Application of Bayesian Vector Autoregressive Models in the Analysis of Quasi Money and Money Supply: A Case Study of Nigeria.

ABSTRACT

Aims: The aim of this study is to model the relationship between Nigerian quasi money and money supply using the Bayesian Vector Autoregressive (BVAR) model.

Study design: The study collected and analyzed monthly data from the Central Bank of Nigeria (CBN) money and credit statistics over an 8-year period (November 2015 to December 2022). The analysis utilized both Vector Autoregressive (VAR) Model and BVAR model to examine the dynamics between these variables and their implications for monetary policy.

Methodology: The study employed the Bayesian Vector Autoregressive (BVAR) model to analyze the relationship between Nigerian quasi money and money supply. Monthly data from the Central Bank of Nigeria (CBN) over an 8-year period was collected and subjected to both Vector Autoregressive (VAR) Model and BVAR model for analysis.

Results: The findings indicated that there is no long-run relationship between Nigerian narrow money and quasi money, but quasi money does granger cause changes in narrow money, and vice versa. This suggests a multi-directional effect between the two variables. The BVAR model consistently outperformed the VAR model in terms of higher Adjusted-R^2 values, indicating its stronger ability to explain the variance in the data. The BVAR model provided a more robust and accurate representation of the relationship between these variables. The model exhibited stability and the absence of heteroscedasticity in the residuals, indicating a stable relationship between the variables. The impulse response function showed an immediate impact of changes in narrow money on the overall money supply in Nigeria.

Conclusion: This study contributes to existing knowledge by empirically examining the relationship between Nigerian narrow money and quasi money and also concluded that there existed no co-integrating relationship between narrow money and quasi money, which has important implications for effective monetary policy strategies, particularly in Nigeria.

Keywords: BVAR, Money Supply, Time Series, Quasi Money,

1. INTRODUCTION

The relationship between quasi money and money supply plays a vital role in understanding the functioning of the monetary system and its impact on the broader economy (Lenza, 2010). Quasi money refers to highly liquid financial assets that act as near substitutes for money, including savings deposits, time deposits, and money market funds. On the other hand, money supply represents the total stock of money circulating in the economy, comprising currency, demand deposits, and other liquid instruments.

Analyzing the relationship between quasi money and money supply is of paramount importance for policymakers, central banks, and economists. It provides valuable insights into the effectiveness of monetary policies, the transmission mechanisms of monetary changes, and the stability of the financial system (Mishra et al., 2012). Understanding the dynamics between these variables helps in formulating appropriate policies to manage inflation, interest rates, and overall macroeconomic stability.Bayesian Vector autoregressive (BVAR) modeling is a powerful econometric technique that allows for a comprehensive analysis of the interdependencies and dynamic interactions between multiple time series variables (Lütkepohl, 2005). By estimating a BVAR model, researchers can capture the simultaneous feedback effects, short-term and long-term relationships, and the transmission mechanisms between quasi money and money supply (Lütkepohl, 2005).

Nigeria's quasi money and money supply are important indicators for understanding the country's monetary system and its impact on the economy. Quasi money refers to highly liquid financial assets that serve as substitutes for money, such as savings deposits, time deposits, and money market funds. Money supply, on the other hand, represents the total stock of money circulating in the Nigerian economy, including currency in circulation, demand deposits, and other liquid instruments.Analyzing the relationship between Nigerian quasi money and money supply provides valuable insights into the effectiveness of monetary policies, the stability of the financial system, and the overall macroeconomic environment. It helps policymakers and central banks make informed decisions regarding interest rates, inflation management, and economic stability (Ogundipe et al., 2019).

Nigeria's quasi money and money supply have been subject to various factors and policy measures that influence their dynamics. These include changes in monetary policy instruments, government interventions in the financial sector, and economic factors such as inflation and exchange rates. Understanding the interdependencies between these variables is crucial for formulating appropriate monetary policies that promote economic growth and stability in Nigeria (Anyanwu &Oyefusi, 2016).

The aim of this work is to model the relationship between the Nigerian quasi money and money supply using the Bayesian Vector Autoregressive (BVAR) model.

Several authors have conducted an empirical study on the use of the Vector Autocorrelation (VAR) model. For instance, In the work of Yan et al., (2022), Analysis of the Impact of U.S. Trade Policy Uncertainty on China Based on Bayesian VAR Model was focuses on examining the effects of U.S. trade policy uncertainty on China using a Bayesian Vector Autoregression (VAR) model. The study aims to shed light on the dynamic relationship between trade policy uncertainty and economic variables in China. The authors employ a

Bayesian VAR framework, which allows them to capture the interdependencies among variables and incorporate prior information.

The work by Petrella and Rossi (2018) investigates the implications of sectoral linkages and durable goods in the context of monetary policy. Petrella and Rossi (2018) develop a Bayesian VAR model with sectoral linkages and durable goods to study the transmission of monetary policy shocks. The study emphasizes the importance of incorporating sector-specific dynamics and heterogeneity in VAR. The authors analyze how changes in monetary policy affect different sectors of the economy, particularly those related to durable goods. The framework that incorporates sectoral heterogeneity and the role of durable goods in transmitting monetary policy shocks. The study finds that durable goods sectors play a crucial role in amplifying the effects of monetary policy on aggregate output and inflation. The findings highlight the importance of considering sectoral linkages and the specific characteristics of durable goods when formulating and evaluating monetary policy. Overall, the article contributes to our understanding of the transmission channels of monetary policy and provides insights for policymakers in designing effective policy measures.

Another comparative study conducted by Martinez and Moura (2020) compared the performance of VAR and BVAR models in forecasting economic activity in Mexico. The results indicated that BVAR models provided more accurate forecasts compared to VAR models, particularly during periods of economic uncertainty and volatility. The study highlighted the advantage of incorporating panel data in capturing the heterogeneity across regions and improving forecast accuracy.

Furthermore, a comparative analysis by Ang and Poon (2020) examined the effectiveness of VAR and BVAR models in studying the transmission of monetary policy shocks in Asian economies. The study found that BVAR models, which accounted for cross-country interactions, provided more robust estimates of the effects of monetary policy shocks compared to VAR models. The results emphasized the importance of considering regional interdependencies in analyzing the transmission mechanisms of monetary policy.

In a study by Ahmadi et al. (2018), the authors compared the performance of VAR and BVAR models in modeling exchange rate dynamics in a panel of emerging economies. Their findings suggested that BVAR models, which incorporated cross-sectional information, captured the common factors driving exchange rate movements more effectively than VAR models. The study highlighted the advantage of BVAR models in capturing both idiosyncratic and common shocks across countries.

2. MATERIAL AND METHODS

2.1 Data

The study will focus on analyzing the relationship between Nigerian quasi money and money supply using Bayesian vector autoregressive (BVAR) modeling techniques. It will specifically examine the monthly data on Nigerian quasi money and money supply from November 2015 to December 2022. This time frame allows for a comprehensive analysis of the dynamics between these variables over a period of almost eight years, capturing various economic conditions and policy changes within Nigeria. The data was obtained from the Central Bank of Nigeria (CBN) statistical database www.cbn.gov.ng

2.2: Methodology

This study adopts event study approach. This approach is considered suitable because specific event, in this case, the performance of the Nigerian Quasi Money and money supply. Two variables shall be considered in this study. These includes monthly data on Nigerian Quasi Money and Nigerian monthly data on Nigerian Money Supply from November 2015 through December, 2022.

The chosen technique for estimation in this study is the Bayesian Vector Autoregression (BVAR) model. The only difference between usual VAR models and BVAR models is the way parameter estimates are obtained and interpreted. VAR models are usually estimated by ordinary least square (OLS), which is a simple and computationally fast estimator. By contrast, Bayesian estimators are slightly more complicated and more burdensome in terms of algebra and calculation power. The coefficients obtained by so-called frequentist estimators like OLS are interpreted based on the concept of the sampling distribution. In Bayesian inference, the coefficients are assumed to have their own distribution. A more detailed treatment of the difference between frequentist and Bayesian inference can be found in Richard et al., (2008), which provides a short introduction to the Bayesian approach and a series of references for interested readers. Koop (2013) provide a very good introduction to Bayesian VAR estimators.

Bayesian VAR (BVAR) models have the same mathematical form as any other VAR model, i.e.

$$y_t = c + \sum_{i=1}^{p} A_i y_{t-1} + \varepsilon_t \qquad (2.1)$$

where y_t is a K×1 vector of endogenous variables in period t, A_i is the coefficient matrix corresponding to the l^{th} lag of y_t , c is a constant deterministic term and ϵ is an error term with zero mean vector andvariance-covariance matrix Σ.

This study specifies the functional relationship between the Nigerian Quasi Money and Money Supply. The Bayesian Vector Autoregressive Model of order k that is *VAR(k)* model for this study are specified in Equations (2.1) to Equation (2.3) as shown below.

$$QM_t = \alpha_1 + \sum_{i=1}^{k} \beta_i QM_{t-i} + \sum_{j=1}^{k} \phi_j MS_{t-j} + u_{1t} \qquad (2.2)$$

$$MS_t = \alpha_2 + \sum_{j=1}^{k} \phi_j \beta_i MS_{t-i} + \sum_{i=1}^{k} \beta_i QM_{t-j} + u_{2t} \qquad (2.3)$$

Where

QM_t	=	Monthly Nigerian Quasi Money
MS_t	=	Monthly Nigerian Money Supply
α_{1-2}	=	The constant terms for the two interacting variables respectively

u_{1t-2t} = the stochastic error terms for the two variables respectively

Numerical Data for this study shall be presented using line plots and BVAR modelling shall be conducted computationally using EViews 10 Statistical Software.

Model Selection Criteria

Model selection shall be done using two criteria which include: the Akaike information criteria (AIC) and and Adjusted R^2. The Akaike information criteria (AIC) is one of the most suitable and commonly used fitness statistics test (Vrieze, 2012).

In a given set of statistical models used in estimating and fitting a data set, the most preferred model among the set of statistical model is the one with the minimum AIC value i.e. the model with the smallest AIC value is the best model. It does not only reward model goodness-of-fit but also levies penalty on an increasing function of the number of estimated parameters Chakrabarti and Ghosh, (2011). It is refine as shown below in the two formulae:

$$AIC(n) = \frac{-2}{n}[L-K] \text{ and } AIC(1) = -2[L-K] \quad (2.4)$$

Where K is the number of predictors including the intercept, while AIC(1) is usually an output by statistical of software applications. L is the maximized value of the likelihood function for the model.

The adjusted R2 is defined as:

$$Ajd - R^2 = 1 - (1-R^2)\frac{n-1}{n-k} \quad (2.5)$$

(Gayawan and Ipinyomi,2009).

All numerical computations was done using Eviews 10 statistical software.

3. RESULTS AND DISCUSSION

3.1 Results

3.1.1 Data Presentation and Stationarity Test

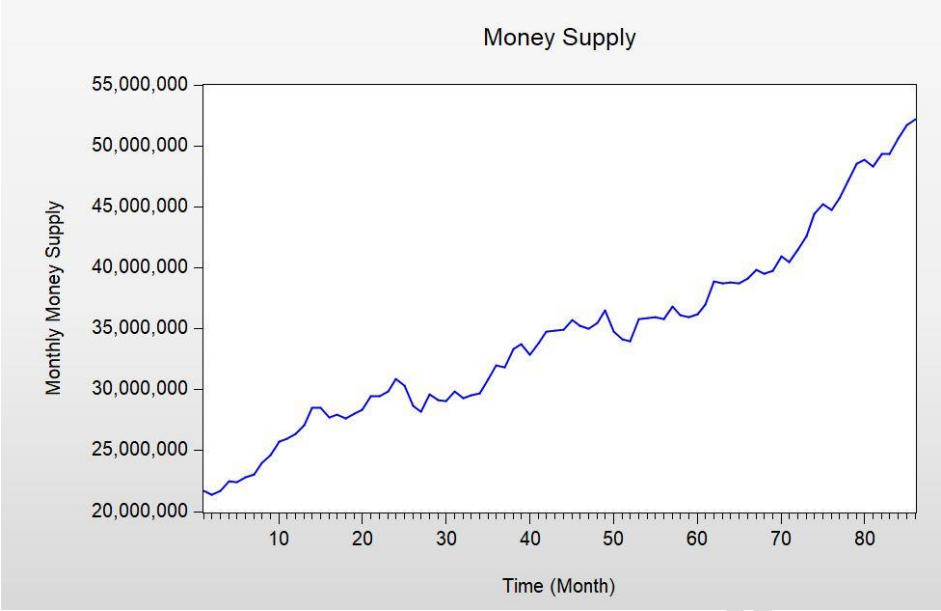

Figure 1: Time Plot of Nigerian Monthly Money Supply from November 2015 – December 2022 at Level

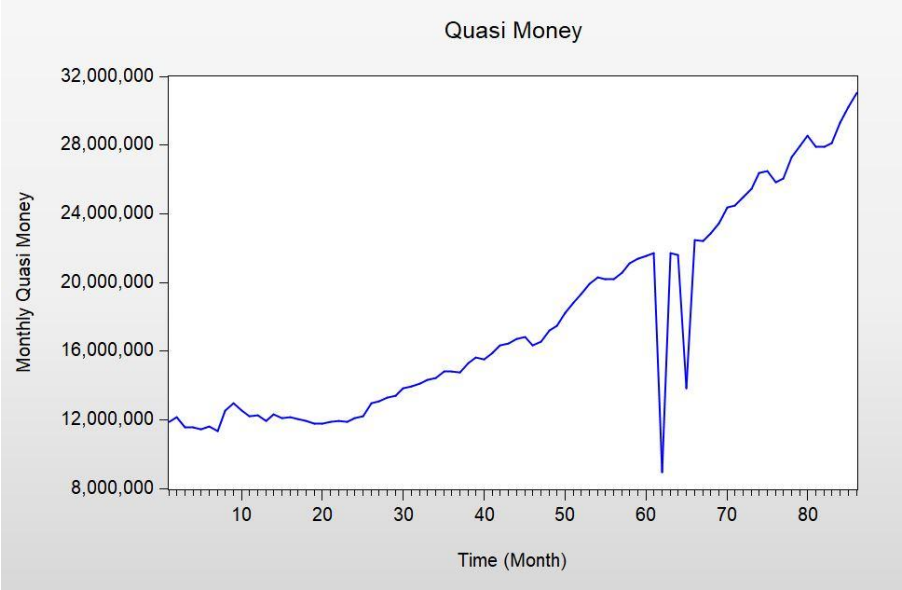

Figure 2: Time Plot of Nigerian Monthly Quasi Money from November 2015 – December 2022 at Level

Table 1: Unit Root Test using Augmented Dickey Fuller

Variable (s)	Stat. level	1%	5%	10%	ADFTS	Prob.	Remarks
MONEY_SUPPLY	I(0)	-3.51	-2.90	-2.59	1.01	0.9965	Not Stationary

	I(1)	-3.51	-2.90	-2.59	-8.89	0.0000	Stationary
QUASI_MONEY	I(0)	-3.51	-2.90	-2.59	1.14	0.9976	Not Stationary
	I(1)	-3.51	-2.90	-2.59	-12.55	0.0001	Stationary

The results were tested at 1%, 5%, and 10% level of significance respectively
1(0) = Test at level
1(1) = Test at first difference
ADFTS = Augmented Dickey Fuller Test Statistic

Table 2: VAR length Order Selection of Interacting Variables

VAR Lag Order Selection Criteria
Endogenous variables: D(MONEY_SUPPLY) D(QUASI_MONEY)
Exogenous variables: C
Date: 09/05/23 Time: 17:55
Sample: 1 86
Included observations: 77

Lag	LogL	LR	FPE	AIC	SC	HQ
0	-2394.866	NA	3.74e+24	62.25626	62.31714	62.28061
1	-2384.294	20.32058	3.15e+24	62.08556	62.26819	62.15861
2	-2365.958	34.29055*	2.17e+24*	**61.71319***	62.01758*	61.83495*
3	-2365.787	0.309975	2.40e+24	61.81266	62.23881	61.98312
4	-2363.852	3.417762	2.54e+24	61.86630	62.41420	62.08545
5	-2362.675	2.018045	2.73e+24	61.93962	62.60928	62.20747
6	-2358.829	6.393408	2.75e+24	61.94362	62.73503	62.26017
7	-2356.428	3.866140	2.88e+24	61.98515	62.89833	62.35041
8	-2356.034	0.615476	3.18e+24	62.07879	63.11372	62.49275

3.1.2 Model Estimation using BVAR

This section presented the result output for the BVAR(8) model.
BVAR 1 2 D(MONEY_SUPPLY) D(QUASI_MONEY)

BVAR Model - Substituted Coefficients:
==========

$$\Delta MONEY\_SUPPLY_t = 0.011 * \Delta \text{MONEY\_SUPPLY}_{t-1} - 0.032 * \Delta \text{MONEY\_SUPPLY}_{t-2} + 0.006 * \Delta \text{QUASI\_MONEY}_{t-1} - 0.007 * \Delta \text{QUASI\_MONEY}_{t-2} + 374148.480 \quad (3.1)$$

$$\Delta QUASI\_MONEY_t = 0.084 * \Delta \text{MONEY\_SUPPLY}_{t-1} + 0.029 * \Delta \text{MONEY\_SUPPLY}_{t-2} - 0.325 * \Delta \text{QUASI\_MONEY}_{t-1} - 0.101 * \Delta \text{QUASI\_MONEY}_{t-2} + 286321.663 \quad (3.2)$$

Table 2. Comparing the Performance of VAR to BVAR

Model	Equation	AIC	Adjusted R^2
VAR	Δ (Money_Supply)	29.96182	0.841498
	Δ (Quasi_Money)	31.65017	0.810369
BVAR	Δ (Money_Supply)	26.41245	0.892085
	Δ (Quasi_Money)	27.41214	0.880961

3.1.3 Residual Diagnostics

Table 3. BVAR Model Stability Test

Diagnostic Test	**Test Statistics**	**df**	**Test Statistic Value**	**Prob. Value (p-value)**	**Remarks**
VAR Residual Normality Test	Orthogonalization: Cholesky (Lutkepohl)	2	111.5763	0.0000	Multivariate residual is not normal
		2	629.3967	0.0000	
		2	740.9460	0.0000	
VAR Residual Heteroscedasticity Test	Chi-square	6	19.60427	0.0850	No Heteroscedastic

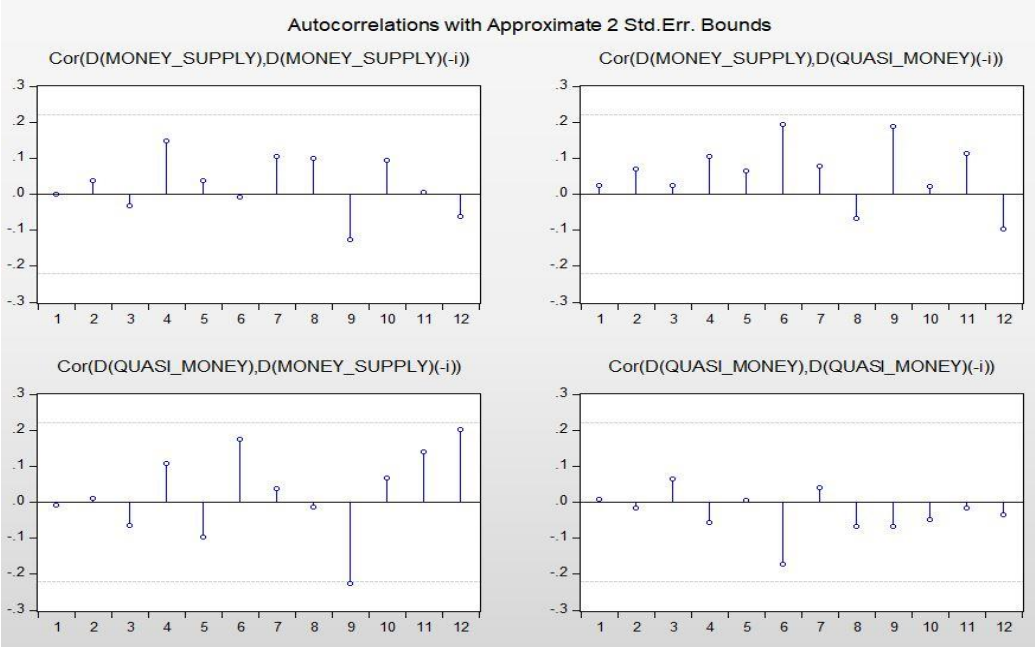

Figure 3: Correlogram of Residuals of the BVAR(2) Model

From Figure 3, no heteroscedasticity and aoutocorrelation effect on residuals since the bars didn't lie oustside of the blue line.

Table 4 BVAR Model Granger Causality/Block Exogeneity Wald Tests

Dependent variable: MONEY_SUPPLY			
Excluded	Chi-sq	df	Prob.
QUASI_MONEY	6.830455	2	0.0329
All	6.830455	2	0.0329

Dependent variable: QUASI_MONEY			
Excluded	Chi-sq	df	Prob.
MONEY_SUPPLY	16.16497	2	0.0003
All	16.16497	2	0.0003

3.1.4 Forecasting using the BVAR(2) Model

Table 5. Variance Decomposition of the BVAR(2) Model

Variance Decomposition of D(MONEY_SUPPLY):			
Period	S.E.	D(MONEY_SUPPLY)	D(QUASI_MONEY)
1	753736.7	100.0000	0.000000
2	754093.0	99.99198	0.008019
3	768338.8	99.40533	0.594672
4	769486.3	99.16158	0.838420
5	769986.8	99.12580	0.874197
6	770735.1	98.95466	1.045341
7	770905.8	98.92112	1.078882
8	770946.3	98.91302	1.086983
9	771069.6	98.88452	1.115476
10	771094.8	98.87812	1.121883
11	771100.3	98.87700	1.123000
12	771121.5	98.87186	1.128144

Variance Decomposition of D(QUASI_MONEY):			
Period	S.E.	D(MONEY_SUPPLY)	D(QUASI_MONEY)
1	1753230.	2.982620	97.01738
2	2214089.	3.685052	96.31495
3	2214610.	3.720603	96.27940
4	2342029.	4.147246	95.85275
5	2414638.	4.144012	95.85599
6	2414988.	4.158416	95.84158
7	2435889.	4.214726	95.78527
8	2449467.	4.209637	95.79036
9	2449574.	4.211003	95.78900
10	2453202.	4.220534	95.77947

11	2455806.	4.219937	95.78006
12	2455840.	4.220015	95.77998

Cholesky Ordering: D(MONEY_SUPPLY) D(QUASI_MONEY)

3.2 Discussion of Result

The selection of the appropriate lag length is a crucial step in determining the order of a Vector Autoregressive (VAR) model. This analysis utilized the Akaike information criterion (AIC) to find the optimal lag length, which strikes a balance between model fit and complexity. Table 4 displays the results of this process, showing AIC values for different lag lengths. The VAR model with a lag length of 2 had the lowest AIC value, indicating it provides the best balance between complexity and fit. It's important to note that while the AIC was used in this study, other criteria like BIC, HQIC, and SBC can also be employed. All of these criteria aligned with the AIC in selecting a lag length of 2, adding robustness to the choice of order for the VAR and BVAR models.

Table 2 presents key insights from a comprehensive analysis comparing the performance of Vector Autoregressive (VAR) and Bayesian Vector Autoregressive (BVAR) models for Money Supply and Quasi Money In Nigeria. Comparing the two models, VAR(2) and BVAR(2), using Quasi Money and Money Supply variables. The BVAR(2) model performs better in explaining the relationship between these variables. For example, when looking at changes in Money Supply, the BVAR(2) model explains about 89.5% of the variation, while the VAR(2) model explains slightly less at 84.4%. This means the BVAR(2) model is more accurate in predicting changes in Money Supply. This was also supported by the AIC value of the BVAR model being lower than that of the VAR model for Quasi Money and Money Supply. The same pattern holds for Quasi Money. Overall, the BVAR(2) model is more effective in understanding and predicting the interaction between these important monetary factors. The residual diagnostic test in Table 3 indicated no evidence of heteroscedasticity, indicating the BVAR(2) model is adequate. In Table 4 we see that quasi money does granger cause changes in narrow money, and vice versa.

In Table 5, the variance decomposition of the BVAR(2) model reveals important insights into the relative contributions of different variables in explaining the behavior of the money supply and quasi money over a forecast horizon of 12 months. Specifically, it highlights the proportions of the forecast error variances of these variables that can be attributed to shocks from other variables in the system.As the periods progress, we see changes in the contribution of each variable to the overall variance. This information is important for understanding which variable has a greater impact on changes in money supply and quasi money over time.

4. CONCLUSION

This study aimed to model the relationship between Nigerian quasi money and money supply using the Bayesian Vector Autoregressive (BVAR) model. The objectives included fitting an appropriate BVAR model, examining the short-term and long-term relationships, analyzing the impact of changes in quasi money on money supply and vice versa, and providing insights for policymakers on effectively regulating and managing these dynamics for macroeconomic stability and sustainable economic development in Nigeria. In this study, data from the Central Bank of Nigeria (CBN) money and credit statistics covering a period of 8 years, from 2015 to 2022, was collected and analyzed. The data analysis was conducted

using EViews 10 statistical software. To examine the relationship between Nigerian quasi money and money supply, both VAR and Bayesian Vector Autoregressive (BVAR) models were employed in the study. These models allowed for a comprehensive analysis of the dynamics between these variables and provided valuable insights into their interactions and implications for monetary policy in Nigeria.

The analysis in this study utilized data on Narrow money and Quasi money. The findings indicated that there is no co-integrating or long-run relationship between Nigerian narrow money and quasi money. However, it was revealed that quasi money granger caused changes in narrow money, and vice versa. This suggests that monetary policy has a significant impact on quasi money, and there is a multi-directional effect between quasi money and narrow money. In other words, changes in quasi money can influence narrow money, and vice versa. These results highlight the importance of considering both variables in monetary policy decisions and indicate the complex nature of their relationship. In order to assess the model strength and adequacy, a comparison was made between the performances of the VAR and BVAR models. The results clearly showed that the BVAR model consistently outperformed the VAR model in terms of higher Adjusted R^2 values. This indicates that the BVAR model had a stronger ability to explain the variance observed in the data. The higher Adjusted R^2 values obtained from the BVAR model suggest that it provided a more robust and accurate representation of the relationship between the Nigerian quasi money and money supply variables. This finding highlights the superiority of the BVAR model in capturing the complexities and dynamics of the relationship between these variables, providing a more reliable tool for analysis and forecasting.

This study has made significant contributions to the field by empirically examining the relationship between Nigerian narrow money and quasi money using vector autoregressive (VAR) modeling. The findings offer valuable insights for guiding monetary policy decisions. Additionally, the study suggests that the BVAR model outperforms the VAR model in modeling macroeconomic variables. Furthermore, the study provides empirical evidence that there is no co-integrating relationship between narrow money and quasi money in the specific geographical area studied. This finding enhances our understanding of the dynamics between these variables and has important implications for the formulation of effective monetary policy strategies especially in Nigeria.

REFERENCES

1. Abrego, L., & Österholm, P. (2010). External linkages and economic growth in Colombia: Insights from a Bayesian VAR model. The World Economy, 33(12), 1788-1810.
2. Ahmadi, M., Anoruo, E., & Ahmad, R. (2018). The exchange rate dynamics in a panel of emerging markets: Can Bayesian VAR models explain the behavior of exchange rates. Research in International Business and Finance, 45, 304-311.
3. Ang, J. B., & Poon, W. K. (2020). Monetary policy transmission in Asian economies: VAR versus Bayesian VAR. International Review of Economics & Finance, 66, 211-225.
4. Anyanwu, J. C., & Oyefusi, A. (2016). Monetary Policy Measures in Nigeria: The Challenges of Transmission Mechanism. In The Nigerian Economy and the Challenges of Development (pp. 79-99). Springer.
5. Lenza, M., Pill, H., & Reichlin, L. (2010). Monetary policy in exceptional times. Economic Policy, 25(62), 295-339.

6. Lütkepohl, H. (2005). New Introduction to Multiple Time Series Analysis. Springer-Verlag.
7. Martinez, L. M., & Moura, M. (2020). Forecasting economic activity in Mexico: A comparison between VAR and Bayesian VAR models. Economic Modelling, Journal of Economics and Sustainable Development , 91, 493-503.

8. Mishra, P., Montiel, P. J., & Spilimbergo, A. (2012). Monetary transmission in low-income countries: effectiveness and policy implications. IMF Economic Review, 60(2), 270-302.
9. Ogundipe, A. A., Alabi, J., Asaleye, A. J., & Ogundipe, O. M. (2019). Exchange rate volatility and foreign portfolio investment in Nigeria. Investment Management & Financial Innovations, 16(3), 241.
10. Petrella, I., & Rossi, R. (2018). Monetary policy with sectoral linkages and durable goods. Journal of Monetary Economics, 98, 50-69.

11. Petrevski, G., Exterkate, P., Tevdovski, D., & Bogoev, J. (2015). The transmission of foreign shocks to South Eastern European economies: A Bayesian VAR approach. Economic Systems, 39(4), 632-643.

12. Yan, H., Xiao, W., Deng, Q., & Xiong, S. (2022). Analysis of the Impact of US Trade Policy Uncertainty on China Based on Bayesian VAR Model. Journal of Mathematics, 2022.

13. Koop, G. M. (2013). Forecasting with medium and large Bayesian VARs. Journal of Applied Econometrics, 28(2), 177-203.
14. Vrieze, S. I. (2012). Model selection and psychological theory: a discussion of the differences between the Akaike information criterion (AIC) and the Bayesian information criterion (BIC). Psychological methods, 17(2), 22-34.
15. Chakrabarti, A., & Ghosh, J. K. (2011). AIC, BIC and recent advances in model selection. Philosophy of statistics, 83-97.
16. Gayawan, E., &Ipinyomi, R. A. (2009). A comparison of Akaike, Schwarz and R square criteria for model selection using some fertility models. Australian Journal of Basic and Applied Sciences, 3(4), 24-35.