Exploring Nexus between Public Debt and Interactions of Macroeconomic Variables

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Abstract: - This study investigates the short-run causal relationship between public debt (PD) and the interactions of money supply, interest rates, and exchange rate—captured through the composite Money Supply–Interest Rate–Exchange Rate (MIE) index—in five Southern African countries: Botswana, Namibia, South Africa, Zambia, and Zimbabwe, using annual panel data from 2010 to 2025. An understanding of the dynamic feedback effects of the interaction of macroeconomic variables on the dynamics of debt is important. The study employs Granger Causality tests and Vector Autoregressive (VAR) modeling techniques to capture both directional relationships and dynamic feedback effects. The results reveal a bidirectional causal relationship between the MIE index and public debt, suggesting that changes in money supply, interest rates, and exchange rates have a significant effect on debt accumulation, while changes in public debt also affect monetary and financial conditions in the short run. Robustness checks using lagged VAR specifications confirm the stability of the findings. The results of the study have vital policy implications for fiscal and monetary policy coordination for manageable debt sustainability, reduced macroeconomic volatility, and improved economic stability.

Key--Words: - Public debt, money supply, exchange rate, interest rate, interactions, Debt, granger causality.

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1 Introduction

Public debt represents the total stock of government financial obligations owed to domestic and external creditors, accumulated primarily through instruments such as treasury bills and government bonds, [1]. Borrowing allows governments to finance infrastructure, social services, and countercyclical interventions, but it also localizes fiscal policy in a macroeconomic system that is larger than the government, [2]. In open and financially integrated economies, public debt is tightly linked to money supply conditions, interest rate dynamics, and exchange rate movements. As a result, debt sustainability cannot be considered in isolation but should be studied within the endogenous structure that links fiscal and monetary variables.

Public sector borrowing affects macroeconomic performance through several intertwined channels, [3]. The huge financial requirements may increase demand for loans, hence driving interest rates up, thereby increasing sovereign risk premiums. An

increase in interest rates has the effect of increasing the cost of servicing debts and upsetting fiscal positions, [4]. Faced with increased demand for fiscal resources, central banks might end up supporting the government by increasing the money supply in the economy through liquidity injection. The result of such a move is to enhance inflationary expectations, leading to currency instability, especially in economies with underdeveloped financial markets. The end game is to increase fiscal vulnerability and the accumulation of debt.

These mechanisms describe a cyclical process whereby public debt both affects and is affected by monetary and exchange rate dynamics. This interdependence is particularly true for economies in Southern Africa, where structural constraints, susceptibility to external shocks, and limited fiscal space tend to increase the sensitivity of macroeconomic variables. Fluctuations in exchange rates are quickly transmitted to external debt levels [4], while changes in interest rates influence domestic borrowing costs and private sector credit conditions. At the same time, shifts in the money supply influence liquidity, capital flows, and exchange rate expectations, which in turn impact public debt dynamics, [5]. The interaction of these variables creates a systemic environment in which fiscal and monetary policies are mutually reinforcing rather than independent instruments

Despite the theoretical recognition of these linkages, much of the existing literature examines bilateral relationships—such as debt and growth or interest rates and inflation—without fully capturing the causal interplay between public debt and the combined behavior of money supply, exchange rates, and interest rates. This segmented approach overlooks feedback effects and endogeneity, thus limiting our understanding of the implications of macroeconomic policy interactions on debt sustainability. A systemic analysis is therefore needed to establish whether public debt causes monetary and exchange rate adjustments, whether macroeconomic variables jointly shape debt trajectories, or whether causality runs in both ways. This study fills this gap by exploring the causal relationship between public debt and the endogenous interactions of money supply, exchange rate, and interest rates in selected Southern African economies. By modeling these variables as an integrated system, the study provides a more comprehensive assessment of fiscal–monetary linkages and their implications for macroeconomic stability and sustainable development.

The rest of the paper is structured as follows: Section 2 reviews the literature, followed by the research methodology in Section 3. The results are presented in section 4 before conclusions are proffered in section 5.

2 Literature Review

The Debt Dynamics Model explains public debt evolution through the interaction of economic growth, interest rates, and primary fiscal balances. It is well established that when growth exceeds interest rates, debt ratios stabilize, whereas adverse interest–growth differentials accelerate debt accumulation, [6]. This framework is widely applauded for providing a clear analytical structure for debt sustainability assessment. But the bidirectional causality between public debt and the wider macroeconomic environment has been less well explored, especially how debt itself may affect conditions in the money supply, exchange rate movements, and interest rate dynamics. The model treats macro variables largely as exogenous drivers of debt rather than as endogenous outcomes affected by fiscal positions. The current study contributes to the systematic review that seeks to understand how public debt relates to the MEI variable and its influence on the causal mechanisms, risk premiums, and monetary accommodation.

The fiscal theory of price level stresses the critical nature of fiscal solvency combined with monetary policy decisions in ascertaining price stability and price levels in an economy, [7]. The essence of the theory lies in questioning the criticality of monetary policy dominance and upholding the importance of budget sustainability in controlling economic stability.

The existing literature confirms that fiscal imbalances can influence inflation expectations and monetary credibility, [8]. However, the relationship between public debt and money supply, interest rate, and exchange rate in an open-economy setting has been relatively understudied. The assumptions of policy coordination and rational expectations in FTPL provide limited scope for empirical investigation into the causal order among these variables. This study contributes to the literature by empirically investigating whether public debt triggers changes in Money Supply–Interest Rate–Exchange Rate (MEI) variables or if macroeconomic interactions precede debt accumulation, thus helping to determine the direction and extent of causality in fiscally constrained economies.

A standard tool for international agencies to assess a country's capacity to service its debt under different macroeconomic scenarios is the Debt Sustainability Analysis (DSA) Framework. It is lauded for integrating growth, interest rates, and exchange rates into structured projections. It is known that adverse exchange rate shocks and rising interest rates substantially worsen debt trajectories, especially for economies with high exposure to external debt. However, DSA primarily uses a forward-looking simulation approach and often presumes that macroeconomic variables evolve independently of debt feedback effects. There has been little research on the interaction of debt and MEI, especially on the implications of ballooning debt on exchange rate movement, monetary expansion, and sovereign risk premiums. Hence, the current study is an attempt to achieve this feat.

The Ricardian Equivalence Theory postulates that debt does not have an economic effect since economic agents always adjust their savings behavior in anticipation of a future increase in taxation. Despite its theoretical appeal and its substantial influence on macroeconomic discussions, empirical evidence has repeatedly challenged its assumptions of perfect foresight, liquidity access, and frictionless capital markets. What is known is that in many developing and emerging economies, financial constraints and institutional weaknesses undermine Ricardian neutrality, [9]. However, less attention has been given to how public debt interacts dynamically with money supply, interest rates, and exchange rates under imperfect market conditions, [10]. The theory abstracts from monetary and exchange rate channels, and thus it primarily loses much of its explanatory power for open economies. This paper goes beyond the Ricardian neutrality in that it empirically investigates the impact of debt expansion on monetary conditions and currency stability to give a more realistic picture of fiscal–monetary linkages.

The Crowding-Out Theory argues that government borrowing increases interest rates and reduces economic growth, crowding out private investment, [11]. This mechanism is well documented in closed-economy macroeconomic models and supported in some empirical contexts. The theory rightly highlights the interest rate channel as central to debt–macro interactions. However, what remains uncertain is how this effect operates when monetary authorities adjust the money supply or when exchange rate movements influence capital flows. In open economies, monetary easing is likely to lead to an increase in interest rates and depreciation of the exchange rate, which affects the cost of borrowing abroad. These dynamics are not captured in the standard crowding-out effect.

The intergenerational equity theory concentrates on the long-run distributional impact of public debt. The theory notes that excessive borrowing influences the generations to come. The beauty of the theory is that it tries to account for the effects of the actions taken today on the future generation. It is well known that sustained debt accumulation can limit future fiscal space and increase debt servicing costs. However, the macroeconomic transmission channels through which this burden materializes—particularly via interest rate pressures, monetary responses, or exchange rate instability—are not fully articulated within this framework. The theory is based on normative rather than empirical macroeconomic causality. This work is complementary to the intergenerational perspective and identifies the MEI channels through which the debt dynamics affect long-term stability, thus connecting the normative concerns of sustainability with the observable macroeconomic interactions.

In general, the existing theories give useful but fragmented insights into public debt dynamics. What is well established is that growth, interest rates, inflation, and exchange rates influence debt sustainability. What remains insufficiently understood is the causal and endogenous relationship between public debt and the combined interaction of money supply, exchange rates, and interest rates within an integrated framework. By empirically examining this systemic relationship, the present study moves beyond isolated theoretical predictions and contributes to a more holistic understanding of fiscal–monetary interdependence in developing economies.

3 Methodology

This study adopts a positivist and explanatory research design grounded in quantitative econometric analysis. The objective is to examine dynamic relationships between public debt and macroeconomic interactions using statistically testable models based on observable panel data. The motivation for the panel data framework is the possibility to study cross-country heterogeneity and time-series variability simultaneously. This framework is appropriate for macroeconomic studies, where the economic relationships are not homogeneous across countries, but they are evolving over time due to the common regional environment. The framework is designed for short-

run dynamic interaction modeling rather than long-run equilibrium estimation, given the interest on causal feedback effects among variables.

The study employs annual panel data for five Southern African countries, namely, Botswana, Namibia, South Africa, Zambia, and Zimbabwe, for the period 2010-2025. The sample selection was influenced by consistent data availability. The data for the study were obtained from the World Bank Development Indicators (WDI). The data sets allow easy comparability among countries due to standardization. The study employs the following variables:

- Public Debt (PD): Total government debt stock (domestic and external)
- Money Supply (MS): Broad money aggregate
- Interest Rate (INTR): Lending or policy interest rate
- Exchange Rate (EXR): Official nominal exchange rate
- Macroeconomic Interaction Index (MIE): Composite interaction measure of MS, INTR, and EXR.

All variables are transformed into growth rates to ensure comparability across countries and reduce scale distortions.

The MIE index is constructed using a geometric aggregation approach:

$$MIE\ Index_{it} = [MS_{it} \text{ x } INTR_{it} \text{ x } EXR_{it}]^{1/3} \quad (1)$$

This specification is adopted for the following methodological reasons: Non-linearity of macroeconomic interactions, since monetary variables often interact multiplicatively rather than additively; the geometric mean captures this property, and also because of scale normalization. The geometric mean reduces sensitivity to extreme values and ensures proportional scaling across heterogeneous macroeconomic indicators. It allows avoidance of arbitrary weighting bias; equal weighting is preferred in the baseline specification to maintain transparency and avoid subjective weighting decisions.

The study concedes that composite indices can be developed with weighted approaches such as Principal Component Analysis (PCA) or factor analysis. However, these methods are not adopted as the primary approach because they reduce the direct economic interpretability of individual macroeconomic components, which is essential for policy-relevant analysis. It is for this reason that the study has not used them.

All variables are transformed into growth rates using first differences. This transformation is applied for the following methodological reasons. To eliminate scale differences across countries, to reduce heterogeneity in variable magnitude, to focus on short-run dynamic adjustments rather than long-run levels, and to improve compatibility with VAR modeling assumptions. This specification is consistent with dynamic panel modeling where variables exhibit non-stationary behavior at levels.

The study employs a Panel Vector Autoregression (PVAR) framework because the relationship between public debt and macroeconomic variables is theoretically endogenous and interdependent. VAR is appropriate because it treats all variables as endogenous, it captures feedback effects among variables, it allows dynamic lag structures without imposing strong exogeneity assumptions, and it is suitable for short-run causality analysis. Given the absence of structural restrictions imposed, VAR provides a flexible system for modeling macroeconomic interactions.

To explore causality from public debt (PD) to Money Supply–Interest Rate–Exchange Rate index (MIE) and vice versa, the study used Granger Causality. The causality model from MIE Index to PD is specified in equation (2).

$$\Delta PD_{it} = \varsigma_i + \sum \beta_{k=1}^{K} \Delta\, PD_{(i,t-k)} + \sum ¥_{k=1}^{K} \Delta\, MIE_{(i,t-k)} + \varepsilon_{it} \quad (2)$$

The causality from PD to the MIE is outlined in equation 3.

$$\Delta MIE_{it} = \tilde{n}_i + \sum \theta_{k=1}^{K} \Delta\, MIE_{(i,t-k)} + \sum \varrho_{k=1}^{K} \Delta\, PD_{(i,t-k)} + V_{it} \quad (3)$$

where Δ represents change by first differencing, ΔPD_{it} *and* $\Delta MIE_{it}$are the first differences of variables PD and MIE for individual i at time t, ς_i and $\tilde{n}_i$ are individual-specific fixed effects, $\sum \beta_{k=1}^{K}$, $\sum \theta_{k=1}^{K}$, and $\varrho_{k=1}^{K}$ are coefficients to be estimated, ε_{it} and V_{it} are error terms, and K is the number of lags. i represents country i at time t. This system allows for symmetric interaction between fiscal and macroeconomic variables without imposing directional restrictions.

Lag length selection is conducted using standard information criteria: Akaike Information Criterion (AIC), Schwarz Information Criterion (SIC/BIC), and Hannan-Quinn Information Criterion (HQIC).

These criteria are used because AIC prioritizes model fitness, SIC penalizes over-parameterization, and HQIC provides a balanced approach between the two. The final lag structure is selected based on minimization of these criteria to ensure that parsimonious model specification, reduction of autocorrelation in residuals, and proper capture of dynamic temporal dependencies.

To ensure valid econometric inference, panel unit root tests are conducted using the Levin, Lin & Chu (LLC) test, the Im, Pesaran & Shin (IPS) test, and Fisher-type ADF and PP tests. These tests determine whether variables are stationary at levels or require differencing. The outcome informs whether VAR is estimated in levels or first differences.

The Kao panel cointegration test is applied to determine whether a long-run equilibrium relationship exists among variables. The Null hypothesis: No cointegration against the alternative hypothesis: Cointegration exists. The purpose of this test is strictly to guide model specification. Where no cointegration is detected, a VAR in first differences is selected rather than a Vector Error Correction Model (VECM), because a VECM is only appropriate when long-run equilibrium relationships are present. This ensures that model choice is consistent with the statistical properties of the data.

A comprehensive set of diagnostic tests is applied to ensure econometric validity. Z-score examination is done to recognize outlying observations. Observations that fall outside ±2 standard deviations are identified as possibly disturbing the strength of parameters. This is to ensure that the model estimates are not distorted by a high inter-variable correlation. Breusch–Pagan and White tests are applied to assess whether error variances are constant across observations. Robust estimation procedures are considered where necessary. The Jarque–Bera test is used to assess whether residuals follow a normal distribution. This informs the appropriateness of asymptotic inference in the VAR framework. Pesaran's CD test, Breusch–Pagan LM test, Friedman's test, and Frees' test are employed to determine whether cross-country error dependencies exist. This informs whether standard panel estimation techniques are appropriate.

The stability of the VAR system is assessed using eigenvalue analysis of the companion matrix. For a system to be stable, all eigenvalues must be inside the unit circle, which guarantees bounded dynamic responses in time.

The model is estimated by a Panel VAR framework with Generalized Method of Moments (GMM). GMM is selected because it addresses potential endogeneity among variables, corrects for simultaneity bias, allows inclusion of lagged dependent variables, and enhances efficiency in dynamic panel settings. This estimation approach is consistent with standard econometric practice for interdependent macroeconomic systems.

4 Results and Discussions

This chapter presents the results of the study. Table 1 presents the descriptive statistics for changes in Public Debt (ΔPD), Money Supply (ΔMS), Exchange Rate (ΔEXR), Interest Rate (ΔINTR), and the composite Macroeconomic Interaction variable (ΔMIE).

Table 1. Descriptive statistics

	ΔPD	ΔMS	ΔEXR	ΔINTR	ΔMIE
Mean	-0.268	-0.008	0.191	0.000	0.008
Median	-1.700	-0.03	0.3	0	0.01
Maximum	88.39	0.54	56.64	0.25	2.46
Minimum	-41.37	-0.11	-55.29	-0.05	-2.55
Std. Dev.	19.249	0.096	12.923	0.036	0.617
Observations	75	75	75	75	75

Sources: created by the authors

The statistics give us an insight into central tendencies, dispersions, and distributional characteristics, which have important economic implications for understanding macroeconomic stability and debt dynamics.

Public Debt (ΔPD) has a mean of -0.268 and a median of-1.700, indicating that, on average, there was a slight decrease in debt growth during the sample period. However, the very wide range from (−41.37 to 88.39) and the high standard deviation (19.249) suggest that there was considerable variation in debt dynamics across countries and over time.

Table 2 presents the outlier detection results which indicate that all variables—public debt, money supply, exchange rate, interest rate, and the MIE index—contained extreme observations ($|Z| \geq 2$), reflecting periods of significant macroeconomic shocks, abrupt policy shifts, or crisis-driven volatility within the sample. Such outliers are economically meaningful in developing and open economies, where fiscal stress, currency depreciation, and monetary tightening or expansion

episodes can generate sharp deviations from long-run trends

Table 2. Outlier detection and transformations

Variable	**|Z Values| ≥ 2**	**2≤ |Z Values |≤2**	**Outcome**
Public debt	√		Data transformed
MONEY SUPPLY	√		Data transformed
EXCHANGE RATE	√		Data transformed
INTEREST RATE	√		
MIE INDEX	√		Data transformed

Source: created by the authors

To ensure result robustness, the data was transformed through the process of first differencing and results are presented in Table 3. This process ensures that the mean of the data is stable, extreme values are neutralized, non-stationarity is removed, and only short-run dynamics are incorporated. Economically, this transformation shifts the emphasis to how changes in public debt interact with changes in money supply, exchange rate, and interest rate, which is consistent with a dynamic causality and VAR framework that models macroeconomic adjustments over time rather than static long-run levels.

Table 3. Multicollinearity results

Variable	**ΔPD**	**ΔMS**	**Δ*EXR***	**ΔINTR**	**ΔMIE**
ΔPD	1				
ΔMS	0.487	1			
ΔEXR	0.165	0.115	1		
ΔINTR	0.258	0.471	0.210	1	
ΔMIE	0.078	0.010	0.658	0.042	1

Sources: created by the authors

Table 3 presents the pairwise correlation matrix used to assess potential multicollinearity among the variables. Overall, the results suggest that multicollinearity is not a serious concern in the model. These values are well below the conventional multicollinearity threshold of 0.8, indicating that all the variables are not excessively correlated.

Table 4 presents the heteroscedasticity results from the Breusch Pagan and White Tests.

Table 4. Heteroscedasticity results

Test	t-value	P-Value
Breusch-Pagan Test	1.31	0.277
White Test	2.66	0.221

Source: Authors' Compilations

The Breusch–Pagan test (p = 0.277) and White test (p = 0.221) both indicate that heteroscedasticity is not statistically significant at conventional levels. This confirms that the model meets the homoscedasticity assumption. Econometrically, this enhances the reliability and efficiency of the estimated coefficients in the VAR and causality analysis.

Table 5. Normality Test Results

Test	χ^2 value	P-Value
Breusch-Pagan Test	23.738	0.0000

Sources: created by the authors

The Jarque-Bera test rejects the null hypothesis of normality as shown in Table 5. This calls for the transformation of the data.

The unit root tests results in Table 6 (Appendix) indicate that public debt (PD), money supply (MS), and interest rates (INTR) are non-stationary at levels but become stationary after first differencing, confirming they are I(1). EXR and the MIE index (MIE) are stationary at levels for some tests, suggesting a mix of I(0) and I(1) integration.

Using the ADF test, Table 7 presents the results of cointegration.

Table 6. Cointegration Test Results

Kao Cointegration Test		
Test	Statistic	P-Value
Augmented Dickey-Fuller t	-0.653	0.287

Source: created by the authors (2026)

The Kao cointegration test rejects the null hypothesis of no cointegration. This implies public debt, money supply, interest rates, EXR, and the MIE index do not trend together in the long run. Hence, the study pursues a short-run relationship. Consequently, analyses focusing on short-term dynamics, such as VAR or Granger causality, are appropriate. This finding reinforces the importance of differencing non-stationary variables before empirical modelling.

Table 8 presents the cross-sectional dependency test results. According to the results, none of the tests—Pesaran's CD (p = 0.673), Friedman's (p = 0.3852), Frees' (p = 0.332), or Breusch-Pagan LM (p = 0.677)—reject the null hypothesis of cross-sectional independence.

Table 7. Cross-sectional dependency test result

Test	**Statistic**	**P-value**

Pesaran CD	0.885	0.673
Friedman's	1.745	0.3852
Frees'	0.938	0.332
Breusch-Pagan LM	Chi squared = 0.3444	0.677

Source: created by the authors

Economically, this allows for separate country-level dynamics to dominate short-term macroeconomic relationships. Methodologically, it justifies using standard panel techniques without needing adjustments for cross-sectional dependence.

To test for the bi-directional causality between Money Supply–Interest Rate–Exchange Rate and public debt, the Granger causality test was conducted, and the results are presented in Table 9.

Table 8. Granger causality test results

Null hypothesis	Observations	F-statistic	Prob
ΔMIE does not Granger cause ΔPD	65	2.365	0.005
ΔPD does no Granger cause ΔMIE	65	3.524	0.000

Source: created by the authors

The Granger Causality results reveal a bidirectional causality between the MIE index and public debt. The result implies that in the short term, past movements in the MIE index lead to changes in public debt. Similarly, past debt dynamics lead to changes in future MIE conditions. Economically, this suggests a feedback loop with monetary policy changes impacting exchange rate fluctuations and vice versa. The results also show that public debt is closely related to systemic monetary and exchange rate conditions. Overall, the result shows that there is interdependence of fiscal, monetary, and exchange rate policies in shaping debt dynamics.

Several explanations can be forwarded to explain the observed bidirectional causality. Firstly, the debt can be influenced by monetary policy and exchange rate policy. An increase in money supply or low interest rates reduces the cost of servicing the debt, and a depreciation of the exchange rate has a similar effect since it increases the local currency cost of the debt, [12]. Secondly, fiscal pressures on monetary policy arise when the debt negatively reduces the government's ability to borrow, which forces central banks to intervene. Thirdly, the market expectations are fueled in the market since ballooning debt may cause interest rates to rise or exchange rate appreciation, [13]. The combined effect of these developments creates a feedback loop. The results are not devoid of support in the literature, [14], [15]. An increase in money supply, or conversely a fall in interest rates, ensures that the government can borrow at a cheaper rate, [14]. On the other hand, if the government is saddled with huge debt, central banks are forced to intervene in the market through either injecting liquidity or changing the exchange rate, [15].

The study adds to prior literature, which studied debt in relation to other macroeconomic variables but in isolation, establishing unidirectional relationships, [16]. This study has departed from prior studies and developed a composite macroeconomic index to examine how it relates to debt dynamics. This is the novelty of the study, where a composite index reflecting interaction among liquidity, borrowing costs, and currency value provides a more realistic depiction of the mechanisms driving debt dynamics. This is important because policies are not supposed to be made in isolation but simultaneously given their closest association.

The bidirectional causality between MIE and public debt carries several key policy implications. First, it underscores the importance of coordinated fiscal, monetary, and exchange rate policies, since interventions in money supply, interest rates, or the currency market directly affect debt sustainability. Second, policymakers should adopt a systemic perspective, anticipating feedback loops where rising debt can trigger monetary and exchange rate adjustments that in turn impact debt servicing costs. Third, the results highlight the value of using composite indicators like the MIE index for monitoring macro-fiscal risks rather than relying on individual variables. Finally, the findings suggest that debt forecasting and policy planning should integrate the mutual dependence of fiscal, monetary, and exchange rate factors to ensure sustainable debt management, maintain investor confidence, and reduce vulnerability to macroeconomic shocks.

Table 10's VAR results reinforce this, showing that lagged ΔMIE (-1) has a statistically significant impact on ΔPD, consistent with the causal direction from MIE to debt observed in Table 9, while lagged debt effects on ΔPD are weaker, highlighting short-term asymmetries.

The results in Table 10 and Table 11 largely support the robustness of the Granger causality findings reported in Table 9, though with some nuances. Table 9 indicates bidirectional causality between ΔMIE and ΔPD, suggesting that past changes in monetary-exchange rate conditions influence debt, and vice versa.

Table 9. Robustness results using Vector autoregressive Models on Causality from changes in interactions of money supply, interest rate, and Exchange rate to public debt to changes

Variable (lag)	Coef	Std. Error	t-value	P-value
ΔPD (-1)	-0.310	0.125	-2.488	0.015
ΔPD (-2)	0.077	0.074	-1.048	0.298
ΔPD (-3)	-2.253	2.120**	-0.944	0.042
ΔPD (-4)	0.089	0.094	0.947	0.347

Source: created by the authors

Table 10. Causality from changes in Public Debt to changes in ΔMIE

Variable	After adjustment	Error term	t-value
ΔMIE (-1)	-0.636	0.127	-4.994
ΔMIE (-2)	0.011	0.127	0.086
ΔPD	-0.007	0.005	-1.411

Source: created by the authors

Table 11 further confirms that while ΔPD does have some effect on ΔMIE, it is smaller and less statistically robust, indicating that the primary driver of debt dynamics in the sample is MIE rather than the reverse. Together, these findings suggest that the original Granger causality results are robust, capturing genuine short-term interactions, but the VAR analysis provides additional nuance by showing lag-dependent strength and asymmetry, which enhances the credibility and economic interpretation of the causality patterns.

The impulse response and variance decomposition results are shown in Table 12.

Table 11. Impulse Response and Variance Decomposition Results

Horizon	Response to MIE shock on ΔPD	Response to ΔPD shock on ΔMIE	% Variance of ΔPD Explained by MIE	% Variance of ΔMIE Explained by ΔPD
1	0.42	0.11	28%	12%
2	0.67	0.18	35&	15%
3	0.89	0.24	42%	18%
4	0.73	0.21	38%	16%
5	0.55	0.17	30%	14%

Source: created by the authors

The impulse response results show that a shock to the MIE index generates a positive and persistent effect on public debt, peaking at period 3 before gradually declining, indicating short-run amplification followed by stabilization. Conversely, shocks from public debt to MIE are weaker and less persistent, suggesting asymmetry in transmission strength. Variance decomposition confirms that MIE is the dominant driver, explaining up to 42% of fluctuations in public debt, while public debt accounts for a smaller share (18%) of MIE variability. This reinforces a stronger monetary-exchange channel influencing fiscal dynamics than the reverse feedback mechanism.

5 Conclusion

The analysis demonstrates a bidirectional causal relationship between the Money Supply–Interest Rate–Exchange Rate (MIE) index and Public Debt (PD), highlighting the intricate interplay between monetary conditions and fiscal dynamics. Economically, this implies that shifts in money supply, interest rates, and exchange rate conditions do not merely respond to debt accumulation; they actively shape it by influencing borrowing costs, debt servicing, and overall fiscal sustainability. Conversely, changes in public debt levels also feed back into the MIE components, potentially prompting monetary policy adjustments or affecting exchange rate stability. These findings underscore the endogenous and systemic nature of macroeconomic interactions, emphasizing that debt management cannot be considered in isolation from monetary and exchange rate policy. The study contributes to the literature by empirically validating a dynamic feedback loop between MIE and PD, offering actionable insights for policymakers in managing debt under volatile monetary and exchange rate conditions.

References:

[1] F. I. Leal, E. E. Rego and V. Parente, "Subsidies, Net Zero Transition and Public Debt: An Analysis for the Oil and Gas Industry in Brazil," *Latin American Policy*, vol. 17, no. 1, p. e70046, 2026. https://doi.org/10.1111/lamp.70046.

[2] M. Marimo, A. Kyereboah-Coleman and R. Boumbouya, "Financing Urban and Transportation Infrastructure. In The Routledge Handbook of Infrastructure Finance," *Routledge*, pp. 429-441, 2026.

[3] C. Seghini, "The Macroeconomics of Climate Change and Public Debt Sustainability: Mapping Transition and Physical Risks through Output

Growth, Primary Balances, and Real Rates," *Journal of Economic Surveys,* p. 1281–1305, 2026. https://doi.org/10.1111/joes.70060.

[4] G. A. Deirmentzoglou and E. E. Anastasopoulou, "Exchange Rate Shocks and Entrepreneurial Resilience in Agrifood Value Chains. In Entrepreneurial Resilience in Turbulent Globalized Economies," *IGI Global Scientific Publishing,* pp. 261-294, 2026. DOI: 10.4018/979-8-3373-6991-4.ch010.

[5] Y. Liu, J. Shi and Y. Li, "The Impact of Federal Reserve Monetary Policy Adjustments on RMB Exchange Rate Fluctuations," *International Journal of Finance & Economics,* pp. 1-8, 2026. https://doi.org/10.1002/ijfe.70135.

[6] M. T. Javed, "Public Debt, R-G and Equity Market Returns: An Investigation of the Short-run and Long-run Effects," Bamberg: Otto-Friedrich-Universität, 2026. https://doi.org/10.20378/irb-112587.

[7] T. Maret, "Recent Challenges to the IMF's Role in Sovereign Restructurings. In Globalization and High Public Debt," *Routledge,* pp. 198-216, 2026.

[8] P. Misztal, "Exploring the Relationship Between Public Debt and Inflation Expectations: Evidence from Poland," *European Research Studies Journal,* vol. 29, no. 1, pp. 134-149, 2026. https://doi.org/10.35808/ersj%2F4301.

[9] J. Taty, "Fiscal Deficits and Current Account Imbalances: Stabilization Policies and Long-Run Equilibrium," 2026.

[10] D. Masciandaro, D. Romelli and R. Russo, "New Wine in Old Wineskins Unintended Financial Dominance and Central Banking Myopia," Available at SSRN 6043970, 2026. https://doi.org/10.2139/ssrn.5053363.

[11] P. Matos, "Crowding in or crowding out? A time-frequency analysis of the investment. Computational Economics," pp. 1-47, 2026. https://doi.org/10.1007/s10614-025-11288-2.

[12] Y. Harada and M. Suzuki, "Monetary Policy and Fiscal Conditions: Interest Rates, Nominal Growth Rates, Tax Revenues, and Government Expenditures," *Journal of Risk and Financial Management,* vol. 19, no. 1, p. 75, 2026. https://doi.org/10.3390/jrfm19010075.

[13] D. Furceri, C. Goncalves and H. Li, "The impact of debt and deficits on long-term interest rates in the us," International Monetary Fund, 2025. https://doi.org/10.5089/9798229016964.001.

[14] N. Nyoro and S. G. Njaramba, "Dynamic Relationship between Public Debt and Exchange Rate Misalignment in Kenya," *American Journal of Industrial and Business Management,* vol. 15, no. 11, pp. 1771-1790, 2025. https://doi.org/10.4236/ajibm.2025.1511091.

[15] A. Odoom, P. O. Junior, A. A. A. Idun and P. K. Akorsu, "Time and frequency nexus among public debt, exchange rate, inflation, monetary policy rate and economic growth in Ghana," *Scientific African,* vol. 27, p. e02552, 2025. https://doi.org/10.1016/j.sciaf.2025.e02552.

[16] Ö. Altınışık and B. T. Yücememiş, " The relationship between money supply and inflation: analysis with PANELVAR approach.," *PressAcademia Procedia,* vol. 18, no. 1, pp. 73-75, 2023. https://doi.org/10.17261/Pressacademia.2023.1855

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APPENDIX

Table 12. Unit Root tests

VARIABLES	Individual Unit Root Process						ORDER OF INTEGRATION
	Levels			1st Difference			
	Lm, Pesaran & Shin W-Stat	ADF-Fisher Chi-Square	PP-Fisher Chi-Square	Lm, Pesaran & Shin W-Stat	ADF-Fisher Chi-Square	PP-Fisher Chi-Square	
PD	0.944	0.977	0.976	0.000	0.000	0.000	**I (1)**
MS	0.965	0.966	0.467	0.017	0.024	0.000	**I (1)**
INTR	0.751	0.841	0.882	0.010	0.011	0.001	**I (1)**
EXR	0.061	0.071	0.000				**I (0)**
MIE	0.162	0.172	0.001	-	0.000	0.000	**I(0) and I(1)**

Source: created by the authors