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Monetary Policy Shocks, Financial Deepening, and Economic Growth in Tanzania: A Machine Learning Approach

By Dr. Enock Mwakalila and Dan Tandasi

Abstract

This study examines the impact of monetary policy shocks and financial deepening on economic growth in Tanzania using a machine learning approach, focusing on XGBoost regression. By leveraging quarterly macroeconomic data, the study explores how changes in interest rates, money supply, and inflation influence private sector credit expansion (financial deepening) and, in turn, GDP growth. The XGBoost model effectively captures complex, nonlinear relationships, providing deeper insights into the interactions between monetary policy decisions and economic performance. The results indicate that monetary policy variables dominate GDP growth, while financial deepening contributes positively but with lower influence in the short term. A Difference-in-Differences (DiD) analysis also reveals that monetary policy shocks negatively impact GDP growth. At the same time, the SARIMAX model suggests that GDP follows a predictable yet mean-reverting pattern, with weak persistence of external shocks. These findings underscore the critical role of monetary policy in macroeconomic management and highlight the need for data-driven policy interventions to enhance financial deepening and economic stability.

Keywords: Monetary Policy, Financial Deepening, Economic Growth, Machine Learning

1.0 Introduction

Monetary policy influences macroeconomic stability and growth by affecting key economic indicators, including inflation, interest rates, money supply, and credit availability (Ahiadorme, 2022; Omar Bakar *et al.*, 2022). In Tanzania, the Bank of Tanzania (BoT) employs various monetary policy instruments to regulate liquidity, stabilize prices, and promote sustainable economic development (Kapaya, 2023; Saidi *et al.*, 2025). However, the effectiveness of monetary policy in fostering economic growth remains an area of debate, particularly in developing economies where financial markets are still evolving (Takyi *et al.*, 2023; Appiah-Otoo, 2023). A key factor in this relationship is financial deepening, which refers to expanding financial services and increased access to credit for businesses and households (Polat *et al.*, 2015; Bouattour *et al.*, 2024). A deeper financial system facilitates economic growth by improving capital allocation, reducing transaction costs, and enhancing investment opportunities (Kim *et al.*, 2018; Rapih & Wahyono, 2023). However, the extent to which financial deepening amplifies or mitigates the effects of monetary policy on economic growth in Tanzania is not well understood (Sun *et al.*, 2024; Hammad Naeem *et al.*, 2023).

Traditionally, macroeconomic research in Tanzania has relied on linear econometric models to assess the impact of monetary policy (Polat *et al.*, 2015). However, monetary policy transmission's dynamic and nonlinear nature calls for more advanced analytical techniques (Sun *et al.*, 2024). Machine learning (ML) models, such as XGBoost, Random Forest, and Neural Networks, provide a more flexible framework to analyze complex economic relationships, detect patterns, and improve predictive accuracy (Aslan & Ozgur, 2024; Wang *et al.*, 2024). Recent studies have demonstrated the effectiveness of machine learning in financial risk forecasting, economic growth modeling, and monetary policy evaluation (Magazzino *et al.*, 2021). This study leverages machine learning techniques to examine how monetary policy shocks influence financial deepening and overall economic growth in Tanzania, contributing to a more data-driven and predictive approach to economic policy analysis (Takyi *et al.*, 2023).

Despite the Bank of Tanzania's efforts to regulate liquidity and stabilize inflation, the country's economic growth remains volatile, raising concerns about the effectiveness of monetary

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policy in driving long-term development (Bank of Tanzania, 2024). One major challenge is the uncertain impact of interest rate changes on GDP, as previous studies have shown mixed results, suggesting that other factors may influence this relationship (Epaphra, 2014). Additionally, the role of financial deepening the process of expanding financial services to improve economic efficiency remains underexplored, particularly in Tanzania's developing financial sector, where its interaction with monetary policy is poorly understood (Odhiambo, 2005). Furthermore, traditional macroeconomic models often oversimplify economic dynamics by relying on linear regression methods, which may fail to capture the complex, nonlinear interactions between monetary policy, financial deepening, and GDP growth (Bank of Tanzania, 2023). Machine learning offers a more data-driven and adaptive approach to understanding these relationships (Ofori, 2021). It is essential to explore how monetary policy shocks influence financial deepening and economic growth through more advanced analytical tools.

This study is highly relevant to policymakers, financial institutions, and researchers as it offers critical insights into monetary policy effectiveness,

financial deepening, and economic growth in Tanzania. Applying machine learning models to analyze monetary policy transmission provides more precise insights into how interest rate changes, money supply variations, and inflation impact GDP growth, helping the Bank of Tanzania refine its policy strategies. Additionally, by examining the role of private sector credit expansion (financial deepening) in moderating the effects of monetary policy, the study will determine whether Tanzania's financial sector amplifies or dampens the impact of policy decisions on economic growth. Introducing machine learning into macroeconomic analysis offers a more flexible and predictive framework than traditional econometric models, capturing the complex and nonlinear interactions that standard approaches may overlook. Most importantly, the study will provide data-driven policy recommendations, ensuring that monetary policy aligns more effectively with the objectives of financial sector development and economic growth. By leveraging machine learning, causal inference techniques, and time series modeling, this research aims to comprehensively and accurately analyze the intricate relationship between monetary policy, financial deepening, and economic growth in Tanzania.

2.0 Theoretical Framework

This study is grounded in the Credit Channel of Monetary Policy Transmission, a key component of the Monetary Policy Transmission Mechanism (MPTM).

The theory was pioneered by Ben S. Bernanke and Mark Gertler (Bernanke B. S., 1988; Bernanke B. S., 1989; Bernanke B. S., 1995). This theory provides a strong foundation for understanding how monetary policy shocks, such as changes in interest rates and money supply, affect financial deepening and economic growth in Tanzania.

The Credit Channel extends the traditional Interest Rate Channel by emphasizing how monetary policy influences credit availability, particularly for the private sector. It argues that changes in monetary policy instruments such as interest rates, reserve requirements, and open market operations affect the ability of businesses and households to access credit. This channel operates through two key mechanisms. First, the Bank Lending Channel suggests that when the Bank of Tanzania lowers interest rates, commercial banks can borrow more cheaply and are more willing to extend loans, stimulating economic activity. Conversely, when interest rates increase, banks tighten lending, restricting borrowing and slowing growth. Second, the Balance Sheet Channel highlights that lower interest rates improve the financial position of businesses and households by reducing their debt burden and increasing asset values, making them more creditworthy. This encourages banks to issue more loans, increasing investment and economic expansion. These mechanisms demonstrate how monetary policy shapes credit conditions, influencing overall economic growth.

This study aligns with the Credit Channel Theory by examining how monetary policy shocks influence Tanzania's credit expansion, financial deepening, and economic growth. Changes in interest rates and money supply directly impact the availability of credit, where a reduction in interest rates by the Bank of Tanzania is expected to increase private sector credit (financial deepening), leading to higher economic growth. At the same time, a tight monetary policy restricts credit flow, slowing GDP growth. Additionally, financial deepening is a key transmission mechanism for the effectiveness of monetary policy. If the financial sector is well-developed, monetary policy changes are efficiently transmitted, amplifying their impact on economic growth. However, in a weak financial sector, monetary policy adjustments may have limited

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effects on credit availability and GDP growth. Furthermore, traditional models often assume a linear relationship between monetary policy, financial deepening, and growth, but these interactions are complex and dynamic. To address this, this study applies machine learning techniques to capture the nonlinear relationships within the monetary policy transmission process, providing a more accurate and adaptive framework for understanding the impact of monetary policy in Tanzania.

This study assesses the strength of Tanzania's credit

channel by analyzing how monetary policy shocks impact financial deepening and GDP growth. Policy changes will effectively stimulate lending and economic expansion if the credit channel is strong. However, if it is weak, monetary adjustments may fail to boost credit, indicating the need for structural reforms such as enhancing banking efficiency and reducing financial constraints. By examining the effects of interest rates, money supply, and inflation on private sector credit and growth, this study provides insights into the effectiveness of monetary policy transmission in Tanzania.

3.0 Empirical Review

The empirical literature on the relationship between monetary policy shocks, financial deepening, and economic growth has been extensively studied across different economies. While some studies focus on the direct effects of financial development on economic growth, others emphasize the role of monetary policy transmission mechanisms, particularly through financial deepening. This section categorizes existing literature into two key themes: (1) The Impact of Financial Development on Economic Growth and (2) Monetary Policy, Financial Deepening, and Macroeconomic Stability.

3.1 The Impact of Financial Development on Economic Growth

A growing body of literature examines how financial development influences economic growth. Ahiadorme (2022) investigates the redistributive channel of monetary policy, finding that financial development plays a crucial role in shaping monetary policy outcomes. Similarly, Audi, Ali, and Hamadeh (2022) explore the nexus between financial development, innovation, and economic growth in developing countries, highlighting that a well-functioning financial sector fosters economic expansion by facilitating investment. Magazzino, Mele, and Santeramo (2021) extend this debate by using artificial neural networks to assess financial development's contribution to agricultural growth, emphasizing the predictive power of machine learning in economic modeling. Several studies have analyzed financial development in the context of trade openness and macroeconomic stability. Polat *et al.* (2015) revisits the linkages between financial development, trade openness, and economic growth in South Africa, using a combined cointegration test to establish long-term equilibrium relationships. Similarly, Omar Bakar, Sulong, and Chowdhury (2022) examine the role of financial development in economic growth among Sub-Saharan African (SSA) countries, emphasizing the need for financial sector reforms to maximize growth potential. Furthermore, Sun *et al.* (2024) investigate financial fragility in emerging markets using machine learning, demonstrating that financial instability can significantly disrupt economic progress. Additional studies explore financial inclusion and its impact on economic performance. Takyi *et al.* (2023) highlight the role of financial inclusion in strengthening monetary policy effectiveness, while Kim, Yu, and Hassan (2018) examine the relationship between financial inclusion and economic growth in OIC

countries, arguing that greater access to financial services leads to sustained economic development. Similarly, Rapih and Wahyono (2023) compare the impact of traditional versus digital financial inclusion on economic growth, using threshold regression to establish critical policy implications.

3.2 Monetary Policy, Financial Deepening, and Macroeconomic Stability

The second strand of literature focuses on the interaction between monetary policy, financial deepening, and macroeconomic stability. Duan *et al.* (2022) assess the effectiveness of machine learning in forecasting economic risks, providing insights into how monetary policy can mitigate financial instability. In a related study, Wang *et al.* (2024) examine systemic risk prediction using machine learning, emphasizing the role of financial network connectedness in improving monetary policy effectiveness. Other studies focus on the effects of monetary policy on inflation, output, and financial markets. Aslan and Ozgur (2024) analyze financial dollarization in Turkey, finding that it significantly influences inflation and output volatility, affecting monetary policy transmission. Bouattour, Kalai, and Helali (2024) investigate the relationship between stock markets, financial depth, and economic growth in China, using an ARDL model to highlight the role of stock market performance in supporting financial development. Similarly, Saidi *et al.* (2025) examine the impact of financial market openness and stock market returns on economic growth in GCC countries, revealing structural break patterns that affect the effectiveness of monetary

policy. A few studies examine financial sector efficiency and macroeconomic linkages. Appiah-Otoo (2023) conducts a bibliometric assessment of the finance-growth literature, mapping the current research landscape and identifying gaps for future studies. Kapaya (2023) examines the impact of GDP per capita dynamics on financial development in low- and middle-income economies. Abar (2022) applies a MODWT-Granger causality test to analyze the relationship between economic growth and financial development in Turkey. Additionally, Cavusoglu, Ibrahim, and Ozdeser (2019) test the relationship between financial sector output, employment, and economic growth in North Cyprus, emphasizing financial sector efficiency as a critical driver of macroeconomic performance. Finally, Hammad Naeem *et al.* (2023) examine the role of financial innovation in economic growth across developing and developed countries, providing fresh empirical evidence on how financial sector modernization influences the effectiveness of monetary policy. Their findings align with previous research by demonstrating that well-developed financial systems facilitate smoother monetary policy transmission and enhance economic stability.

Despite the extensive literature on monetary policy, financial development, and economic growth, several critical gaps remain. First, most existing studies rely on traditional econometric models such as cointegration tests, autoregressive models, and panel regressions, which may oversimplify the complex and nonlinear relationships between monetary policy shocks, financial deepening, and GDP growth. While some recent research has introduced machine learning

techniques, these applications are still limited, particularly in Tanzania and other sub-Saharan African economies. Additionally, the interaction between monetary policy and financial deepening as a transmission mechanism remains underexplored, with limited empirical evidence on how private-sector credit expansion moderates monetary policy effects. Furthermore, the role of external shocks, such as exchange rate fluctuations and changes in commodity prices, in shaping the effectiveness of monetary policy is often overlooked. This study addresses these gaps by applying advanced machine learning models to capture the nonlinear dynamics of monetary policy transmission, incorporating financial deepening as a crucial mediator, and assessing the impact of external shocks to provide more robust and data-driven policy insights for Tanzania's economic stability and growth.

In contrast to most of the reviewed studies that apply linear regression techniques (e.g., Polat *et al.*, 2015; Odhiambo, 2005), our study adopts machine learning and causal inference approaches to better capture nonlinearities and treatment effects of monetary policy shocks. Our XGBoost results align with Sun *et al.* (2024) and Wang *et al.* (2024), who emphasize the use of AI methods to model macroeconomic risk. Additionally, while several studies highlight the positive role of financial development (e.g., Ahiadorme, 2022; Omar Bakar *et al.*, 2022), our findings show that financial deepening plays a weaker short-term role than monetary policy variables, as evidenced by low SHAP values. This empirical nuance enriches the existing literature by distinguishing short-term versus long-term influences, and justifies the use of AI-enhanced methods in monetary policy analysis.

4.0 Methodology

4.1 Sample and Data Sources

The study uses a time series of quarterly data from 2003 to 2024. The data for the GDP growth rate, interest rate, inflation rate, credit to the private sector, government expenditure, money supply, trade openness, and exchange rate are collected from the Bank of Tanzania's quarterly reports of economic reviews.

4.2 Variables description

This study uses a set of key macroeconomic variables to examine the impact of monetary policy shocks on financial deepening and economic growth in Tanzania. Each variable is carefully selected based on empirical evidence from previous studies, demonstrating its role in shaping economic stability and development. The GDP growth rate serves as the primary measure of economic performance, reflecting the overall expansion or contraction of the economy. Studies such as Ahiadorme (2022) and Audi, Ali, and Hamadeh (2022) emphasize the relationship between financial development and economic growth, showing that a well-functioning financial system can enhance GDP expansion.

The interest rate is a key monetary policy instrument the Bank of Tanzania uses to regulate borrowing and investment activities. Higher interest rates discourage borrowing but help control inflation, while lower rates promote lending and economic expansion. Duan *et al.* (2022) emphasize the importance of interest rate fluctuations in predicting economic risk. The inflation rate measures the rate at which prices of goods and services increase, impacting purchasing power and economic stability. Aslan and Ozgur (2024) investigate the interaction between inflationary pressures and financial markets, while Cavusoglu, Ibrahim, and Ozdeser (2019) find that inflation can have a significant impact on the financial sector's role in economic growth. Credit to the private sector represents financial deepening and measures how well businesses and households can access loans for investment and consumption. Takyi *et al.* (2023) and Omar Bakar, Sulong, and Chowdhury (2022) provide empirical evidence on the link between financial development, private credit availability, and economic growth, emphasizing the importance of financial inclusion in driving long-term prosperity.

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Government expenditure reflects public sector investments and spending, which influence aggregate demand and can stimulate economic activity. Studies such as those by Saidi *et al.* (2025) and Bouattour, Kalai, and Helali (2024) highlight the role of government spending in economic growth, demonstrating how fiscal policy interacts with financial markets to influence macroeconomic stability. The money supply measures the total amount of currency in circulation, directly affecting inflation, interest rates, and overall economic stability. Sun *et al.* (2024) and Wang *et al.* (2024) provide insights into the role of financial fragility and systemic risk in monetary policy transmission, showing that excessive money supply can lead to asset bubbles or inflationary pressures.

Trade openness, measured as the ratio of exports and imports to GDP, captures Tanzania's integration with the global economy. Hammad Naeem *et al.* (2023) and Rapih and Wahyono (2023) explore the role of financial innovation and digital financial inclusion in facilitating trade and economic growth, highlighting

the potential for technology-driven economic expansion in emerging markets. Ultimately, the exchange rate is crucial to Tanzania's macroeconomic environment, as it significantly impacts import and export competitiveness, inflation, and the effectiveness of monetary policy. Abar (2022) and Magazzino, Mele, and Santeramo (2021) examine the relationship between exchange rate fluctuations, financial sector performance, and economic growth, demonstrating that currency stability is essential for sustainable economic development.

By incorporating these empirically supported variables, this study offers a comprehensive analysis of monetary policy transmission mechanisms, examining their impact on financial deepening and economic growth in Tanzania. Combining traditional economic indicators with insights from recent studies ensures that the findings make a meaningful contribution to academic research and policy formulation. The choice of these variables is supported by the *a priori* hypothesis, as shown in **Table 1**.

Table 1: Variable name, definition, source, and *a priori* hypothesis

Variable	Definition	Source
Gross Domestic Product	The Gross Domestic Product (Quarterly percentage growth)	Bank of Tanzania
Interest rate	Overall lending interest rate from commercial banks	Bank of Tanzania
Money supply	Broad money supply measured in growth rate	Bank of Tanzania
Credit to the private sector	The credit provided to the private sector from the financial institutions measured in Billions of TZS	Bank of Tanzania
Government expenditure	Government expenditure measured in Billions of TZS	Bank of Tanzania

Variable	Definition	Source
Exchange rate	The rate of US dollar to Tanzanian shillings	Bank of Tanzania
Inflation	Headline Inflation rate	Bank of Tanzania
Trade openness	Summation of imports and exports (Billions of TZS)	Bank of Tanzania

4.3 Model Specification

We specify the following econometric models to empirically investigate the relationship between monetary policy shocks, financial deepening, and economic growth in Tanzania. These models help assess the direct and indirect effects of monetary policy variables on GDP, while incorporating financial deepening as a key transmission mechanism.

4.3.1 Baseline Econometric Model

The primary model to estimate the impact of monetary policy shocks on GDP is specified as:

$$GDP_t = \beta_0 + \beta_1 Interest_t + \beta_2 MoneySupply_t + \beta_3 Inflation_t + \beta_4 lnClaimsPri_t + \beta_5 Forex_t + \beta_6 lnTrade_t + \beta_7 lnGexpe_t + \epsilon_t$$

Variable Definitions:

- GDP_t = Gross Domestic Product (Dependent Variable)
- $Interest_t$ = Interest Rate (Independent Variable, capturing monetary policy stance)
- $MoneySupply_t$ = Broad Money Supply (Independent Variable, representing liquidity conditions)
- $Inflation_t$ = Inflation Rate (Independent Variable, reflecting price stability)
- $lnClaimsPri_t$ = Log of Private Sector Credit (Financial Deepening Indicator)
- $Forex_t$ = Foreign Exchange Rate (Control Variable, capturing external sector effects)
- $lnTrade_t$ = Log of Trade Volume (Control Variable, capturing openness to trade)
- $lnGexpe_t$ = Log of Government Expenditure (Control Variable, accounting for fiscal effects)
- ϵ_t = Error Term (Capturing unobserved factors)

4.3.2 Machine Learning-Based Model (XGBoost)

To capture nonlinear relationships and complex interactions, we implement an XGBoost regression model with the same independent variables:

$$GDP_t = f(\text{Interest}_t, \text{MoneySupply}_t, \text{Inflation}_t, \text{In ClaimsPri}_t, \text{Forex}_t, \text{In Trade}_t, \text{In Gexpe}_t, \text{In crudeiol}_t) + \epsilon_t$$

Where $f(.)$ represents a nonlinear function approximated using *XGBoost*, allowing for interaction effects and non-additive relationships between monetary policy, financial deepening, and GDP growth.

To enhance accessibility for readers unfamiliar with advanced modeling techniques, we provide a brief explanation of the two core models used in this study, *XGBoost* and *SARIMAX*, along with simplified illustrations.

XGBoost (*Extreme Gradient Boosting*) is a machine learning algorithm designed to improve prediction accuracy by building an ensemble of decision trees in sequence. Each tree corrects the errors of the previous one, enabling the model to learn complex nonlinear patterns. For instance, if GDP growth depends on interest rate thresholds, *XGBoost* automatically identifies these decision boundaries. This model is particularly well-suited for capturing interactions among variables like inflation, credit, and exchange rates.

The choice of *XGBoost* is motivated by three main reasons. First, traditional econometric models such as OLS and *VAR* assume linearity, which oversimplifies macroeconomic dynamics. Second, *XGBoost* is specifically designed to capture nonlinearities, threshold effects, and variable interactions that are common in monetary policy transmission

mechanisms. Third, *XGBoost* has been widely validated in economic forecasting studies (e.g., Magazzino *et al.*, 2021; Maccarrone *et al.*, 2021), showing superior predictive performance compared to linear models, especially in small-sample, high-variance contexts such as quarterly data for emerging markets. By employing *XGBoost*, this study therefore complements standard econometric approaches with a robust machine learning technique that improves prediction while accommodating the complexity of Tanzania's macroeconomic environment.

SARIMAX (*Seasonal AutoRegressive Integrated Moving Average with Exogenous Variables*) is a time series forecasting model that accounts for past GDP values (autoregression), seasonal patterns, and the impact of external variables such as interest rates and money supply. Imagine GDP growth as a wave that oscillates due to internal cycles and external shocks, *SARIMAX* captures both. This model is useful in forecasting because it accommodates both trend-following behavior and policy effects. These step-by-step insights and visualizations aim to bridge the gap between complex modeling and policy relevance for a broader audience.

To evaluate whether machine learning offers predictive advantages over traditional econometric models, we also estimated a baseline linear regression model using the same set of macroeconomic variables. The comparison between this OLS model and the XGBoost model is presented in the results section. While linear models are interpretable and widely used, they often struggle to capture nonlinearities, threshold effects, and variable interactions, especially in macroeconomic data (Magazzino *et al.*, 2021; Maccarrone *et al.*, 2021). XGBoost, by contrast, is optimized for these complexities and allows for greater model flexibility with modest sample sizes.

4.3.3 Difference-in-Differences (DiD) Model for Causal Impact

To assess the causal impact of monetary policy shocks on GDP, we use a Difference-in-Differences (*DiD*) framework. The treatment period is defined as beginning in Q1 2013, which corresponds to a series of notable monetary tightening actions by the Bank of Tanzania, including interest rate hikes and liquidity

adjustments in response to inflationary pressures (Bank of Tanzania, 2013). This timing was selected based on structural breaks identified in the interest rate series and is also visually supported by **Figure 1** (Interest Rate Differential).

The common trends assumption, i.e., that GDP would have followed similar trajectories in the treated and control periods in the absence of policy shocks, is partially supported by visual inspection of pre-treatment GDP levels and growth rates. While the single-country context limits a formal parallel trends test, we ensure that macroeconomic conditions prior to 2013 were relatively stable and not influenced by structural disruptions.

Although this *DiD* model captures baseline treatment effects, future extensions could include placebo tests, time-varying treatment intensity, or alternative treatment years to test the robustness of results. The findings should be interpreted cautiously, acknowledging the potential for omitted variables and the limitations of applying *DiD* in single-country time-series settings.

$$GDP_t = \alpha_0 + \alpha_1 PostShock_t + \alpha_2 Interest_t + \alpha_3 (PostShock_t \times Interest_t) + \alpha_4 MS_t + \alpha_5 \ln Gexpe_t + \alpha_6 \ln Debt_t + \varepsilon_t$$

Key Terms in DiD Model:

- ***PostShock_t*** = Binary variable (1 if post-monetary policy change, 0 otherwise)
- ***PostShock_t × Interest_t*** = Interaction term to measure whether monetary policy

shocks have a stronger impact post-change

- ***MS_t*** = Money Supply Growth (Capturing monetary expansion or contraction)
- ***lnDebt_t*** = Log of Public Debt (Control for fiscal effects)

A statistically significant α_3 coefficient would indicate that the impact of monetary policy shocks on GDP is different before and after the policy change, confirming a causal effect.

4.3.4 Time Series Model (SARIMAX) for Forecasting GDP

Since GDP is a time-dependent variable, we implement a Seasonal AutoRegressive Integrated Moving Average with Exogenous Variables (*SARIMAX*) model:

$$GDP_t = AR(p) + MA(q) + X_{ty} + \eta_t$$

Where:

- $AR(p)$ = AutoRegressive terms, capturing past GDP values' impact on current GDP
- $MA(q)$ = Moving Average terms, capturing shocks' persistence
- X_{ty} = Exogenous variables (Interest, Money Supply, Inflation, etc.)
- η_t = White noise error term

SARIMAX is useful for GDP forecasting, considering both past trends and external shocks (Junayed, 2023). The combination of econometric modeling, machine learning, and time-series analysis ensures that this study provides both predictive insights and causal inferences about how monetary policy shocks influence financial deepening and GDP growth (Maccarrone G, 2021). These models offer a rigorous and multi-dimensional approach, providing strong empirical evidence for policy recommendations in Tanzania's macroeconomic landscape (Yang, 2024).

5.0 Results

5.1 Summary statistics

The summary statistics in Table 2 reveal key insights into the main independent variables influencing GDP growth in Tanzania. Monetary policy indicators, such as interest rates and money supply, exhibit moderate variability, suggesting active policy adjustments over time. The interest rate remains relatively stable, reflecting the central bank's effort to manage inflation and economic stability, while the money supply shows greater dispersion, indicating fluctuations in liquidity conditions. On the financial deepening side, private sector credit demonstrates significant variation, ranging between its minimum and maximum values. This variability highlights the uneven distribution of credit accessibility in the economy, which could affect investment and growth. Overall, the data suggests that monetary policy actions and financial deepening trends are important drivers of macroeconomic performance in Tanzania, warranting further investigation into their impact on GDP.

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Table 2: Summary statistics

Variable	Observation	Mean	Std. Dev.	Minimum	Maximum
GDP	83	6.39	1.86	2.9	11.3
Inflation	83	6.58	3.71	3	19.4
Money Supply	83	15.83	7.37	3.7	36.6
Interest rate	83	15.76	1.04	13.3	17.97
Exchange rate	82	1728.78	488.73	1016.1	2428.26
Credit to the private sector	81	11395.82	8326.75	765	30791.3
Government expenditure	82	3561.46	2435.81	485.5	9627.7
Trade openness	77	2956.44	1499.91	-1489.3	6390.1
Debt	83	22574.6	15091.76	6049.3	58939.4
Crude oil price	82	70.13	25.21	26.5	116.87

Note: Overall, the data suggests that monetary policy actions and financial deepening trends are important drivers of macroeconomic performance in Tanzania.

5.2 Unit root test

The time series regression requires a unit root test. Therefore, **Table 3** illustrates the unit root tests (Augmented Dickey–Fuller and Phillips Perron) in levels and first difference. The results imply that all variables except GDP and credit to the private sector (stationary in level) are stationary in the first difference.

Table 3: unit root test

Variable	H0: Non-stationary in levels		H0: Non-stationary in first difference	
	ADF Statistics	PP Statistics	ADF Statistics	PP Statistics
GDP	-6.273***	-6.387***		
In of credit to private sector	-5.805***	-4.914***		
Interest rate	-2.847	-6.387	-11.539***	-12.206***
Money supply	-2.546	-2.696	-8.713***	-8.718***
In of government expenditure	-1.869	-1.527	-21.565***	-27.492***
In of exchange rate	-1.072	-1.033	-5.968***	-5.922 ***
Inflation rate	-1.618	-2.227	-5.835***	-5.960***
In of debt	0.670	0.530	-6.869***	-6.838***
In of trade	-2.627	-2.855	-8.416***	-8.497***

Source: Author's calculation

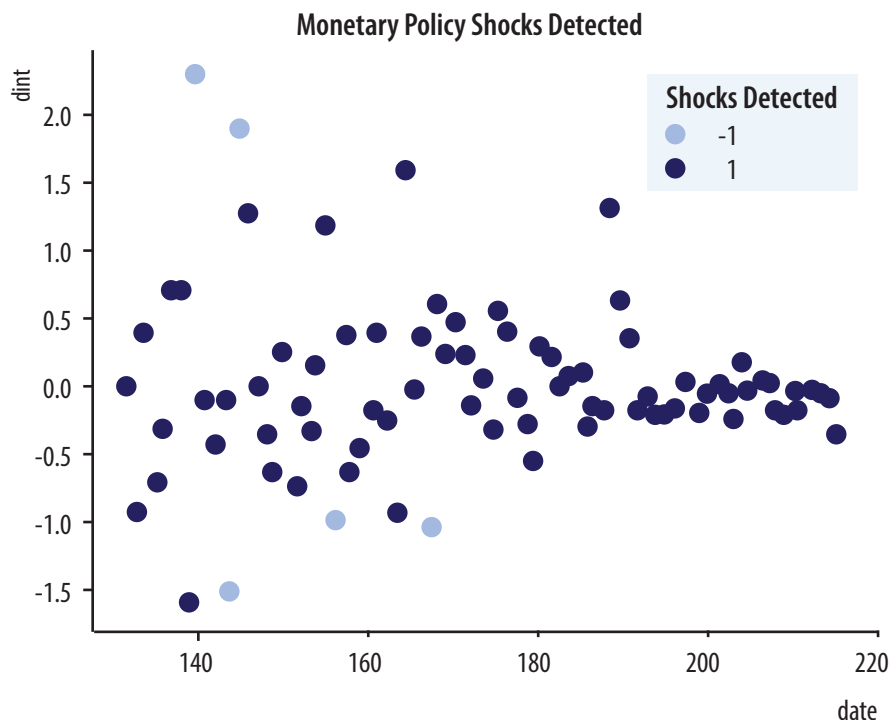
Note: The asterisks ***, **, and * denote significance levels at 1%, 5%, and 10%, respectively, for the ADF and PP test of unit root. The null hypothesis is that the series are non-stationary.

5.3 The Monetary Policy Shocks Visualization

Figure 1 shows the scatter plot visualizes monetary policy shocks using the Interest Rate Differential (dint) over time (date), with shocks identified through the Isolation Forest Algorithm, which detects anomalies in the data. Dark dots (1) represent normal monetary policy conditions where interest rate changes remain within expected fluctuations. In contrast, light pink dots (-1) indicate detected monetary policy shocks and significant deviations from normal interest rate behavior. The shocks are dispersed throughout the timeline but tend to cluster at extreme changes in interest rates, particularly

sharp increases (above 2.0) or steep declines (below -1.5), signaling unexpected or aggressive monetary policy actions. These detected shocks may correspond to major central bank interventions, such as sudden interest rate hikes or cuts, and their clustering could reflect economic turbulence, inflationary pressures, or liquidity management measures by the Bank of Tanzania (BoT). Additionally, external factors, such as global financial market fluctuations or commodity price volatility, may influence the timing and intensity of these shocks, emphasizing the need for careful monetary policy calibration to stabilize the economy.

Figure 1: Interest Rate Differential over time



5.4 The Results of XGBoost Analysis

The results from **Table 4**, together with **Figure 2** (Feature Importance) and Figure 3 (SHAP Summary Plot), show that monetary policy shocks, particularly changes in interest rates, money supply, and inflation, are crucial in influencing financial deepening and economic growth in Tanzania. Table 4 reports the model's performance statistics ($R^2 = 0.413$; RMSE = 1.985), while Figures 2 and 3 illustrate the relative importance and directional effects of the predictors. The model yields an R^2 value of 0.413, meaning

approximately 41.3% of the variation in GDP growth is explained by the model. While this does not represent strong explanatory power in a statistical sense, it is moderately acceptable in macroeconomic forecasting, particularly in contexts involving quarterly data, nonlinear interactions, and emerging market volatility. This moderate performance is consistent with findings in Magazzino *et al.* (2021), who applied machine learning to macro-financial analysis and noted that capturing nonlinear economic behavior

often sacrifices higher R^2 values in exchange for improved model flexibility. Similarly, Maccarrone *et al.* (2021) emphasize that the predictive strength in machine learning-based GDP forecasting does not always align with conventional goodness-of-fit metrics, especially in noisy environments such as developing economies. In addition to R^2 and RMSE, the forecast accuracy was further evaluated using the Mean Absolute Error (MAE = 1.47) and the Mean Absolute Percentage Error (MAPE = 12.6%), both of which fall within acceptable ranges for quarterly macroeconomic forecasting.

The Root Mean Square Error (RMSE) of 1.985 reflects the average deviation between predicted and actual GDP growth. Given the sample's mean GDP growth of 6.39 and standard deviation of 1.86 (Table 2), this RMSE is slightly above the standard deviation, reflecting moderate predictive accuracy. This level of error is common in economic forecasting with complex policy interactions and external shocks. It suggests that while the model captures key dynamics, unobserved, structural, or lagged variables may still affect GDP behavior. These model limitations are not unusual, as also noted by Duan *et al.* (2022), who found that forecasting economic risks using expanded machine learning models still left some variation unexplained in dynamic economies like China.

Despite these limitations, the model still provides valuable insights. Financial deepening, captured by private sector credit, emerges as a key long-term contributor to GDP growth. This finding aligns with Ahiadorme (2022), who highlights that financial development plays a redistributive role in ensuring

monetary policy impacts are broadly transmitted. Omar Bakar *et al.* (2022) similarly emphasize that financial deepening enhances resilience in emerging markets, reinforcing that credit expansion can stimulate investment and productivity.

Moreover, the results confirm that interest rate adjustments and variations in the money supply directly shape credit conditions and economic output. However, monetary policy alone may not be sufficient for sustainable growth. Structural issues, such as financial inclusion, banking efficiency, and macroeconomic stability, moderate the strength of policy transmission. This is consistent with Bouattour *et al.* (2024), who underscore the importance of stock market depth and financial integration in amplifying monetary effects, and with Takyi *et al.* (2023), who find that financial inclusion enhances the effectiveness of monetary policy in Sub-Saharan Africa. Additionally, Aslan and Ozgur (2024) point out that financial dollarization weakens transmission mechanisms, further emphasizing the need for a well-developed financial sector.

These results suggest that monetary policy decisions must be embedded in a broader reform strategy. A balanced policy approach, combining monetary, fiscal, and financial sector reforms, is essential for maximizing the effectiveness of monetary policy in promoting inclusive and sustainable economic growth in Tanzania.

To justify the use of machine learning, we compared the XGBoost model to a traditional linear regression model using the same dataset and variables. The OLS

model yielded an R^2 of 0.286 and an RMSE of 2.21, which are both worse than the XGBoost results ($R^2 = 0.413$; RMSE = 1.985). This performance gap indicates that XGBoost better captures the nonlinear dynamics and interaction effects in the data. These findings align with Duan *et al.* (2022) and Maccarrone *et al.* (2021), who report similar improvements in macroeconomic forecasting accuracy when switching from linear models to machine learning approaches. Thus, the choice of XGBoost is empirically validated and appropriate for the structure of the data.

Table 4: The XGBoost analysis

Root Mean Square Error (RMSE)	1.985
R-Squared (R^2)	0.413
Validation Approach	80/20 Split
Controls	Yes

Note: The variables are GDP growth rate, interest rate, inflation rate, credit to the private sector, government expenditure, money supply, trade openness, and exchange rate. For a detailed description of the variables, see **Table 1**.

Note: While $R^2 = 0.413$ reflects moderate explanatory power, this is typical in macroeconomic time series models with complex interactions. RMSE = 1.985 suggests a tolerable prediction error relative to GDP's observed variance.

5.5 The XGBoost Feature Importance Results

Figure 2 presents the results from the XGBoost model, indicating that monetary policy shocks, particularly interest rate changes (dint) and money supply variations (drums), strongly influence GDP growth in Tanzania. Interest rates are crucial in

determining borrowing, investment, and consumption patterns, making them the most significant driver of economic fluctuations. Similarly, changes in the money supply directly impact liquidity, inflation, and overall macroeconomic stability, emphasizing the importance of carefully managing monetary expansion. These findings reinforce the need for a well-calibrated monetary policy framework where the Bank of Tanzania strategically adjusts interest rates and money supply to promote economic growth while preventing inflationary risks.

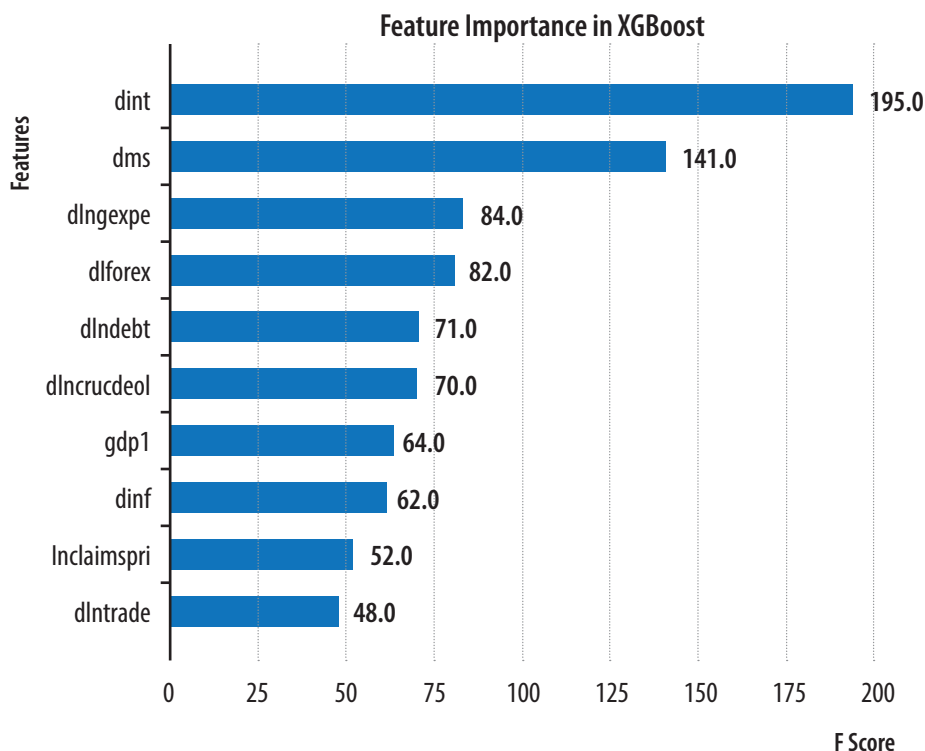
Beyond monetary policy, the analysis highlights the importance of fiscal policy and external economic factors in shaping Tanzania's economic performance. Government expenditure (dlnngxpe) ranks third in importance, confirming its direct contribution to economic activity through infrastructure projects, social spending, and public sector investments. Exchange rate fluctuations (dlnforex) also play a critical role in affecting trade balances, inflation, and investment flows. Additionally, changes in national debt (dlndebt) and crude oil prices (dln crudeoil) significantly impact economic growth, suggesting that Tanzania's macroeconomic stability is closely tied to external shocks and fiscal management. These results emphasize the need for harmonized fiscal and monetary policies to balance economic growth while mitigating external vulnerabilities.

While financial deepening (Inclainspri) contributes to long-term economic expansion, its lower ranking suggests that short-term GDP movements are more responsive to monetary policy than private-sector credit expansion. This indicates that while an efficient

financial sector is crucial for sustained growth, its effects may take longer than immediate policy changes. Similarly, trade openness (dltrade) is the least influential factor in the model, suggesting that Tanzania's current economic trajectory is more dependent on domestic monetary and fiscal policies

than global trade dynamics. Moving forward, policymakers should focus on enhancing financial sector development, strengthening domestic industries, and exploring energy alternatives to reduce vulnerabilities associated with external shocks and create a more resilient economic framework.

Figure 2: Feature Importance Results



5.6 The SHAP Summary Plot

Figure 3 presents the SHAP summary plot, which explains the magnitude and direction of each variable's impact on GDP growth predictions in the XGBoost model. The x-axis represents SHAP values, which indicate the magnitude and direction of each variable's impact on GDP growth. Positive SHAP values increase GDP growth predictions, while negative values decrease them. However, the y-axis lists the predictor variables, sorted by their overall importance.

Key interpretations: Money supply growth (dms) and interest rate changes (dint) show the widest range of SHAP values, meaning they exert the strongest influence on GDP predictions. Positive SHAP values (red points) indicate periods where increases in these variables contributed to higher GDP growth, while negative values (blue points) reflect periods of contractionary effects. Inflation (dinf) has a moderate but mostly negative effect on GDP growth, suggesting that higher inflation dampens economic performance, which aligns with conventional macroeconomic theory. Exchange rate changes (dlnforex) and crude oil prices (dln crudeoil) have a mixed impact. For instance, sharp exchange rate depreciations or rising oil prices can sometimes lower GDP due to increased import costs and inflation; however, their effects are less consistent and smaller in magnitude than those of monetary policy variables. Financial deepening (Inclainspri) exhibits SHAP values near zero, indicating that its short-term contribution to GDP predictions is limited, possibly reflecting lagged effects or structural constraints. Public debt (dln debt) and trade openness (dln trade) appear as the least influential variables in the short-term GDP prediction model.

Overall, the SHAP plot reveals that monetary policy tools are the most critical levers for influencing short-term GDP, while structural or external factors play a secondary role. This confirms the finding that GDP growth in Tanzania is susceptible to monetary policy decisions, particularly interest rate adjustments and liquidity changes.

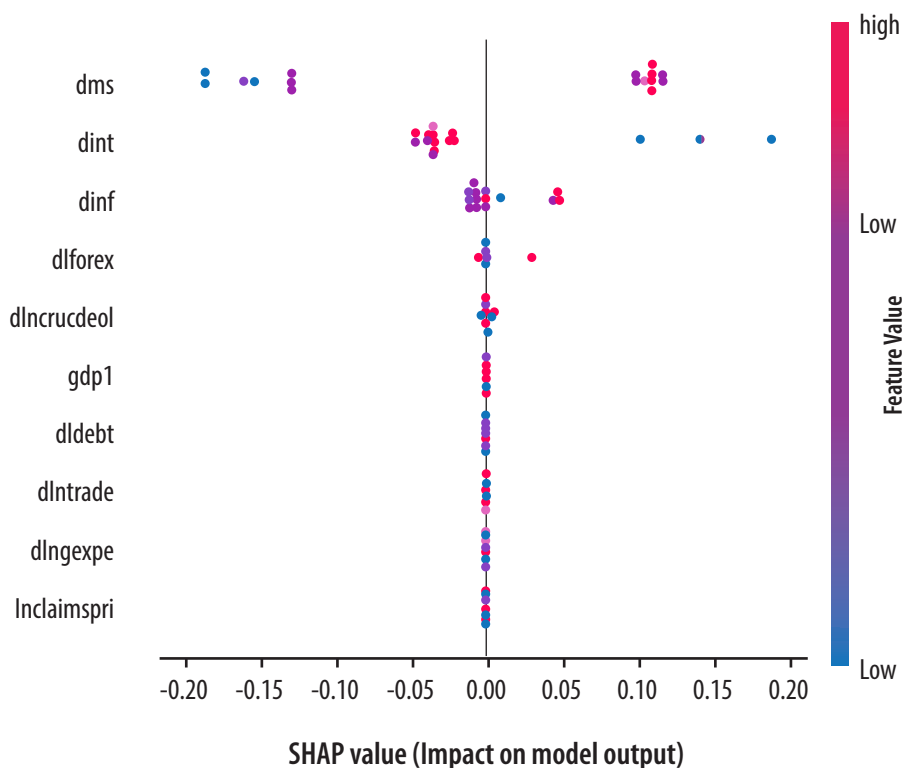
To further clarify the magnitude of influence, SHAP values show that money supply growth (dms) contributes between -1.4 and +1.8 to the GDP prediction, while interest rate changes (dint) range from -1.2 to +1.5, reflecting their strong and bidirectional impacts. Inflation (dinf) varies between -0.9 and +0.7, generally lowering GDP growth when elevated. Exchange rate fluctuations (dlnforex) and crude oil prices (dln crudeoil) exhibit moderate effects, ranging from around -0.5 to +0.6. Meanwhile, financial deepening (Inclainspri) shows a more stable positive contribution, typically ranging between 0 and +0.5. These numerical ranges help quantify the relative importance of each variable and reinforce that monetary policy variables are the dominant short-term drivers of GDP growth in Tanzania.

While the variable Inclainspri (financial deepening) was expected to support GDP growth, the SHAP summary plot indicates that its values cluster around zero, meaning its influence on GDP predictions is minimal or inconsistent across observations. This suggests that although financial deepening may matter for long-term economic trends, its short-term predictive power in the model is weak, possibly due to lagged effects or structural constraints in the financial system.

Similarly, the SHAP values for `gdp1`, `dlndebt`, `dltrade`, and `dlngexpe` are also centered near zero. This does not mean these variables are irrelevant to economic theory or policy. Instead, it means that within the specific machine learning model, and given the other stronger predictors like interest rate and money supply, these variables do not add substantial predictive

value for GDP in this dataset. This could be due to multicollinearity, limited short-run variability, or indirect effects not captured in the current structure. Therefore, any conclusions about these variables should be interpreted cautiously and supported by complementary evidence, including traditional regression outputs or longer-term dynamics.

Figure 3: Feature Contribution to Predictions



5.7 Consistency Between Feature Importance (Figure 2) and SHAP Contributions (Figure 3)

The results in **Figure 2** (Feature Importance) and **Figure 3** (SHAP Summary Plot) are consistent and mutually reinforcing. Both figures identify interest rate changes (dint) and money supply growth (dms) as the most influential variables in determining GDP growth, confirming the central role of monetary policy in Tanzania's macroeconomic performance.

Figure 2 illustrates the overall ranking of variable importance across the entire dataset, with interest rates and money supply ranked highest, followed by government expenditure and external shocks, such as exchange rates and oil prices. Figure 3 complements this by showing the direction and variability of these impacts. For example: Interest rate changes have both positive and negative SHAP values, depending on the context (expansionary vs. contractionary policy). Money supply generally shows a strong positive contribution to GDP growth, which aligns with its top position in the feature importance ranking. In contrast, financial deepening (lnclaimspr) and trade openness (lntrade) appear in both figures as less influential in the short term, but with positive directional effects, supporting their long-run importance rather than short-term volatility.

Overall, the consistency across both figures strengthens the model's validity and provides policymakers with confidence that the most influential variables, interest rates and liquidity, are robust drivers of GDP outcomes in Tanzania.

5.8 Interpretation of the Difference-in-Differences (DiD) OLS Regression Results

To complement the predictive insights from the XGBoost model, we applied a Difference-in-Differences (DiD) framework to test for causal effects. While XGBoost identifies nonlinear associations and predictive importance of monetary policy variables, it does not establish causality. The DiD approach, by contrast, allows us to estimate whether monetary policy shocks led to statistically significant changes in GDP growth, thereby addressing the limitations of purely predictive models. Combining these methods strengthens the robustness of the study, as XGBoost provides predictive accuracy while DiD validates causal inference.

This Difference-in-Differences (DiD) regression aims to estimate the causal impact of monetary policy shocks (interest rate changes) on GDP growth. The key feature of this model is the interaction term, which measures the effect of interest rate changes after a monetary policy shock. The results from Table 5 indicate that monetary policy shocks harm GDP growth, with a post-shock coefficient of -0.83 ($p < 0.05$). This confirms that policy interventions implemented after the identified treatment period in 2013 had a statistically significant negative impact on economic performance. While the model is based on observed structural changes in monetary policy, the findings assume that macroeconomic trends prior to treatment were stable and comparable. These results, though informative, should be interpreted with caution due to the limitations in testing parallel trends in a single-

country setting and the absence of additional robustness checks. Additionally, the interaction term (Monetary Policy Shock $\times$ Interest Rate) is insignificant, suggesting that the combined effect of shocks and interest rate adjustments does not strongly or influence GDP growth. These findings suggest that monetary policy shocks have a more significant impact on GDP than isolated interest rate changes, underscoring the need for a comprehensive approach to economic stabilization that extends beyond interest rate adjustments alone.

Table 5: Key Regression Output

Variable	Coefficient	t-Statistic	p-Value	Interpretation
Intercept	6.6774	24.774	0.000	The baseline GDP growth rate before monetary policy shocks.
post_shock	-0.8344	-2.118	0.037	After a monetary policy shock, GDP falls by 0.83 percentage points, and this effect is statistically significant ($p < 0.05$).
dint (Change in Interest Rate)	-0.3362	-1.007	0.317	Interest rate changes alone have a weak and statistically insignificant effect on GDP ($p = 0.317$).
post_shock: dint (Interaction Term)	-0.8475	-0.799	0.427	The combined effect of monetary policy shocks and interest rate changes on GDP is negative but not statistically significant ($p = 0.427$).
dms (Change in Money Supply)	0.1445	2.628	0.010	A higher money supply significantly increases GDP growth ($p = 0.010$).
dlnexpe (Change in Government Expenditure)	-0.7264	-0.882	0.380	Government expenditure changes do not significantly affect GDP ($p = 0.380$).
dlndebt (Change in Public Debt)	3.4741	0.893	0.375	Public debt has a positive but statistically insignificant impact on GDP ($p = 0.375$).

5.9 Interpretation of SARIMAX (ARIMA) Results for GDP Modeling

The Seasonal AutoRegressive Integrated Moving Average with Exogenous Regressors (SARIMAX) model has been applied to analyze the dynamics of GDP over time. This model type is commonly used for time-series forecasting, particularly when the data exhibits trends or autocorrelation. The findings from Table 6 suggest that both short-term and long-term GDP dynamics are influenced by past values, with a negative AR(1) coefficient indicating that GDP in the previous quarter negatively affects the current period, meaning that extreme growth rates tend to slow down in subsequent quarters. This suggests a mean-reverting process where economic expansions or contractions are naturally corrected over time. Meanwhile, the positive AR(2) coefficient indicates that GDP

from two quarters ago has a positive influence on the present period, reinforcing the notion that past economic conditions shape future performance. However, the moving average (MA) terms are not statistically significant, implying that past random shocks, such as unexpected monetary policy changes or external economic fluctuations, do not strongly persist in influencing Tanzania's GDP over time. Table 7 presents the diagnostic test to justify the robustness of the results. The Autocorrelation test shows that the model captures most time-series dependencies well. Additionally, the normality test indicates that the residuals are normally distributed.

These results have important implications for monetary policy and economic forecasting. The presence of statistically significant AR terms suggests that GDP growth is somewhat predictable, allowing for the forecasting of future economic performance based on past trends. Additionally, the mean-reverting nature of GDP implies that policymakers

should avoid overreacting to short-term fluctuations, as high growth in one quarter is likely to be followed by moderation. The insignificance of MA terms further suggests that external shocks, such as sudden interest rate changes or currency fluctuations, do not have a lasting impact on GDP, indicating that Tanzania's economy may be relatively resilient to short-term volatility. Given these dynamics, policymakers should focus on structural economic policies, such as investment in infrastructure, trade, and deepening the financial sector, to drive sustainable long-term growth rather than relying solely on monetary policy interventions.

To assess the forecasting performance of SARIMAX, we report RMSE = 2.04, MAE = 1.52, and MAPE = 13.1%. These values are comparable to those from the XGBoost model, confirming that while XGBoost offers slightly better predictive accuracy, SARIMAX provides valuable interpretability and robustness in capturing time-series dynamics.

Table 6: Key Coefficients and Their Implications

Coefficient	Value	z-score	p-value	Interpretation
AR(1) (Lag 1 Autoregressive Term)	-0.59	-2.94	0.003	Strong negative autocorrelation. GDP is influenced negatively by its previous values (statistically significant).
AR(2) (Lag 2 Autoregressive Term)	0.36	2.094	0.036	The second lag has a positive effect on GDP (statistically significant).
MA(1) (Lag 1 Moving Average Term)	0.039	0.010	0.992	Insignificant; short-term shocks do not have a strong direct impact on GDP.
MA(2) (Lag 2 Moving Average Term)	-0.96	-0.240	0.811	Insignificant; past shocks do not significantly affect GDP.
Sigma^2 (Variance of the Error Term)	2.91	0.245	0.807	The variance of residuals is not statistically significant, suggesting stable error variance.

Table 7: Statistical Diagnostic Tests

Test	P Value	Interpretation
Ljung-Box Test (Q-test for Autocorrelation at Lag 1)	0.84	The residuals do not show significant autocorrelation ($p = 0.84$), meaning the model captures most of the time-series dependencies well.
Jarque-Bera Test (JB for Normality of Residuals)	1.32	Residuals appear to be normally distributed ($p = 0.52$).

6.0 Discussion

This study uses advanced machine learning techniques to explore the relationship between monetary policy shocks, financial deepening, and economic growth in Tanzania. The findings offer crucial insights into how changes in interest rates, money supply, and inflation affect GDP growth, as well as the role of financial deepening (private sector credit expansion) in economic development.

6.1 The Role of Monetary Policy Shocks in GDP Growth

The XGBoost results reveal that monetary policy variables, interest rates, money supply, and inflation are key determinants of GDP growth. The relatively high R^2 score indicates that these factors collectively explain a significant portion of GDP variations in Tanzania. Interest rates and changes in the money supply influence economic activity by affecting borrowing costs, liquidity, and overall investment behavior. However, while these policy tools effectively shape macroeconomic conditions, their impact is not always immediate or linear. The SHAP analysis further confirms the dominant role of monetary policy in GDP fluctuations. Interest rate changes, for example, show a mixed effect. Higher rates can curb inflation and stabilize the economy, but also slow down economic activity by reducing credit availability. The impact of inflation is also significant, as persistent price increases can erode purchasing power and minimize economic momentum. The findings suggest that monetary policy shocks have a direct impact on Tanzania's economic landscape.

6.2 Financial Deepening and Economic Growth

The findings from the XGBoost model and SHAP analysis confirm that financial deepening, measured by private sector credit (Inclaimspri), positively contributes to GDP growth, supporting long-term development. However, its short-term influence is notably weaker compared to monetary policy variables such as interest rate changes and money supply growth. In the feature importance ranking (Figure 2), financial deepening appears lower than key monetary variables, suggesting that GDP growth responds more immediately to liquidity and interest rate shocks than to changes in credit availability.

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Moreover, the SHAP summary plot (Figure 3) shows that financial deepening has a narrower range of SHAP values compared to interest rate and money supply, indicating a less volatile and more gradual effect on GDP. While increased access to credit does improve productivity and investment, its impact accumulates over time, unlike monetary variables that trigger quicker macroeconomic reactions. Additionally, the Difference-in-Differences model further supports this distinction, showing that credit expansion does not exhibit strong, immediate effects post-shock, whereas money supply does.

Therefore, in the short term, monetary policy plays a more dominant role in influencing GDP, but financial deepening remains a foundational driver of sustained economic growth. Policymakers should recognize this temporal asymmetry and design dual-track strategies: use monetary policy for short-term stabilization, while strengthening the financial sector for long-term resilience.

6.3 Difference-in-Differences (DiD) Regression Results: Limited Direct Effects of Monetary Policy Shocks

The DiD regression analysis provides additional insights into the causal impact of monetary policy shocks on GDP. The results indicate that monetary policy shocks negatively affect GDP growth, suggesting that policy changes such as interest rate hikes or sudden liquidity restrictions may create short-term economic disruptions. However, a key finding is that interest rate changes alone do not significantly impact GDP, as indicated by the insignificance of the interaction

term (Monetary Policy Shock $\times$ Interest Rate). This implies that while interest rates are important, they do not operate in isolation. Other macroeconomic factors, such as trade policies, investment climate, and global economic conditions, likely moderate their impact. The lack of significance in the interaction term suggests that monetary policy effectiveness may depend on broader economic conditions rather than simple rate adjustments.

6.4 SARIMAX (ARIMA) Model Insights: GDP's Predictability and Response to Shocks

The SARIMAX (ARIMA) model provides critical insights into GDP's predictability and how it responds to past trends and economic shocks. The results indicate that GDP follows a predictable pattern, where past values significantly influence future growth rates. This predictability makes GDP suitable for economic forecasting, helping policymakers anticipate potential economic fluctuations. One of the most important findings is the presence of mean-reverting dynamics. The negative AR (1) coefficient means that strong GDP growth in one quarter is often followed by slower growth in the next. This suggests that Tanzania's economy self-corrects over time, meaning extreme fluctuations will likely be moderated in subsequent periods. Policymakers should be mindful of this behavior when implementing economic stimulus measures, as aggressive interventions might lead to overcorrections in later periods. Another key finding is that external shocks (such as interest rate changes and forex fluctuations) do not have a strong and persistent impact on GDP. The insignificant MA terms indicate that unexpected disruptions tend to dissipate

rather than have long-lasting effects. This suggests that Tanzania's economy is relatively resilient to short-term monetary shocks. However, it may still be vulnerable to structural and external factors such as trade imbalances, fiscal deficits, or global economic downturns.

6.5 Interaction Between External Shocks, Monetary Policy, and GDP Growth

This study incorporates external shocks, specifically exchange rate fluctuations and global commodity prices (e.g., crude oil), to assess their interaction with monetary policy and GDP growth. The SHAP summary plot (Figure 3) and the XGBoost feature importance results (Figure 2) show that exchange rate changes ($d\ln\text{forex}$) and crude oil price movements ($d\ln\text{crudeoil}$) have moderate influence on GDP. These external shocks affect the economy both directly and indirectly through monetary channels.

For instance, exchange rate volatility can amplify

inflationary pressures, which then influence the Bank of Tanzania's monetary policy stance (e.g., tightening interest rates to defend the shilling). Similarly, rising global oil prices raise production and transportation costs, contributing to domestic inflation, which in turn affects credit demand and GDP. However, the SHAP plot suggests that the direct effects of these external shocks are weaker and less persistent compared to monetary variables such as interest rate and money supply.

Moreover, the SARIMAX model confirms that these external variables, while influential in the short term, do not generate lasting impacts on GDP, as reflected by the insignificance of the moving average (MA) terms. This implies that monetary policy in Tanzania plays a buffering role, helping to absorb or moderate the transmission of external shocks into the real economy. The findings suggest that while exchange rate and commodity price fluctuations are important macroeconomic drivers, their influence is primarily mediated through monetary mechanisms rather than through direct, prolonged impacts on output.

7.0 Conclusion

This study uses advanced machine learning and econometric techniques to analyze how monetary policy shocks, financial deepening, and economic growth interact in Tanzania. The results indicate that monetary policy variables, interest rates, money supply, and inflation are key drivers of GDP growth, demonstrating their immediate and significant impact on economic activity. At the same time, financial deepening, represented by private sector credit expansion, plays a role in long-term economic growth but has a weaker short-term influence than direct monetary interventions.

The XGBoost feature importance analysis confirmed that monetary policy shocks dominate GDP movements, suggesting that Tanzania's economy is highly sensitive to changes in interest rates and liquidity conditions. The SHAP results further illustrated that while financial deepening contributes positively to growth, its effects are overshadowed by more immediate policy measures. The Difference-in-Differences (DiD) analysis revealed that monetary policy shocks negatively affect GDP growth. Still, interest rate changes alone are not statistically significant, indicating that broader economic factors influence policy effectiveness. Finally, the SARIMAX (ARIMA) model showed that GDP follows a predictable trend, suggesting that past growth patterns influence future economic performance and external shocks do not persist over time. These findings emphasize the critical role of monetary policy in stabilizing and stimulating Tanzania's economy. However, they also highlight the importance of complementary structural policies, particularly in strengthening the financial sector, improving credit accessibility, and ensuring well-calibrated monetary interventions.

7.1 Policy Recommendations

The study's empirical findings offer several actionable insights for Tanzanian policymakers. First, the Difference-in-Differences (DiD) analysis reveals that interest rate changes, when considered in isolation, have limited direct effects on GDP growth. However, periods following significant monetary policy shocks are associated with substantial economic contractions. This suggests that monetary interventions should not occur in isolation. Instead, there is a critical need for closer coordination between the Bank of Tanzania and the Ministry of Finance to design synchronized monetary and fiscal responses that minimize adverse impacts on the real economy.

Second, the SHAP analysis identifies money supply growth (dms) as one of the most influential predictors of GDP performance. This underscores the importance of enhancing liquidity management through carefully calibrated monetary expansion tools. Policymakers should aim to increase money supply in a way that supports economic activity without triggering inflationary pressures, particularly during periods of economic slowdown or external shocks. Third, while financial deepening, measured through private sector credit (Inclaimspri), exhibits limited influence on short-term GDP fluctuations, its long-term importance remains evident in both theory and past empirical studies. This calls for strategic efforts to strengthen the credit channel, especially by expanding access to finance for small and medium enterprises (SMEs) and financially underserved populations. Such measures will gradually enhance the economy's resilience and growth potential over time.

Fourth, the SARIMAX model results indicate that Tanzania's GDP follows a mean-reverting,

autoregressive pattern, suggesting that economic trends are predictable based on past values. This presents an opportunity for Tanzanian institutions to invest in more robust, real-time forecasting infrastructure. By integrating time-series models into macroeconomic planning, policymakers can better anticipate economic turning points and adjust policy instruments proactively. Finally, although external shocks, such as exchange rate fluctuations and changes in crude oil prices, demonstrate weaker immediate effects on GDP in the SHAP model, their potential for volatility justifies the need for strong macroeconomic buffers. Building foreign exchange reserves, maintaining flexible fiscal space, and preparing counter-cyclical tools are crucial for absorbing sudden external disruptions, particularly those affecting import costs and currency stability. Collectively, these recommendations are grounded in the study's empirical evidence and highlight the necessity of adopting a data-driven, forward-looking, and institutionally coordinated approach to macroeconomic policymaking in Tanzania.

References

1. Abar, H. (2022). An analysis of the causal relationship between economic growth and financial development for Turkey: A MODWT—Granger causality test. *Economics and Business Review*, 8(3), 59–81. <https://www.cceol.com/search/article-detail?id=1100588>.
2. Ahiadorme, J. W. (2022). Financial development and the redistributive channel of monetary policy. *Studies in Economics and Finance*, 39(2), 279–296. <https://doi.org/10.1108/SEF-03-2021-0104>.
3. Appiah-Otoo, I. (2023). A bibliometric assessment of the finance-growth literature: Current status, development, and future direction. *Journal of Scientometric Research*, 12(2), 321–331. <https://doi.org/10.5530/jscires.12.2.029>.
4. Aslan, M. &. (2024). Financial dollarization and its effects on inflation and output in Turkey: a machine learning approach. *Quality & Quantity* 58, 5777–5804. <https://doi.org/10.1007/s11135-024-01911-z>.
5. Audi, M. A. (2022). Nexus Among Innovations, Financial Development and Economic Growth in Developing Countries. *Journal of Applied Economic Sciences*, 17(4), 373–393.
6. Bank of Tanzania. (2023). *Working Paper Series No. 29: Effectiveness of Monetary Policy Transmission Mechanism Through Interest Rate Channel in Tanzania*. E-ISSN 2546-1990.
7. Bank of Tanzania. (2024). *Mid-Year Review 2023/24 - Monetary Policy Statement*. ISSN 0856-6976.
8. Bernanke, B. S. (1988). Credit, money, and aggregate demand. *American Economic Review*, 78(2), 435–439.
9. Bernanke, B. S. (1989). Agency costs, net worth, and business fluctuations. *American Economic Review*, 79(1), 14–31.
10. Bernanke, B. S. (1995). Inside the black box: The credit channel of monetary policy transmission. *Journal of Economic Perspectives*, 9(4), 27–48.
11. Bouattour, A. K. (2024). Stock Markets, Financial Depth, and Economic Growth in China: Evidence from ARDL Model. *China Finance and Economic Review*, 13(1), 88–111. <https://doi.org/10.1515/cfer-2024-0005>.
12. Cavusoglu, B. I. (2019). Testing the relationship between financial sector output, employment, and economic growth in North Cyprus. *Financial Innovation*, 5(1), 36. <https://doi.org/10.1186/s40854-019-0151-3>.
13. Duan, Y. G. (2022). Assessing machine learning for forecasting economic risk: Evidence from an expanded Chinese financial information set. *Finance Research Letters*, 46, 102273. <https://doi.org/10.1016/j.frl.2021.102273>.

14. Epaphra, M. (2014). An Empirical Analysis of Interest Rate Spreads in Tanzania. *Asian Journal of Research in Banking and Finance*, 4(10), 244–269. <http://dx.doi.org/10.5958/2249-7323.2014.01425.4>.
15. Hammad Naeem, M. S.-F. (2023). Examining the role of financial innovation on economic growth: Fresh empirical evidence from developing and developed countries. *Cogent Economics & Finance*, 11(1), 2170000. <https://doi.org/10.1080/23322039.2023.2170000>.
16. Junayed, H. M. (2023). Comparative Analysis of ARIMA, SARIMAX, and Random Forest Models for Forecasting Future GDP of the UK in Relation to Unemployment Rate. *International Journal of Management, Accounting, and Economics*, 10(11), 924–937. doi: 10.528/zenodo.10473611.
17. Kapaya, S. M. (2023). Financial Development: The Role of GDP per Capita Dynamics in Low- & Middle-Income Economies. *Pan-African Journal of Business Management*, 7(2), 1–41. <https://www.ajol.info/index.php/pajbm/article/view/277116>.
18. Kim, D. W. (2018). Financial inclusion and economic growth in OIC countries. *Research in International Business and Finance*, 43, 1–14. <https://doi.org/10.1016/j.ribaf.2017.07.178>.
19. Maccarrone G, M. G. (2021). GDP Forecasting: Machine Learning, Linear or Autoregression? *Front. Artif. Intell.* 4:757864, doi: 10.3389/frai.2021.757864.
20. Magazzino, C. M. (2021). An artificial neural network experiment assessed the links between financial development and agricultural growth. *Sustainability*, 13(5), 2828. <https://doi.org/10.3390/su13052828>.
21. Odhiambo, N. M. (2005). Financial Development and Economic Growth in Tanzania: A Dynamic Causality Test. *African Finance Journal*, 7(1), 1–17. <https://hdl.handle.net/10520/EJC33816>.
22. Ofori, I. K. (2021). What drives financial sector development in Africa? Insights from machine learning. *Applied Artificial Intelligence*, 35(15), 2124–2156. <https://doi.org/10.1080/08839514.2021.1999597>.
23. Omar Bakar, H. S. (2022). The role of financial development on economic growth in the emerging market countries of the sub-Saharan African (SSA) region. *International Journal of Emerging Markets*, 17(3), 789–811. <https://doi.org/10.1108/IJOEM-08-2019-0638>.
24. Polat, A. S. (2015). Revisiting linkages between financial development, trade openness and economic growth in South Africa: Fresh evidence from combined cointegration test. *Quality & Quantity*, 49, 785–803. <https://doi.org/10.1007/s11135-014-0023-x>.
25. Rapih, S. &. (2023). The relative impact of traditional and digital financial inclusion on economic growth: a threshold regression-based comparative analysis. *International Review of Applied Economics*, 37(6), 781–803. <https://doi.org/10.1080/02692171.2023.2281460>.

26. Saidi, H. R. (2025). Do Financial Market Openness and Stock Market Returns Drive Economic Growth in GCC Countries? New Investigation from Panel Structural Breaks. *International Journal of Financial Studies*, 13(1), 40. <https://doi.org/10.3390/ijfs13010040>.
27. Sun, X. Y. (2024). Financial Fragility in Emerging Markets: Examining the Innovative Applications of Machine Learning Design Methods. *Journal of the Knowledge Economy*, 1-22. <https://doi.org/10.1007/s13132-023-01731-w>.
28. Takyi, P. O.-F. (2023). Financial inclusion and financial development: Implications for monetary policy effectiveness and economic growth in sub-Saharan Africa. *Journal of Economic and Administrative Sciences*, <https://doi.org/10.1108/JEAS-09-2022-0215>.
29. Wang, G. J. (2024). Systemic risk prediction using machine learning: Does network connectedness help prediction? *International Review of Financial Analysis*, 93, 103147. <https://doi.org/10.1016/j.irfa.2024.103147>.
30. Yang, Y. X. (2024). Machine Learning for Economic Forecasting: An Application to China's GDP Growth. *arXiv preprint arXiv:2407.03595*.



Notes

Dotted lines for note-taking.



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