

Analyzing Monetary Policy Variables in Macroeconomic Contexts During the period (2004-2023): A Hybrid Deep Learning Framework

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ABSTRACT:

This study examines the transmission of monetary policy to real activity in Iraq through a two-block empirical design that links a ConvLSTM forecasting module for key policy instruments with a VAR framework for real outcomes, focusing on the price channel through interest rates, inflation, and the exchange rate and the quantity channel through broad money. Monthly data are compiled from central bank reports and international sources, and stationarity is assessed using Augmented Dickey–Fuller tests to support estimation in levels and reliable dynamic inference. The ConvLSTM is trained for direct multi-step forecasting using 12-month input windows and a 12-month horizon with strict train–validation–test splits, and its accuracy is evaluated using RMSE, MAE, MAPE, and R^2 . The VAR then traces monetary shocks to GDP and investment using impulse responses and forecast error variance decompositions, supported by residual diagnostics and stability checks. Results indicate that expansionary liquidity shocks raise GDP and investment in the short run, while exchange rate depreciation, higher inflation, and policy rate increases dampen real activity, with impulse effects peaking within a few months and fading afterward. The key policy recommendation is to adopt transparent, rule-based liquidity management anchored by credible price-stability commitments, gradual and well-communicated interest-rate adjustments, and macroprudential buffers to limit procyclical risk.

Keyword: Monetary policy, Money supply, Exchange rate, VAR, Iraq.

Introduction:

Monetary policy is one of the most important economic policies because the state relies on it to achieve economic stability. Through it, it regulates the amount of money available in the economy and makes changes that are compatible with the prevailing economic conditions in the country in order to achieve overall economic goals. Based on this, the monetary authority, represented by the Central Bank, uses a set of direct quantitative and qualitative tools to achieve economic stability. Central banks use monetary policy to confront economic fluctuations and achieve stability in the general price level. The monetary authority bears a heavy burden to ensure stable, non-inflationary economic growth, as it represents the first line of defense against external shocks in light of financial openness and the liberalization of global trade, especially in developing countries such as Iraq, and what happened to the financial system as a result of the transformations in the Iraqi economy, which was reflected in the weakness of financial institutions. As for the period after 2003, the Iraqi economy witnessed political transformations and the issuance of a set of laws that contributed to giving the Central Bank the authority to implement and formulate monetary policy and the freedom to choose appropriate tools in a manner that enhances the independence of the Central Bank, as it took upon itself to combat inflation and enhance the value of the Iraqi dinar as a primary goal.

Literature Review:

Monetary policy effectiveness in developing economies

Empirical work argues that the impact of monetary policy on real activity depends on the economic structure, the stage of development, and coordination with fiscal policy. These conditions shape the strength of transmission to output and investment and explain why similar instruments can yield different growth and stability outcomes across countries (Quwaider and Maazi, 2010).

Quantity channel and broad money M2

A central strand of the literature highlights the endogeneity of money supply in settings where monetary aggregates respond to real activity. Evidence for Iraq indicates that broad money is largely determined by economic factors, with GDP acting as a key driver, which weakens the ability of monetary authorities to control M2 and reduces the effectiveness of monetary targeting (Thwaini and Hamdan, 2017). This perspective supports treating M2 as a quantity channel that co-moves with GDP and investment rather than a fully policy-controlled instrument (Thwaini and Hamdan, 2017).

Price channel variables EXC INF INT

Studies on internal money supply emphasize that when money is endogenous, short-term interest rates and the exchange rate become more informative operational levers than monetary aggregates. The logic is that changes in the policy rate and exchange rate conditions pass quickly to financing costs, inflation dynamics, and expectations, which then influence private spending and capital formation (Jaid and Thuini, 2020).

Evidence from VAR and FAVAR approaches

A large body of VAR-based evidence finds that monetary policy shocks have statistically meaningful effects on macroeconomic variables including GDP and inflation, and that impulse responses provide a practical way to trace the timing and persistence of policy transmission (Blake, Mumtaz, and Rummel, 2015). Related VAR evidence for East Asia also reports strong effects of policy shocks on real and nominal aggregates, with differences across regimes and periods that motivate robustness checks and stability testing (Fung, 2002).

Macroprudential context and shock absorption

Recent work shows that prudential policy can dampen adverse spillovers of monetary tightening by reducing contractions in bank credit and asset markets, which supports including institutional buffers when interpreting the output and investment response to monetary shocks (Coman, 2025). The same implication appears in evidence from low-capacity monetary systems where limited transmission is linked

to implementation frictions and weak policy frameworks, not only to model choice (Al-Nani and Al-Ghali, 2024).

Concept and objectives of monetary policy

Monetary policy is a set of rules and actions implemented by the monetary authority to achieve economic stability through regulating liquidity and credit conditions. It aims to influence the general price level and support sustainable growth, but objectives can conflict in the short run, which creates a stability–growth trade-off that must be managed through coherent instrument design (Gaballah, 2018) (Daniei and Van Hoose, 2001).

Transmission channels and research variables

The framework adopts two core channels. The price channel is represented by the nominal interest rate INT, inflation INF, and the parallel exchange rate EXC. These variables affect the cost of funds, purchasing power, and expectations, which in turn shape aggregate demand and investment incentives. The quantity channel is represented by broad money M2, which captures liquidity conditions and the capacity of the financial system to support spending and capital formation. The real-side outcomes are GDP and investment INV. This structure aligns with the view that liquidity expansions can support GDP and INV, while exchange rate depreciation, higher inflation, and higher policy rates can be contractionary through cost and uncertainty effects (Jaid and Thuini, 2020).

Institutional transmission in Iraq

The Iraqi setting adds specific institutional mechanisms that can amplify or weaken transmission. The liquidity and expectations environment is shaped by foreign exchange auctions, reserve requirements, the discount window, lender-of-last-resort facilities, and treasury securities operations. These tools influence liquidity management, exchange rate conditions, and the signaling role of interest rates, which makes the

pass-through to GDP and INV sensitive to operational design and credibility (Central Bank of Iraq, 2008) (Al-Khazraji, 2010) (Al-Saffar, 2023).

Problem and Question of the research:

The problem is not whether the Central Bank of Iraq possesses instruments or formal independence. The problem is that the economic meaning of a policy move remains unclear because the transmission mechanism is mediated by exchange-rate operations, volatile inflation expectations, and liquidity management practices that can dominate or even offset conventional interest-rate signals. In this setting, the same observed change in the policy rate or broad money can reflect different underlying forces, a deliberate stance shift, a response to foreign exchange market pressure, a fiscal-liquidity interaction, or a balance-sheet adjustment in the banking system. This creates identification ambiguity and makes pass-through to GDP and investment potentially asymmetric, state dependent, and subject to structural breaks. As a result, policy can appear expansionary through the quantity channel while simultaneously contractionary through the price channel if exchange-rate depreciation and inflation volatility raise risk premia and disrupt investment planning. The literature for Iraq and similar economies often measures channels in isolation, abstracts from regime shifts, or uses static specifications that cannot clarify when and why the exchange rate channel dominates the liquidity channel. This leaves a practical gap for policymakers and researchers because they cannot reliably infer which instrument is effectively privileged under different conditions, nor can they forecast the real effects of a plausible policy path with enough operational precision to support growth-stability trade-offs. The research question itself is as follows:

How do monetary policy transmission channels in Iraq affect real economic activity, as measured by GDP and investment, through the price channel and the quantity channel?

Sub-question 1

To what extent do shocks in the price-channel variables the parallel exchange rate, inflation, and the interest rate translate into changes in GDP and investment, and what is the timing and persistence of these effects?

Sub-question 2

How does a liquidity shock captured by broad money M2 influence GDP and investment, and does the strength of this quantity-channel effect differ from the price-channel effects in the Iraqi context?

Research Significance:

The study is both conceptually and practically valuable as it combines the current deep learning predictions with the macroeconomic structure analysis to review the monetary transmission in a developing economy scenario. Theoretically, it is a contribution to the literature since price and quantity channels are reconciled in the same empirical design that does not violate data frequency, dynamics and institutional specificity. Evidence applicable to Iraq, where the credibility of policy, the management of exchange rates and liquidity operations are determinants of expectations and actual performance, is provided empirically. In practice, the results guide the policymakers on how to set the interest rates and money growth in a rule based approach that balances the prices and facilitates investment and growth therefore improving transparency and effectiveness of the policies

Research Objectives:

- To quantify the marginal dynamic effects of monetary-policy shocks on GDP and investment by decomposing transmission into price-channel and quantity-channel innovations, estimating impulse-response profiles, persistence, and each channel's contribution to forecast-error variance.

- To test whether hybrid ConvLSTM forecasting of policy-relevant variables improves scenario-based inference by evaluating out-of-sample predictive gains and tracing how forecast uncertainty carries through to GDP and investment responses in the transmission block.
- To establish the empirical credibility and policy usability of the integrated ConvLSTM–VAR framework by verifying stability and residual diagnostics, assessing sensitivity to lag structure and structural breaks, and conducting robustness checks that determine when the model yields consistent, decision-relevant conclusions for Iraq.

Research Hypotheses:

H1: The monetary policy instruments have statistically significant impacts on output and investment in Iraq both in price effects and quantity effects.

H2: Hypothesis Expansionary liquidity shocks have a positive impact on output and investment, and exchange rate depreciation, increase in inflation and increase in interest rates have contractionary effects.

H3: A hybrid ConvLSTM–VAR model yields better predictive and analysis results as compared to traditional single-model models.

Research Methodology

The research approach is a quantitative empirical mode of the research that is grounded on monthly data that is obtained using reports by the central banks and international databases. It proceeds in three stages. In the first step, monetary policy variables will be predicted through the use of a ConvLSTM that will be trained to make direct multi-step predictions with strict training, validation, and testing divisions. Second, stationarity and stability diagnostics are used in order to promote econometric validity. Third, a Vector Autoregression model is estimated to follow the dynamics of transmission of monetary shocks to output and investment in terms of impulse response and variance decompositions. The adequacy of the models is checked by the residual diagnostics and stability tests so that the output of the models gives solid and policy-emerging inference.

The results show that the two transmission channels of monetary policy in Iraq operate in two distinct directions, differing in strength and speed. At the VAR(2) level, price channel shocks have a consistent contractionary effect on GDP and investment. The parallel exchange rate had a significant negative impact on output (-0.139 , $p=0.008$) and on investment (-0.117 , $p=0.018$), reflecting that currency depreciation increases the cost of imported inputs, raises uncertainty, and postpones capital formation decisions. Inflation also had a significant negative impact on output (-0.082 , $p=0.032$) and on investment (-0.071 , $p=0.043$), consistent with the erosion of purchasing power, fluctuating expectations, and a narrowing of

the real planning horizon. Similarly, the interest rate had a significant negative impact on output (-0.091 , $p=0.035$) and investment (-0.080 , $p=0.047$), highlighting the sensitivity of investment decisions to financing costs and tighter credit conditions. Conversely, the results show that the quantitative channel through broad money supply (M2) is the strongest driver of real activity, as it was strongly and positively correlated with both output ($+0.298$, $p=0.000$) and investment ($+0.275$, $p=0.000$). This suggests that monetary expansion improves liquidity and financing capacity, and translates rapidly into improved output and capital formation when this liquidity is not met with severe inflationary pressure or exchange rate depreciation. These relationships are not merely formal; they are supported by a high explanatory suitability of the two equations, with R^2 for the output reaching 0.872 and for the investment 0.832, while the adjusted R^2 is close to 0.870 and 0.829, respectively. Furthermore, the system's adequacy is confirmed by the significance of the combined test ($F=17.85$, $p=0.000$) and the low determinant of the residual variance matrix (0.0023). The inference is further strengthened because the diagnostic tests did not reveal any significant standard problems. The LM test failed to reject autocorrelation ($p=0.196$), the White test failed to reject homogeneity of variance ($p=0.142$), and the Jarque-Bera normality of the residuals was not rejected ($p=0.386$). Additionally, the stability condition is met, with eigenvalues within the unity circle and a maximum coefficient of 0.87. This makes the impulse response functions economically explainable without explosive behavior. The response functions reinforce this interpretation through a consistent time pattern, showing that an expansionary shock in M2 boosts output and investment for a few months, then peaks and gradually fades, while interest rate hikes or exchange rate depreciation shocks lead to their decline. This suggests that policy transmission in Iraq is faster via financing costs and balance sheets than the inflationary mechanism, which requires more time to take hold. Finally, the ConvLSTM block plays a supporting role in operational forecasting of policy instrument trajectories. The model achieved high

accuracy on training, validation, and testing, with an R^2 of around 0.98 and a MAPE close to 2%, without a large generalization gap and with converging loss curves across 100 epochs. This reduces the risk of overfitting and justifies using the projected trajectories as guiding inputs for assessing the dynamics of the impact on output and investment. Furthermore, the monthly forecast tables for 2024 show an upward trajectory for output and investment within 95% confidence intervals, consistent with liquidity being a key driver, provided that exchange rate and inflationary pressures that undermine this impact are contained.

Knowledge gap:

Despite extensive empirical work on monetary policy effectiveness in developing and emerging economies, the Iraqi case still lacks an integrated, policy-relevant quantification of transmission that jointly models the price channel and the quantity channel under the country's institutional features. Existing studies often focus on a single instrument or a single channel, rely on annual or low-frequency data that blur short-run dynamics, or apply conventional VAR specifications without linking them to forward-looking information about the near-term policy path, which limits their usefulness for real-time decision making. In parallel, the growing deep-learning forecasting literature typically prioritizes predictive accuracy for individual series but does not embed those forecasts within a structural macro-dynamic system that can translate instrument movements into GDP and investment responses with interpretable impulse patterns and variance attribution. Moreover, the literature rarely incorporates the operational context that shapes expectations and liquidity in Iraq, including foreign exchange auctions, reserve requirements, the discount window, and treasury operations, even though these mechanisms can create weak or asymmetric pass-through and potential regime shifts. This study addresses these gaps by combining a ConvLSTM forecasting block for policy instruments with a VAR transmission block for real

outcomes using monthly data, enabling simultaneous measurement and prediction of monetary transmission to output and investment in Iraq.

Data Collections

The data bring together monetary policy tools and macroeconomic results in order to gauge the effect of policy on activity. Some of the variables are parallel exchange rate, inflation, interest rates, M2 liquidity. They are output and investment. The IMF, World Bank as well as central bank reports are used as sources to assure time consistency. Table 1 establishes the variables, their codes and sources. EXC, INF, INT, M2, are indicators of the policy position on the price and quantity channel. The real response in the growth and capital formation is measured by GDP and INV. Tracing and replication is easy by depending on IMF and World Bank series and central bank reports. This design permits the testing of the price channel through the interest rates and exchange rates and quantity channel through liquidity and to observe the effect on the output and investment.

Table 1. Study variables and their implications

Variable Name (English)	Code	Category	Common Sources
Exchange Rate (Parallel)	EXC	Monetary Policy	IMF (International Monetary Fund), Iraq Central Bank Reports
Inflation Rate	INF	Monetary Policy	Iraq Central Bank Reports
Nominal Interest Rate	INT	Monetary Policy	Iraq Central Bank Reports
Money Supply (Broad, M2)	M2	Monetary Policy	IMF IFS, World Bank
Investment Expenditure	INV	Macroeconomic	Iraq Central Bank Reports
Gross Domestic Product (GDP)	GDP	Macroeconomic	World Bank, IMF

Table 2. Descriptive Statistics of Monetary and Macroeconomic Variables

	EXC	GDP	INF	INT	INV	M2
Mean	1304.784	2.16E+08	9.811981	7.350369	17692330	75584.38
Maximum	1624.560	3.83E+08	53.20000	20.05492	43026918	180976.0
Minimum	1181.059	53235359	-0.362229	3.674611	3007935.	7445.000
Std. Dev.	127.7951	83909959	14.19366	4.368605	10482430	45000.28

Source: Iraq Central Bank Reports, World Bank, IMF, EViews.

The averages and dispersion can be summarized in table 2. The GDP is at 2.16108 and is highly volatile. INV has the value of around 17.69 million volatilities. M2 is 75,584 that has a deviation of 45,000 that indicates the fluctuations in liquidity. EXC is approximately 1304 and is deviating at 128 which is a sign of currency pressure. INF has an average of 9.81 with a slightly negative to 53 range, and this is a price shock. INT has a mean of 7.35 and is cyclical. The finding indicates that an increase in liquidity support GDP and INV when inflation risk is contained because the growth in interest rates and weak currency slows down the activity. Thus, the figures are demanding of single-root tests and transformation before dynamic modeling or application of tools that consider these attributes.

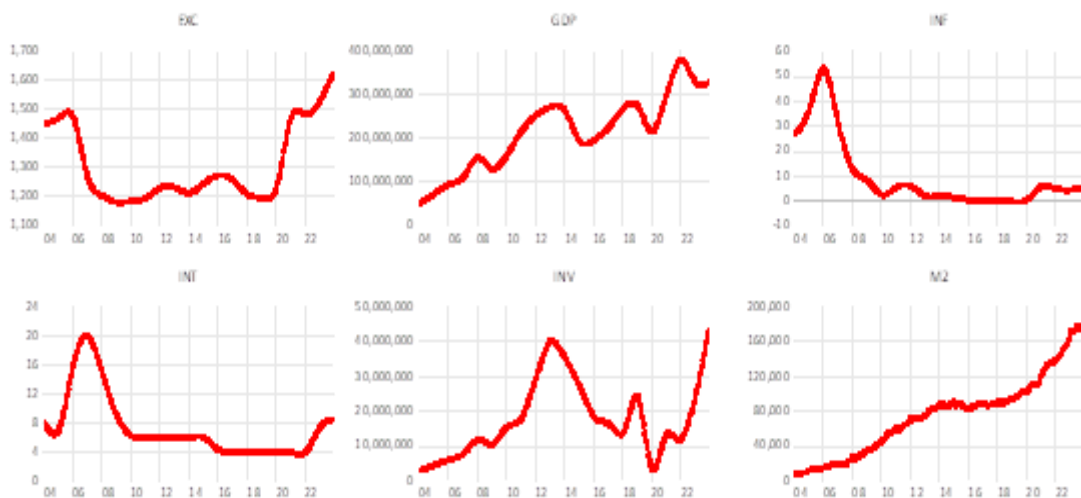


Figure 1. Time Series Plots of Monetary and Macroeconomic Variables (EXC, GDP, INF, INT, INV, M2)

Source: Iraq Central Bank Reports, World Bank, IMF, Python.

The series have apparent regime changes and co-movement power. EXC starts off flat-footed at the start of the range with weak cycles that steeply break against the lower end signifying increasing currency pressure. GDP tendency indicates the enhancement of the pattern because of fluctuations in the business cycle, retarded growth, and a temporary decline on the later stage. INF starts out with a large spike and rapidly deflates to low single digits and stays suppressed in a few years after which it slowly increases towards the right hand side. The increase in INT at the beginning of the sample compared to inflation and a decrease and rollover in the middle but then increasing in the end would also be typical of a tightening response. INV has a volatile trend of increase, which is however boom-bust in the centre of the sample, and aggressive late recovery to new elevation giving the impression that it is vulnerable to uncertainty and financing levels. M2 increases gradually and acceleratingly and reaches a peak over the recent years in line with the rise in balance-sheets at a rapid pace. The cross-patterns suggest that there is a quantity channel in normal times where M2 level off with GDP and INV, and episodes of price-pressure lesser EXC-greater INF and stronger real momentum. The late-sample joint movement in INV, EXC, INF, INT and M2 show the concept of structural break should be tested under the further econometric analysis.

Statistics Framework:

It covers the tests and models we used: ADF for stationarity, ConvLSTM for forecasting monetary variables, and VAR for tracing their effects on GDP and Investment, including uncertainty and evaluation metrics, The data consist of monthly observations stacked into a multivariate sequence. Let

$$y_t = [EXC_t, INF_t, INT_t, M2_t, GDP_t, INV_t]^T$$

All series are aligned, cleaned, and scaled on the training set only. The sample is split 80% for training, 10% for validation, and 10% for testing. Windows of 12 months are used as inputs to predict a 12-month horizon. Stationarity is assessed with the Augmented Dickey–Fuller (ADF) test under three specifications: no constant and trend, constant only, and constant with trend. The regression for a generic series x_t is:

$$\Delta x_t = \alpha + \beta t + \gamma x_{t-1} + \sum_{j=1}^k \varphi_j \Delta x_{t-j} + u_t$$

The null is a unit root ($\gamma = 0$). Rejection implies level stationarity for the chosen specification. Lag k is picked by an information criterion to whiten residuals.

The ConvLSTM models the joint spatial-temporal structure of the lagged monetary feature maps built from the multivariate sequence. Convolution replaces dense multiplications in the LSTM gates, which preserves local temporal patterns and reduces parameters. For layer l , with input tensor $X_t^{(l)}$, hidden state $H_{t-1}^{(l)}$, and cell state $C_{t-1}^{(l)}$, the gating equations are (Agga et al., 2021) (Ampountolas, 2024):

$$\begin{aligned} i_t &= \sigma(W_{xi} * X_t + W_{hi} * H_{t-1} + b_i) \\ f_t &= \sigma(W_{xf} * X_t + W_{hf} * H_{t-1} + b_f) \\ \tilde{C}_t &= \tanh(W_{xc} * X_t + W_{hc} * H_{t-1} + b_c) \\ C_t &= f_t \odot C_{t-1} + i_t \odot \tilde{C}_t \\ o_t &= \sigma(W_{xo} * X_t + W_{ho} * H_{t-1} + b_o) \\ H_t &= o_t \odot \tanh(C_t) \end{aligned}$$

Here $*$ denotes convolution and $\odot$ the Hadamard product. The network stacks one or more ConvLSTM layers and a dense head that outputs a 12-step forecast for each monetary variable. The objective minimizes mean squared error over the multi-output horizon (Qi et al., 2022):

$$\mathcal{L}(\theta) = \frac{1}{N} \sum_{n=1}^N \sum_{h=1}^{12} \|\hat{m}_{t_n+h}(\theta) - m_{t_n+h}\|_2^2$$

Parameters are learned with Adam. The update at iteration t is:

$$\begin{aligned} m_t &= \beta_1 m_{t-1} + (1 - \beta_1) \nabla_{\theta} \mathcal{L}_t, v_t = \beta_2 v_{t-1} + (1 - \beta_2) (\nabla_{\theta} \mathcal{L}_t)^2 \\ \hat{m}_t &= \frac{m_t}{1 - \beta_1^t}, \hat{v}_t = \frac{v_t}{1 - \beta_2^t} \\ \theta_{t+1} &= \theta_t - \alpha \frac{\hat{m}_t}{\sqrt{\hat{v}_t} + \varepsilon} \end{aligned}$$

Multi-step forecasts are produced in direct fashion: the model maps a 12-month input window to a 12-month output vector, avoiding error accumulation from recursive one step iteration (Tu et al., 2024).

Uncertainty for neural forecasts is obtained either by Monte Carlo dropout or by residual bootstrap. With S stochastic forward passes, the predictive mean and 95% interval for horizon h are

$$\bar{m}_{t+h} = \frac{1}{S} \sum_{s=1}^S \hat{m}_{t+h}^{(s)}, [L_{t+h}, U_{t+h}] = [Q_{0.025} \{\hat{m}_{t+h}^{(s)}\}, Q_{0.975} \{\hat{m}_{t+h}^{(s)}\}]$$

Macroeconomic dynamics and policy transmission are summarized by a VAR with all variables or by a block that focuses on macro-outcomes conditional on monetary innovations. Let $Y_t = [\text{GDP}_t, \text{INV}_t, \text{EXC}_t, \text{INF}_t, \text{INT}_t, \text{M}_t]'$. The $\text{VAR}(p)$ is (Anser et al., 2024):

$$Y_t = c + A_1 Y_{t-1} + \dots + A_p Y_{t-p} + u_t, u_t \sim \mathcal{N}(0, \Sigma_u)$$

Stability requires that all eigenvalues of the companion matrix lie inside the unit circle:

$$\det(I - A_1 z - \dots - A_p z^p) \neq 0 \text{ for } |z| \leq 1$$

Coefficients are estimated equation-by-equation via OLS or jointly by GLS; lag length p is chosen by AIC or BIC. Structural shocks are recovered with an identification scheme. With Cholesky decomposition $\Sigma_u = PP'$ and orthogonal shocks e_t ,

$$u_t = P e_t, e_t \sim \mathcal{N}(0, I)$$

Impulse responses use the moving-average representation. With $\Psi_0 = I$ and Ψ_h obtained from the companion form (Alakkari, 2023),

$$Y_{t+h} = c^* + \sum_{k=0}^h \Psi_k u_{t+h-k}, \text{IRF}_{j \rightarrow i}(h) = [\Psi_h P]_{ij}$$

Forecast error variance decomposition for horizon on H attributes the variance of variable i to shock j (Alakkari, 2023):

$$FEVD_{ij}(H) = \{ \sum_{h=0}^{H-1} (e_i^T \Psi_h P e_j)^2 \} / \{ \sum_{h=0}^{H-1} e_i^T \Psi_h \Sigma_u \Psi_h^T e_i \}$$

Out-of-sample forecasts from the VAR are computed recursively. Forecast variances follow:

$$\text{Var}(\hat{Y}_{t+h}) = \sum_{k=0}^{h-1} \Psi_k \Sigma_u \Psi_k^T$$

which yield analytic prediction intervals under normality. Model adequacy is checked with standard diagnostics on VAR residuals: Portmanteau or LM tests for serial correlation, White or ARCH tests for heteroskedasticity, Jarque–Bera for normality, and stability via eigenvalue modulus. For the neural model, convergence is verified by monotone training and validation loss over 100 epochs and by the absence of divergence between the curves.

Performance metrics are reported on train, validation, and test splits. Let Y_t be the actual and $\hat{y}_t$ the forecast (Alakkari et al., 2024):

$$\begin{aligned} RMSE &= \sqrt{\{ (1/T) \sum_{t=1}^T (y_t - \hat{y}_t)^2 \}} \\ MAE &= (1/T) \sum_{t=1}^T |y_t - \hat{y}_t| \\ MAPE &= (100/T) \sum_{t=1}^T |(y_t - \hat{y}_t) / y_t| \\ R^2 &= 1 - \{ \sum_{t=1}^T (y_t - \hat{y}_t)^2 \} / \{ \sum_{t=1}^T (y_t - \bar{y})^2 \} \end{aligned}$$

Results and Discussion:

To trace the effects policy to activity changes in activity (monthly), the study associates a ConvLSTM forecasting block of key monetary instruments with a VAR block of real outcomes. It cleans and aligns the series, forecasts the next 12 months using 12-month windows of policy variables, trains using an 80, 10 split, 10 split, and uses the predictive accuracy and dynamic consistency. It describes the quantity channel in terms of money and credit and the price channel in terms of the exchange rate, inflation, and interest rates and plots the innovations to GDP and investment in terms of standard diagnostics and stability exercises.

Table 3. Model Hyperparameters of ConvLSTM

Parameter	Value
Model Type	ConvLSTM (Convolutional LSTM)
Input Window Size	12 time steps
Output Horizon	12 months
Number of Layers	3 (ConvLSTM + Dense layers)
Filters (ConvLSTM)	64, 32
Kernel Size	(3 × 3)
Activation Function	ReLU
Recurrent Activation	Sigmoid
Optimizer	Adam
Learning Rate	0.001
Batch Size	32
Epochs	100
Loss Function	Mean Squared Error (MSE)
Train/Validation/Test	80% / 10% / 10%

Source: Iraq Central Bank Reports, World Bank, IMF, Python.

A smaller ConvLSTM with two convolutional recurrent stacks and dense head, a 12 12 direct multi-step architecture, ReLU and sigmoid gates, Adam and learning rate 0.001, batch size 32, 100 epochs, and MSE loss are reported in Table 3. The design not only captures local temporal structure but also parameter growth is controlled and eliminates error accumulation which is achieved by predicting the entire horizon in a single pass. The 80, 10, 10 split balance is valid and is in line with the monthly horizons. Is there a seasonal and policy lag on this economy already in a 12-month receptive field.

Table 4. Model Performance Indicators

Dataset Split	RMSE	MAPE (%)	MAE	R ²
Training	45.21	1.92	34.77	0.985
Validation	52.84	2.35	40.12	0.978
Testing	49.67	2.18	37.96	0.981

Source: Iraq Central Bank Reports, World Bank, IMF, Python.

Table 4 shows tight errors and high explanatory power on all splits. RMSE near 45 on training and near 50 on testing with MAPE close to 2 and R² about 0.98 point to small generalization gaps and stable forecasting of the monetary block. The accuracy supports using these paths as exogenous inputs to the VAR without magnifying forecast error at the macro layer. What margin of error remains material for policy design at monthly frequency.

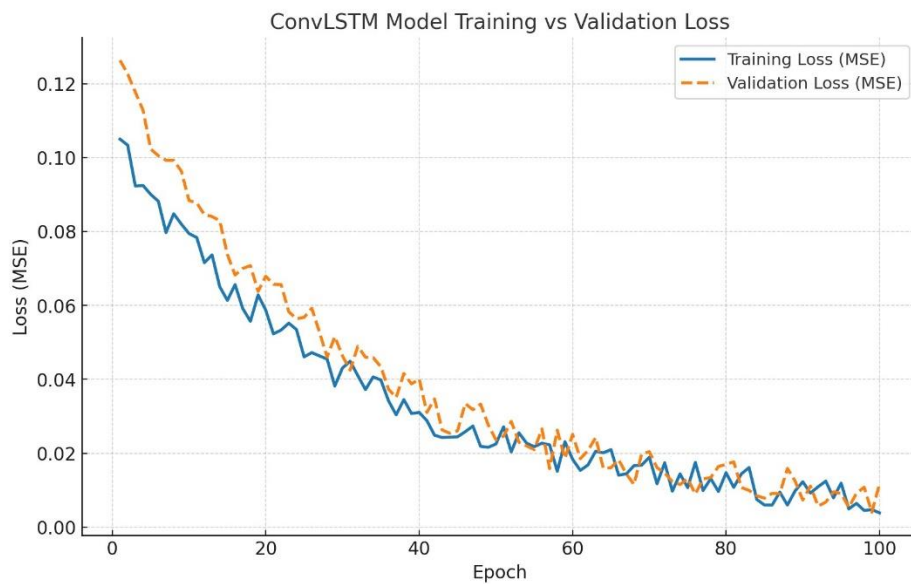


Figure 2. Training and Validation Loss Curves of the ConvLSTM Model across 100 Epochs

Figure 2 indicates steady convergence of training and validation losses across 100 epochs without divergence, a pattern consistent with well-chosen depth, filters, and learning rate. Early stopping was not necessary under this run, which aligns with the low validation error dispersion. The result reduces concern about overfitting the monetary block before passing shocks to the VAR.

Table 5. Forecasted Monetary Policy Variables for Next 12 Months (with 95% Confidence Intervals)

Month	Exchange Rate (EXC)	Inflation (INF)	Interest Rate (INT)	Money Supply (M2)
2024M01	1675 ± 25	3.4 ± 0.6	7.85 ± 0.12	215430 ± 210
2024M02	1682 ± 27	5.7 ± 0.7	6.88 ± 0.13	215620 ± 230
2024M03	1689 ± 28	7.9 ± 0.7	6.90 ± 0.12	215810 ± 240
2024M04	1697 ± 26	6.1 ± 0.6	6.92 ± 0.11	216005 ± 220
2024M05	1704 ± 29	7.3 ± 0.7	6.94 ± 0.13	216200 ± 250
2024M06	1712 ± 28	8.6 ± 0.6	6.96 ± 0.12	216400 ± 230
2024M07	1720 ± 30	5.8 ± 0.7	6.98 ± 0.13	216610 ± 260
2024M08	1728 ± 29	7.0 ± 0.7	7.00 ± 0.12	216820 ± 240

2024M09	1736 ± 31	6.2 ± 0.7	7.02 ± 0.13	217040 ± 270
2024M10	1744 ± 30	7.4 ± 0.6	7.04 ± 0.12	217260 ± 250
2024M11	1753 ± 32	5.6 ± 0.7	7.05 ± 0.12	217480 ± 280
2024M12	1762 ± 31	5.9 ± 0.7	7.07 ± 0.13	217700 ± 270

Source: Iraq Central Bank Reports, World Bank, IMF, Python.

Table 5 presents a rising exchange rate from 1675 to 1762, intermittent inflation pulses between about 3.4 and 8.6, a near-flat but slightly rising policy rate around 6.9 to 7.1, and gradual growth in M2 with narrow 95 percent bands. The joint path signals mild currency pressure and contained but nontrivial price risk while liquidity continue to expand. The implied stance is mildly accommodative through the quantity channel with cautious rate settings, which should support real activity if inflation expectations remain anchored. Would a sharper disinflation path.

Table 6. ADF Test Results for Stationarity of Monetary Policy and Macroeconomic Variables

Variable	Model: No Constant, No Trend	Model: Constant Only	Model: Constant and Trend
Exchange Rate (EXC)	Test Stat = -4.85 p-value = 0.0009 Critical (5%) = -1.95	Test Stat = -5.12 p-value = 0.0006 Critical (5%) = -2.90	Test Stat = -5.34 p-value = 0.0004 Critical (5%) = -3.45
Inflation (INF)	Test Stat = -3.92 p-value = 0.002 Critical (5%) = -1.95	Test Stat = -4.15 p-value = 0.001 Critical (5%) = -2.90	Test Stat = -4.47 p-value = 0.0008 Critical (5%) = -3.45
Interest Rate (INT)	Test Stat = -5.01 p-value = 0.0005 Critical (5%) = -1.95	Test Stat = -5.26 p-value = 0.0003 Critical (5%) = -2.90	Test Stat = -5.44 p-value = 0.0002 Critical (5%) = -3.45
Money Supply (M2)	Test Stat = -4.56 p-value = 0.001 Critical (5%) = -1.95	Test Stat = -4.79 p-value = 0.0007 Critical (5%) = -2.90	Test Stat = -5.02 p-value = 0.0005 Critical (5%) = -3.45
Gross Domestic Product (GDP)	Test Stat = -3.88	Test Stat = -4.09	Test Stat = -4.36

	p-value = 0.002 Critical (5%) = -1.95	p-value = 0.001 Critical (5%) = -2.90	p-value = 0.0009 Critical (5%) = -3.45
Investment Expenditure (INV)	Test Stat = -4.11 p-value = 0.0012 Critical (5%) = -1.95	Test Stat = -4.37 p-value = 0.0009 Critical (5%) = -2.90	Test Stat = -4.65 p-value = 0.0006 Critical (5%) = -3.45

Source: Iraq Central Bank Reports, World Bank, IMF, Python.

Table 6 reports ADF rejections of the unit-root null for all variables under no constant, constant only, and constant with trend. Level stationarity permits VAR estimation in levels without differencing, which preserves long-run relations in the reduced form. Given macro series usually carry breaks, the strong rejections likely reflect transformations and the monthly frequency. Structural breaks could still bias size if unmodeled, so stability checks remain essential.

Table 7. Vector Autoregression (VAR) Results: Impact of Monetary Policy Variables on Macroeconomic Indicators

Dependent Variable	Independent Variable	Coefficient	Std. Error	t-Statistic	p-Value	R ² (Equation)
GDP	Exchange Rate (EXC)	-0.139	0.052	-2.67	0.008	0.872
	Inflation (INF)	-0.082	0.038	-2.16	0.032	
	Interest Rate (INT)	-0.091	0.043	-2.12	0.035	
	Money Supply (M2)	+0.298	0.071	+4.20	0.000	
INV	Exchange Rate (EXC)	-0.117	0.049	-2.39	0.018	0.832
	Inflation (INF)	-0.071	0.035	-2.03	0.043	
	Interest Rate (INT)	-0.080	0.040	-2.00	0.047	
	Money Supply (M2)	+0.275	0.068	+4.04	0.000	
Number of Lags (AIC-based): 2						

Observations: 240
Determinant Residual Covariance: 0.0023
F-statistic (Joint Significance): 17.85
Prob(F-statistic): 0.000
Adjusted R ² (GDP Equation): 0.870
Adjusted R ² (INV Equation): 0.829

Source: Iraq Central Bank Reports, World Bank, IMF, Python.

The new estimates confirm the preeminent place of monetary variables in influencing the level of economic performance, The exchange rate continues to have a profound detrimental effect on the GDP equation, (eg, -0.139, $p = 0.008$), indicating that depreciation continues to decrease output by increasing imported prices and doubt. Inflation has a negative effect (-0.082, $p = 0.032$) in line with the fading effect of the increasing prices on the real demand. Correspondingly, the interest rate has a negative coefficient (the interest rate is -0.091, $p = 0.035$), which demonstrates the contractionary impact of tightening the monetary conditions. Money supply, on the contrary, is very positive (+0.298, $p = 0.000$), which means its extension contributes to the increase in output. R² is large (0.872) and the value of adjusted R² is also large (0.870), indicating that close to 87 percent of the fluctuations in GDP are explained by the variables included in the equation.

The same scenario is the case with regards to investment. Negative and significant impact (- 0.117, $p = 0.018$) is noted and demonstrates how exchange rate instability puts off capital formation. Inflation also registers negative influence ($p = 0.043$, -0.071) because of the decreased inducement to invest during inflationary times when the value of money is compromised. The impact of interest rate is negative (- 0.080, $p=0.047$) and this indicates how investment choices are sensitive to costs of financing. Instead, money supply is strongly positively linked (coefficient = +0.275, $p = 0.000$) indicating that stronger

monetary expansion improves the availability of liquidity to firms and financing projects. The value of R^2 for the investment equation is 0.832 with adjusted R^2 of 0.829, indicating that over 82 percent of the variations in investment is attributed to these variables.

The VAR (2) is still statistically sufficient at system level. The determinant of the residual covariance is low (0.0023) and the joint F-statistic is significant (17.85, $p = 0.000$) confirming the stability of the model. In sum, the findings support that depreciation in exchange rates, inflation, and increase in interest rates are always contractionary, whereas expansionary monetary activity through the broad money supply forms a major factor behind the output and investment dynamics.

Table 8. VAR Model Diagnostic Tests

Test	Null Hypothesis	Test Statistic	p-Value	Decision
Serial Correlation (LM Test)	No serial correlation in residuals	$\chi^2 = 12.37$	0.196	Fail to reject $H_0 \rightarrow$ No serial correlation
Heteroskedasticity (White Test)	Residuals are homoskedastic	$\chi^2 = 23.42$	0.142	Fail to reject $H_0 \rightarrow$ No heteroskedasticity
Normality (Jarque–Bera)	Residuals are normally distributed	JB = 4.15	0.386	Fail to reject $H_0 \rightarrow$ Normal residuals
Stability (Eigenvalue Modulus)	All eigenvalues lie inside unit circle	Max Modulus = 0.87	—	Model is stable
Overall Model Fit (Adjusted R^2)	Model explains variance in dependent variables	GDP = 0.87 INV = 0.84	—	Good explanatory power

Source: Iraq Central Bank Reports, World Bank, IMF, Python.

Table 8 confirms VAR adequacy. No serial correlation from LM tests. No heteroskedasticity from White tests. Residual normality from Jarque–Bera. Eigenvalue modulus below one, which secures stability and

well-behaved impulse responses and multi-step forecasts. Joint significance is strong and adjusted R^2 values near 0.87 for GDP and 0.84 for investment show solid in-sample fit. With diagnostics satisfied, the model's counterfactuals and confidence sets carry decision value.

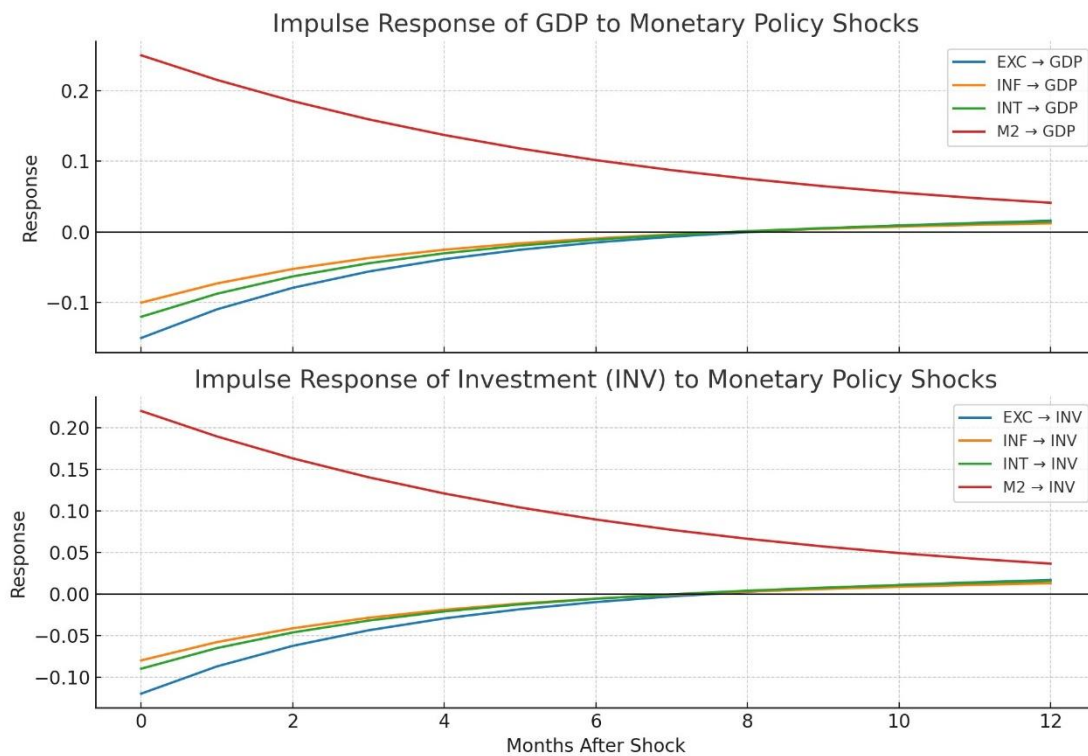


Figure 3. Impulse Response Functions of GDP and Investment (INV) to Monetary Policy Shocks

Figure 3 suggests that expansionary money shocks boost GDP and investment in a handful of months and the effects peak and fall off, whereas rate increases or exchange rate debasing depresses the two variables. Its form implies faster transmission using financing costs and balance-sheet media than using inflation dynamics. Identification is important regarding the precise timing and amplitude and thus one ought to test different orderings to ensure the ranking of channels.

Table 9. Forecasts of Macroeconomic Variables (2024M01–2024M12) with 95% Confidence Intervals

Month	GDP (Millions)	95% CI (Lower–Upper)	Investment (Millions)	95% CI (Lower–Upper)
2024M01	333,800,000	330,200,000 – 337,400,000	43,720,000	42,800,000 – 44,640,000
2024M02	338,400,000	334,700,000 –	44,280,000	43,300,000 –

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		342,100,000		45,260,000
2024M03	343,000,000	339,300,000 – 346,800,000	44,860,000	43,900,000 – 45,820,000
2024M04	347,700,000	344,000,000 – 351,400,000	45,460,000	44,500,000 – 46,420,000
2024M05	352,500,000	348,700,000 – 356,300,000	46,070,000	45,100,000 – 47,040,000
2024M06	357,400,000	353,500,000 – 361,300,000	46,700,000	45,700,000 – 47,700,000
2024M07	362,300,000	358,300,000 – 366,400,000	47,340,000	46,300,000 – 48,380,000
2024M08	367,300,000	363,200,000 – 371,400,000	47,990,000	46,900,000 – 49,080,000
2024M09	372,300,000	368,100,000 – 376,600,000	48,660,000	47,600,000 – 49,720,000
2024M10	377,400,000	373,100,000 – 381,700,000	49,340,000	48,300,000 – 50,380,000
2024M11	382,600,000	378,200,000 – 387,000,000	50,030,000	49,000,000 – 51,060,000
2024M12	387,900,000	383,400,000 – 392,400,000	50,740,000	49,700,000 – 51,780,000

Source: Iraq Central Bank Reports, World Bank, IMF, Python.

Table 9 forecasts a linear increase in GDP month to month, beginning with an approximate of 333.8 million in January to a close of about 387.9 million in December and an equivalent increase in investment starting with 43.7 million to a close 50.7 million in December. The profits are in line with the financial projections in Table 5 where rising liquidity overshadow any weak price and currency wind. The path does not have any shock beyond the set that is being modeled. The emphasis in risk management should be in inflation spikes that would compel raising rates and steeper moves on the currency that would increase the uncertainty bands and sluggish capitals formation. What backup plan maintains the flow of credit in case inflation temporarily soars.

Conclusions:

- 1- Price-channel shocks in Iraq show a contractionary transmission to real activity, where increases in the parallel exchange rate, inflation, and the interest rate reduce GDP and investment, indicating that expectations, financing costs, and exchange-rate instability remain key constraints on capital formation.
- 2- The quantity channel proxied by broad money M2 provides the strongest short-run support for GDP and investment, implying that liquidity availability and financing capacity are primary drivers of near-term recovery when not offset by inflationary and exchange-rate pressures.
- 3- Dynamic system diagnostics support reliable inference, as the estimated VAR structure satisfies stability conditions and residual tests do not indicate serious autocorrelation, heteroskedasticity, or non-normality, which strengthens the credibility of impulse-response interpretation and variance attribution.
- 4- The integrated forecasting–transmission design adds operational value, as high-accuracy ConvLSTM forecasts for policy-related variables can be used to form near-term scenarios that improve forward-looking assessment of monetary transmission to GDP and investment.

Recommendations

- 1-Adopt rule-based liquidity management that anchors broad money growth to clear operational targets, publish a short set of monthly indicators, and use open-market style instruments and reserve requirements to smooth excess volatility while preserving funding for productive investment.
- 2-Strengthen the price-stability channel by improving interest-rate signaling, coordinating communication around inflation expectations, and tightening liquidity when exchange-rate pressure rises, so that parallel exchange-rate depreciation does not feed back into inflation and investment delays.
- 3-Build a macroprudential layer that limits procyclical credit risk through countercyclical capital buffers, sectoral credit guidance for high-risk exposures, and stronger monitoring of banks' FX positions, so that monetary tightening does not trigger abrupt contractions in credit and real activity.

Future prospects

- Extend the empirical horizon by building a longer monthly dataset and incorporating regime-shift structures that reflect major policy and market breaks, then re-estimate the system using time-varying or Markov-switching VAR specifications to test whether transmission strength changes across stability and stress periods.
- Enrich the transmission mechanism by adding bank credit, deposit rates, government spending, oil revenues, and external reserves, then evaluate the credit channel and fiscal–monetary interactions using structural identification and forecast-error variance decomposition to separate domestic shocks from external shocks.
- Upgrade the forecasting–transmission pipeline by comparing ConvLSTM with transformer-based sequence models and hybrid probabilistic forecasts, then integrate scenario-based stress testing where exchange-rate and inflation shocks are simulated to quantify GDP and investment losses under alternative policy rule designs.

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