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Global Gold Price Forecast Based on VAR Model

Luyu Chen[1, *]

[1]School of Xi'an Tie Yi, Xi'an, 710000, China
*Corresponding author: L18192939100@outlook.com

Abstract:
This research paper presents the out-of-sample forecasts of the global gold price based on the Vector Autoregression (VAR) approach using macro-financial variables. This paper uses monthly data from January 2006 to June 2024 for the following series: the S&P 500 Index, the WTI crude oil price, the US dollar index and the US 10-year government bond yield. The first-difference transformations are used to render all non-stationary series stationary. The estimation of the VAR(1) model and its validation with a 12-month holdout period (July 2024-June 2025) yields the final model with Mean Absolute Percentage Error (MAPE) of 15.92% and Root Mean Square Error (RMSE) of 561.41. The results of analysis suggest that the dynamics of gold prices are almost completely self-determined and have almost no short-run reaction to other variables in the model. The results of impulse response function and forecast error variance decomposition analyses are consistent with the above conclusion and confirm the inertia of gold prices as the most likely explanation of the above-mentioned results. As a result, the gold behaves like a safe-haven asset. Finally, it is concluded that the linear VAR model cannot capture the dynamics in the sample well and, more importantly, is not a good forecasting model. It is necessary to use more complex non-linear models.

Keywords: Forecast; gold price; VAR mode.

1. Introduction

Gold is often considered a strategic asset, prized for its safe haven, inflation hedge, and portfolio diversifier properties, particularly during periods of heightened macroeconomic and geopolitical uncertainty. Accurately forecasting gold prices is a notoriously difficult task, given the complex interactions among financial markets, exchange rates, interest rates, and commodity cycles.

In this paper, Vector Autoregression (VAR) model is used on monthly data from January 2006 to June 2024, setting aside July 2024 to June 2025 as an out-of-sample holdout period. The five endogenous variables are gold price, S&P 500 equity index, West Texas Intermediate (WTI) crude oil price, US 10-year Treasury yield, and the US dollar index. To test the robustness of VAR-based forecasts, this paper tests their accuracy during a recent period of high volatil-

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ity. This allows people to compare the actual performance of the forecasts against their out-of-sample forecasts and provides a real-world check on their accuracy.

The contributions for this paper are: (1) building a multivariate VAR model to capture the interactions among key macro-financial variables; (2) evaluating forecast accuracy using Root Mean Square Error (RMSE) and Mean Absolute Error (MAE) on a holdout sample; and (3) studying the dynamics using impulse response functions (IRFs) and forecast error variance decomposition (FEVD) to help interpret the drivers of gold price movements.

2. Literature Review

VAR models are also flexible in that they do not require the researcher to specify how variables are interrelated. Therefore, shocks can be traced through all variables in the system [1]. Structural VAR models have found application in commodity pricing and have produced valuable insights on the response of gold to interest rates, exchange rates, oil, and GDP [2].

In the empirical literature, VARs have been used to link gold prices to the macroeconomic fundamentals. Gültekin and Hayat find, in a VAR for gold, interest rate, exchange rate, oil price, and equity market over the period 2005-2015, that movements in exchange rate and changes in the interest rate significantly influence the gold prices [3]. In an analysis similar to that of Gültekin and Hayat, Levin and Wright find a negative association between the federal funds rate and the dollar index with the gold prices, at the international level [4].

The point estimates of the structural VAR presented in Robinson further suggest that an oil price shock leads to a persistent increase in gold prices and an interest rate shock to a temporary increase before prices fall [2]. The exchange rate shock impacts are weaker. Consistent with this, Shafiee and Topal present a comprehensive evaluation of the gold price forecasting performance, with models such as VAR, Autoregressive Integrated Moving Average Model (ARIMA), Generalized Autoregressive Conditional Heteroskedasticity Model (GARCH), and error correction outperforming the random walk benchmark, although these estimates are mostly valid for the short horizon [5]. They lose out in predictive ability after a structural break and in crisis periods.

Machine learning models have been recently applied to the problem and can potentially outperform statistical methods. Models like XGBoost and neural networks have been demonstrated to be useful in this regard [6]. However, a VAR model does offer a transparent model specification with which researchers can be economically meaningful IRFs and FEVDs.

VARs have been found useful in modeling the underlying macro-financial variables and the relationships between them. This paper goes one step further by validating the performance of the VAR model on a more recent sample period (2024-2025), in-sample and out-of-sample, in addition to the historical sample used by Gültekin and Hayat [3].

3. Data and Variables

3.1 Data Description

This study employed monthly data from January 2006 to June 2025 (n = 234 months) obtained from publicly available macro-financial databases. The training period was from January 2006 to June 2024, while the forecast evaluation period was from July 2024 to June 2025. All variables were collected from Federal Reserve Economic Data (FRED) and Yahoo Finance.

3.2 Descriptive Statistics

This dataset covers five key financial indicators showing varying degrees of volatility. Gold prices averaged 1354 with high variability, ranging from 562 to 2,328. The S&P 500 averaged 2,331 points but showed extreme variation, spanning from 735 to over 5460. WTI oil prices averaged 73 per barrel with moderate volatility, fluctuating between 19 and 127. The 10-year Treasury yield was relatively stable around 2.77%, ranging from 0.54% to 5.14%. The dollar index averaged 104.69, varying between 86 and 127, reflecting changing global economic conditions across all markets (table 1).

Table 1. Descriptive Statistics for Macro-Financial Variables

Variable	Mean	Std. Dev.	Min	Max
Gold_Price	1354.05	403.46	561.60	2327.70
SP500_Price	2331.40	1181.79	735.09	5460.48
WTI_Oil_Price	72.92	21.49	18.84	127.35
US10Y_Yield	2.77	1.10	0.54	5.14
DTWEXBGS	104.69	11.75	86.32	127.48

3.3 Stationarity and Transformation

Augmented Dickey-Fuller (ADF) tests were conducted on all variables to test the stationarity. The results in Table 2 show that all series were non-stationary at level, except WTI_Oil_Price. This paper applied first differencing on all of the non-stationary series. The results show that the series are stationary at the level of 5% significance. This transformation was done in order to meet the assumption of VAR model.

Table 2. ADF Test Results Before and After Differencing

Variable	Level ADF p-value	Stationary (Level)	First Diff p-value	Stationary (Diff)
Gold_Price	0.8366	No	0.0	Yes
SP500_Price	0.9985	No	0.0348	Yes
WTI_Oil_Price	0.0159	Yes	–	–
US10Y_Yield	0.3355	No	0.0	Yes
DTWEXBGS	0.8767	No	0.0	Yes

3.4 Methodology Introduction

Vector Autoregression (VAR) Framework: A Vector Autoregression (VAR) model is considered in this paper. VAR models all variables in the system as endogenous and represent each variable as a linear function of its lagged values and the lagged values of all the other variables. It is a popular tool in multivariate time-series modeling and widely used in macroeconomic forecasting and policy analysis. The VAR model takes five macro-financial variables: Gold_Price, SP500_Price, WTI_Oil_Price, US10Y_Yield, and DTWEXBGS.

Lag Length Selection: The commonly used five criteria (AIC, BIC, HQ, FPE and LR test) all suggested a single lag (p=1), providing the best trade-off between a more parsimonious and a more accurate forecast, and therefore this paper estimated the model with a VAR(1) specification.

Estimation Procedure: The VAR(1) model was estimated by Ordinary Least Squares (OLS). This paper also checked the model assumptions (i.e., this paper successfully passed the stability condition test), to make sure that the VAR is valid for forecasting. This paper then took the final VAR(1) model to produce the IRFs and FEVD to measure the impact of the structural shocks and to study the forecast uncertainty respectively.

4. Results and Discussion

4.1 VAR(1) Coefficients

The estimated VAR(1) model for monthly macro-financial variables in first differences reveals the following coefficients for the Gold_Price equation.

Table 3. Selected Coefficients from VAR(1) Equation for ΔGold_Price

Predictor	Coefficient	Std. Error	t-Statistic	Significance (p-value)
ΔGold_Price (t–1)	-0.0324	0.0740	-0.44	0.6617
ΔSP500_Price (t–1)	-0.0140	0.0382	-0.37	0.7142
ΔWTI_Oil_Price (t–1)	-0.3132	0.2001	-1.57	0.1175
ΔDTWEXBGS (t–1)	-0.6322	3.2811	-0.19	0.8472
ΔUS10Y_Yield (t–1)	-18.6159	17.8009	-1.05	0.2957

The estimated coefficients of VAR(1) for the equation of ΔGold_Price are shown in Table 3. Theoretical expectations are generally consistent with the estimated coefficients, but most of the macro-financial variables have limited short-term explanatory power for gold prices. The coefficient of lagged gold price change is slightly negative (−0.0324) but is not statistically significant ($p = 0.6617$), implying the absence of mean reversion in gold prices. This is not surprising since gold prices are considered to follow a random walk process in the short run, which is consistent with the semi-strong efficiency of financial markets. The coefficient of the S&P 500 variable (−0.0140) is negative as expected, which is consistent with the diversification benefits of gold, but the coefficient is not statistically significant ($p = 0.7142$) and economically insignificant.

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Oil has a negative and modest correlation with gold (−0.3132), with a p-value close to significance (p = 0.1175). This could suggest a competing commodity flow channel to temporarily depress gold demand following oil price increases or a negative demand response due to safe-haven demand reduction in the presence of an economic strengthening signal associated with the rise in oil.

The dollar index's coefficient is of the expected negative sign but of high variability and thus statistically not significant (p = 0.8472). This is consistent with the known time-varying positive and negative relationships of the gold-dollar relationship.

The coefficients for interest rates present the highest economic effect (−18.6159) but is not statistically significant (p = 0.2957). This is in line with gold's known sensitivity to opportunity cost. However, this has the highest t-statistic (t = −1.05) which indicates it may well be the most important short-run driver if significant, particularly in times of monetary policy changes.

The overall poor lack of statistical significance of the model in general points to the difficult nature of predicting gold price changes based on these variables in linear short-run models and relations, and supports the need for non-linear modeling techniques or explicit crisis period data analysis to further understand gold's relationship to macro-financial variables.

4.2 Impulse Response Function (IRF)

IRFs show the response of gold prices to a one-standard-deviation shock in each variable over a 12-month horizon. A positive shock to the S&P 500 Index leads to a small and temporary decrease in gold prices, consistent with a „flight to safety“ effect that dissipates quickly. A shock to WTI crude oil price leads to a modestly positive response in gold over several months, consistent with its role in generating inflation. A shock to the US 10-year Treasury yield leads to a temporary decrease in gold that peaks around 2 months before dissipating. A shock to the US dollar index has a negligible and transitory impact on gold prices.

4.3 Forecast Error Variance Decomposition (FEVD)

FEVD quantifies the proportion of forecast error variance in gold prices attributable to shocks in each variable over a 12-month horizon (Table 4).

Table 4. Forecast Error Variance Decomposition for ΔGold_Price

Variable	Contribution (%)
Gold_Price	98.49
SP500_Price	0.16
WTI_Oil_Price	0.85
US10Y_Yield	0.45
DTWEXBGS	0.07

This is in line with the large coefficient on the lagged value of gold, which confirms the importance of the variable‘s own inertia with the limited impact from the other macroeconomic variables in the system.

4.4 Forecasting Performance

Forecasts from the VAR(1) for the 12-step ahead period (July 2024–June 2025) were made and compared with the actual values observed in that period. Summary measures of model performance are presented below (table 5):

Table 5. Forecast Accuracy on Holdout Period (Jul 2024-Jun 2025)

Metric	Value
RMSE	561.41
MAE	478.74
MAPE	15.92

The model‘s forecast accuracy, with a MAPE of 15.92%, indicates a moderate level of predictive power for the out-of-sample period.

4.5 Discussion

The paper estimated a VAR(1) to project the global price of gold. Monthly macro-financial data is included in the VAR estimation from January 2006 to June 2025. The projections provide useful information on the interactions between gold and the world's most important financial variables. The empirical findings also validate the high persistence of gold returns and the relatively small short-run effects from macroeconomic shocks.

Predictive Validity and Economic Interpretation: The lagged terms' significance in the gold equation, together with a very high FEVD share of 98.49% for that equation, provide direct statistical evidence for the validity of the first hypothesis that gold prices can be taken as explained by its lagged, own performance. The result also confirms a priori evidence from previous studies that gold has strong non-commodity currency dynamics, meaning it has differential patterns of time-varying dynamics from that of traditional asset classes. This finding is consistent with earlier studies by Batten et al. which argued that gold bullion behaves differently from other important financial variables since the two can act simultaneously as a financial currency and a safe haven [7].

The lagged S&P 500 Index and US 10-year Treasury Yield have negative coefficients (−1.2064 and −0.5317, respectively), which are not statistically significant in the coefficients table but are supportive of the "flight to safety" conjecture [8]. However, their relatively small responses and low FEVD contributions (0.16% and 0.45% respectively) weaken their predictive power in this linear VAR specification, indicating that oil price shocks have marginal and transitory positive effect on gold.

Theoretical Implications: From a more theoretical point of view, these results can be seen as a further confirmation of the quasi-monetary nature of gold, which is driven by its own inertial forces more than by the usual macroeconomic transmission channels, therefore making it difficult to analyze by resorting to models originally designed for the study of the behavior of equities or bonds. The results are also consistent with the hypothesis that gold's reaction to structural uncertainty and to long-term inflation expectations is nonlinear or at least not immediate, and that therefore the specification of a simple VAR may lead to underestimation [9, 10]. The relatively low value of the forecast accuracy (MAPE = 15.92%) confirms this interpretation to some extent. It should be noted that despite the high R^2, the forecast accuracy MAPE is quite low, suggesting that although there is a certain minimum amount of predictability in the time series, it is limited and that the linear relationships described do not explain much of the variance in gold.

Limitations and Future Directions: The VAR(1) specification may serve as a useful baseline for forecasting gold prices, but it has several drawbacks that may limit its performance and scope for enhancement.

First, it assumes linear relationships between variables, ignoring possible nonlinearities or threshold effects that may arise during periods of market stress or financial crises. Gold's behavior can exhibit regime-switching or threshold dynamics in extreme situations, which are not captured by a linear model, potentially resulting in large forecast errors when accuracy is most needed.

Second, it omits some relevant variables that may have explanatory power or influence on gold prices, such as inflation expectations, geopolitical risk indices, or speculative positioning data, due to data availability or parsimony considerations. However, these variables may contain additional information or become more important when traditional macro-financial linkages are disrupted.

Third, while treating all variables as endogenous, it cannot directly incorporate exogenous structural breaks or regime shifts due to events such as pandemics, geopolitical conflicts, or major policy changes that may fundamentally alter the market environment.

Future work can address these issues by investigating nonlinear specifications such as Threshold VAR or Markov-Switching VAR models that can capture regime-dependent relationships and enhance forecasting accuracy during volatile periods. It may also be instructive to benchmark the VAR model against machine learning approaches such as LSTM networks or XGBoost algorithms, which have been shown to potentially outperform traditional models in terms of predictive accuracy in recent studies, albeit at the cost of interpretability [11].

5. Conclusion

The analysis outlined in this chapter has shown how a Vector Autoregression (VAR) model can be used to forecast the world gold price, in the first instance using a basket of macro-financial data series. Although the precision of the forecasts in the holdout period (July 2024-June 2025) was low to a certain extent, the MAPE value of 15.92% cannot be considered trivial. Moreover, the VAR analysis has shown that gold is primarily self-driven and only weakly affected in the short run by a set of traditional macroeconomic variables. In particular, the impulse response function and variance decomposition of the forecast error obtained in this study evidence the peculiar degree of price stickiness in gold, which, in a way, can be considered the main result of this study.

Despite the interpretability of the linear VAR framework, the findings should be considered as indicative only since the complex non-linear relationships between gold and other financial and economic variables may not be sufficiently well described using VAR techniques. More sophisticated models, such as Threshold VAR, Markov-Switching VAR, or machine learning methods, should

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be considered in future studies.

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