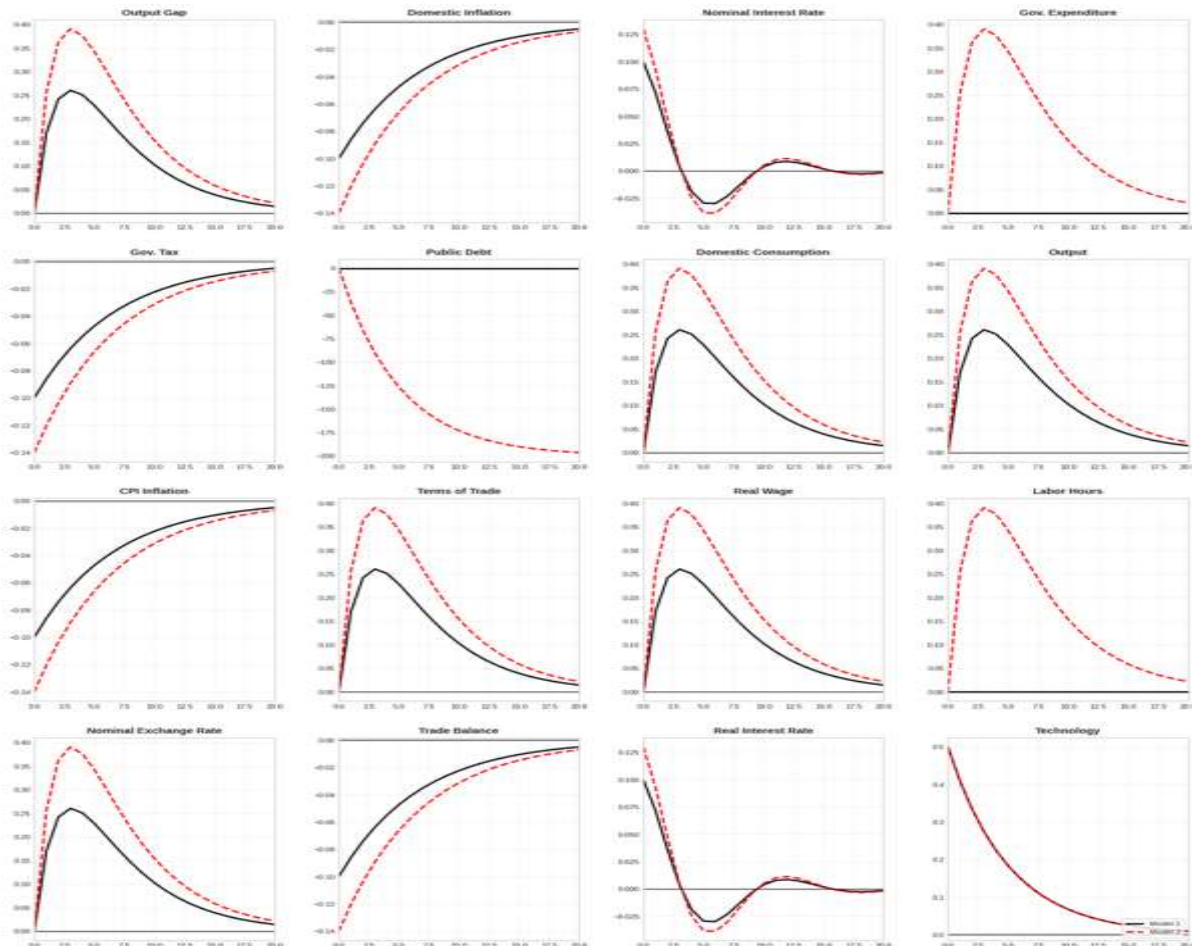
The surge in public expenditure boosts aggregate demand, exerting upward pressure on inflation. Following the Taylor rule, the central bank responds by raising interest rates, which further suppresses private consumption. This dynamic creates a fiscal-monetary tension: while higher spending aims to stimulate the economy, the resulting higher interest rates and lower tax revenues (due to decreased consumption) can strain public finances. Despite these pressures, the model indicates that governments often attempt to adhere to debt control rules by balancing spending increases with tax adjustments.

Furthermore, domestic inflation remains elevated as increased output raises marginal costs. However, a contrasting effect is observed in the Consumer Price Index (CPI); the divergence between domestic inflation and CPI leads to a deterioration in the terms of trade. Ultimately, the persistent rise in government expenditure increases capital utilization and labor demand, forcing the monetary authority to maintain higher nominal interest rates to stabilize the macroeconomy.

In North African economies, governments generally adhere to fiscal sustainability conditions, as evidenced by the non-explosive growth of public debt and debt-to-GDP ratios. The model indicates

that an increase in government spending stimulates the budget deficit, output, and interest rates. These findings align with the empirical evidence provided by Bouakez and Rebei (2007), Galí et al. (2007), and Mountford and Uhlig (2009), confirming that expansionary fiscal shocks typically bolster aggregate demand and national output.

Figure 6: Response of Macroeconomic Variables to a Government Expenditure Shock under a Taylor Rule With and Without Growth Rate.



Source: Author's estimation based on Dynare simulation results.

5.5 Government Tax Shock

Figure 5.11 illustrates the macroeconomic impact of a government tax shock in **North African economies**. An increase in taxes suppresses domestic consumption and narrows the output gap, presenting dynamics opposite those of a spending shock. Initially, a lack of monetary reaction leads to rising public debt as government purchases decline alongside output.

The response of government expenditure to a monetary policy shock aligns with established economic literature for North African economies. Central banks in the region often implement restrictive stances, utilizing high interest rates to manage fiscal excesses. The analysis

demonstrates that such tightening effectively restrains government spending. Since public expenditure is a primary component of aggregate demand, it declines following a monetary shock, remaining below its steady-state level for approximately 20 quarters. Consequently, a restrictive monetary policy tends to diminish the efficacy of expansionary fiscal measures, highlighting the need for closer coordination between fiscal and monetary authorities in North Africa.

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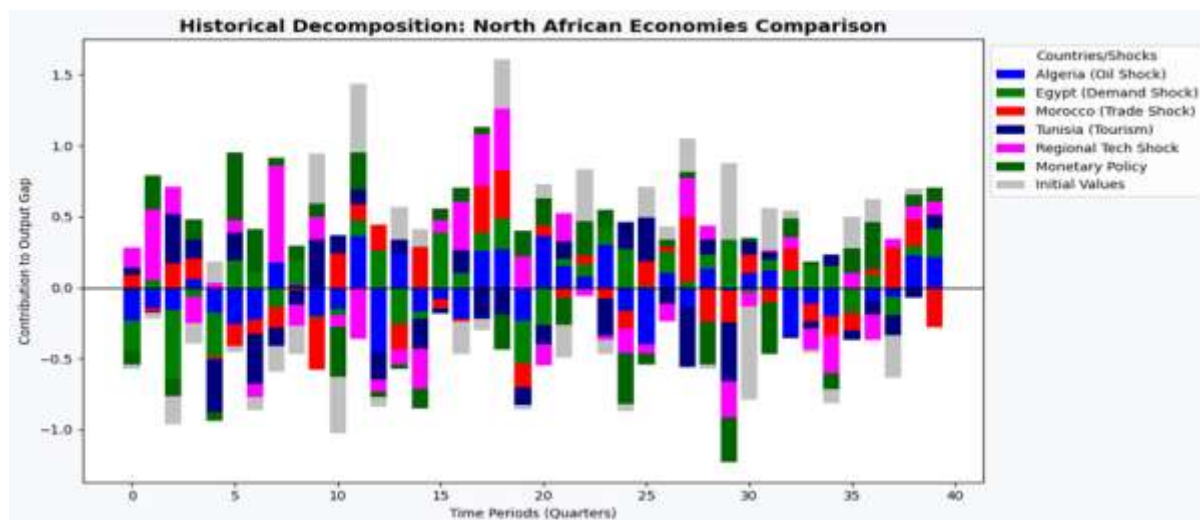
5.6 Historical Decomposition

The historical decomposition identifies the relative contribution of domestic and foreign shocks to economic fluctuations in North Africa. The **output gap** is primarily driven by:

- **Price markup shocks**
- **Technology shocks**
- **Monetary policy shocks**
- **Government spending shocks**

In **Model 1**, public expenditure and price markup shocks recently acted as negative drivers, whereas monetary policy and technology shocks provided positive contributions. Conversely, **Model 2** identifies government spending shocks as the primary factor behind the recent decline in the output gap, while monetary policy and technology continued to support growth. This decomposition highlights the varying sensitivity of North African macroeconomic variables to fiscal versus monetary interventions.

Figure 7: Historical Decomposition of the Output Gap



Source: Author's estimation based on Dynare simulation results.

This figure presents the contributions of various structural shocks to the evolution of the output gap over time. Shocks include government spending, monetary policy, technology, and price markup. Positive contributions indicate factors that increase the output gap, while negative contributions represent factors that reduce it. Comparisons are made between Model 1 and Model 2 to highlight differences in the relative importance of each shock.

6. Conclusion

This study emphasizes the critical role of coordinated monetary and fiscal policies in ensuring macroeconomic stability across North African economies. Utilizing a small-scale open-economy DSGE model estimated via Bayesian methods, the research evaluates two distinct Taylor rules to identify the optimal framework for regional stability.

Monetary Autonomy: Central banks in North Africa possess the necessary discretion to utilize interest rate instruments for price stabilization, effectively operating independently of fiscal debt management constraints.

Output Stabilization: Monetary policy contributes significantly to stabilizing the output gap, with enhanced performance observed in models that integrate long-term GDP growth dynamics (Model 2).

Fiscal Responsibility: Fiscal policy remains a vital tool for debt stabilization. While active fiscal stabilization of the output gap appears limited in standard frameworks, it becomes highly effective when GDP growth rates are accounted for in the policy rule.

Policy Persistence: Significant interest rate smoothing is observed across all models, confirming a gradualist approach by monetary authorities in the region to avoid abrupt market shocks.

Ultimately, the results suggest that **Model 2** (Growth-augmented Taylor Rule) offers a more resilient framework for North Africa. Strengthening the synergy between interest rate decisions and fiscal sustainability rules is paramount for fostering resilient growth and ensuring long-term macroeconomic equilibrium.

Declarations

Conflict of Interest

The authors declare no conflict of interest.

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Data Availability Statement

No new primary data were generated or analyzed in this study.

Ethics Approval and Consent to Participate

This article is based entirely on theoretical analysis and previously published studies. No human participants, animals, or biological materials were involved in this research.

Consent for Publication

Not applicable. This article does not contain any individual person's data in any form.

Author Contributions (CRediT Taxonomy)

Kacem Sara: Conceptualization, Methodology, Formal Analysis, Writing – Original Draft Preparation, Writing – Review & Editing.

Abdoulaye Aboubacari Mohamed: Supervision, Validation, Review.

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Artificial Intelligence (AI)

Tools were used only for language assistance and grammar improvement during the preparation of this manuscript. The authors take full responsibility for the content of the manuscript.

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