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Time-Series Forecasting of Gold and Silver Prices with Holt-Winters' Exponential Smoothing

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Abstract: *The market for precious metals, specifically gold and silver, is quite crucial for the economy of India not only from an investment perspective but also as form of savings. Price of such metals fluctuate a lot because of various factors like changes in economic environment. Rate of inflation, interest and changes in currency value. The current research seeks to predict prices of gold and silver based on time series methodology, especially Holt-Winters exponential smoothing method. While most conventional academic research depends heavily on sophisticated econometrics models, the present investigation applies a practical method for assessing the viability of using a more straightforward model to predict price behaviour. The analysis is carried out on secondary data consisting of monthly gold prices, silver prices and the value of the U.S. Dollar Index collected within a decade long span (2016-2025). Various statistical methods like Holt Winters Trend model and Holt winters seasonal are used and the forecast accuracy is determined by Mean Absolute Error (MAE), Root Mean Squared Error (RMSE) and Mean Absolute Percentage Error (MAPE). From the results, it is clear that there is a trend and seasonality in the pattern of gold prices. This means that the appropriate method for forecasting will be the Holt–Winters multiplicative. On the other hand, the forecast shows that silver prices are dominated by trend but not by seasonality. This implies that the best method of forecasting will be the Holt Trend model since seasonality is very weak and irregular in this case. It is also evident from the results that silver is more accurate when forecasting. The US Dollar Index affects silver negatively. Conclusively, the results of the study indicate that the efficiency of the forecasting models used is greatly determined by the nature of the data used. Proper selection of the forecasting models through consideration of trends and seasonality will enhance prediction. The results are important in providing guidance to investors and traders in precious metals.*

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Introduction

The financial sector is currently dominated by a data-oriented approach in which decision-making processes rely heavily on analytical methods and forecasting models. In the category of financial assets, there is an important place occupied by precious metals like gold and silver, which have been used traditionally and remain significant even in the current investment strategies. Precious metals have been widely used in India not only for cultural reasons but also for their economic importance.

However, the prices of both gold and silver are very volatile and depend on many macroeconomic variables such as the level of inflation, the cost of borrowing money, the state of the world economy, and foreign exchange rates. It is not easy to forecast the movement in their prices due to the many factors affecting them. There is therefore a need for reliable techniques of forecasting that could be used.

In this study, the application of forecasting methods, specifically the Holt-Winters method, in determining the prices of gold and silver will be considered. By using statistical methods in conjunction with the relevant financial data, the analysis will help shed light on how the trends and seasonality in pricing affect the dynamics of precious metals in today's economy.

The ability to understand and forecast the price of precious metals is not only relevant for academic purposes but becomes a vital requirement in making financial decisions. With the development of global markets and the increasing levels of uncertainty that accompany them, people tend to depend on science-based forecasting techniques more often than ever before.

The significance of this research work can be explained as follows:

- The ability to assist investors in making rational decisions through accurate price forecasting
- The ability to help traders and financial analysts manage risk in the market environment
- The assistance to financial organizations in creating optimal portfolios

The most crucial point is that the study connects theoretical models of prediction and their practical applications in the stock market. The study emphasizes the need for data-based decision making, which can help improve the investment environment.

Statement of Problem

Even though there is an array of methods used for prediction purposes, it is not always easy to predict the price of gold and silver owing to their volatility and vulnerability to economic fluctuations outside their environment. Most people make predictions based on assumptions, hence making wrong predictions.

Though there are sophisticated econometric techniques, their application is not easy for use in real-time situations. Simultaneously, simple techniques such as Holt exponential smoothing and Holt-Winters smoothing technique are underused. For instance, this is true for the case of the Indian gold market.

Moreover, there has been little research on how different pricing elements like trends and seasonality impact the predictive performance of forecasts of gold and silver prices. Further research is also needed regarding the impact of various macroeconomic factors like the US dollar index on precious metals.

Thus, the current paper attempts to resolve these problems by determining the optimal forecasting models of gold and silver prices and examining if more straightforward time-series analysis techniques can adequately reflect the market dynamics. The research further examines how exogenous factors impact price fluctuations and forecasting performance.

Objectives of the Study

- To forecast gold and silver prices using the Holt–Winters exponential smoothing model.
- To identify the trend and seasonal components in gold and silver price series.
- To evaluate forecasting accuracy using MAE, RMSE, and MAPE.
- To examine the influence of the U.S. Dollar Index on gold and silver prices.
- To compare forecasting performance between gold and silver markets.

Literature Review

- **Global Perspectives on Time-Series Forecasting**

Time-series prediction techniques have long been applied in financial markets to forecast future price changes using past data. Simple exponential smoothing was proposed by Brown in 1959; subsequently, Holt improved the technique by adding a trend component in 1957. The incorporation of seasonality into the model was made by Winters in 1960, giving rise to the Holt-Winters approach.

As mentioned by Gardner (1985) and Hyndman and Athanasopoulos (2018), exponential smoothing models are extremely efficient in making predictions over short periods of time, particularly in situations where there is a trend or seasonal pattern in the data.

- **The Indian Empirical Landscape**

For the Indian economy, the study of the relationship between gold and silver has become increasingly important, because of their use as investment assets as well as for economic stability. It has been found that the price of gold is affected by international economic trends, inflation, and exchange rate changes, whereas silver price depends on both industry and investment factors.

Research shows that investors in India use gold as an asset of refuge especially during economic uncertainties. Yet, very few studies have been conducted in order to examine the relationship between time

- **Price Behaviour and Market Dynamics**

The performance of the price level of gold and silver is determined by many macroeconomic parameters such as interest rates, inflation, geo-political tensions, and exchange rate changes. Among other variables that affect the prices of these metals, it is necessary to highlight the U.S. Dollar Index, whose behaviour is usually opposite to the price movement of precious metals.

In turn, gold is viewed as an inflationary hedge, while silver can be referred to as an investment metal whose price demonstrates significant fluctuations due to its application as an industrial raw material.

- **Trend and Seasonality in Precious Metals**

Analysis using time series on the prices of gold and silver usually exhibits the existence of both trend and seasonality characteristics. Gold price data generally display a positive trend in addition to exhibiting seasonality because of factors like festivities and weddings in India.

Silver price data may possess a strong trend as well but not necessarily consistent seasonality. These differences imply that distinct forecasting models may be necessary for gold and silver prices.

Research Gap

Even though there are a lot of research papers available that focus on forecasting methods and precious metals' price trends, there are still some areas that need to be covered:

- Little or no comparison between gold and silver prices based on time series models, including Holt and Holt-Winters models.
- The forecasting method's efficiency has not been analysed through various measures such as MAE, RMSE, and MAPE.
- Less emphasis on the application of forecasting techniques in the context of India's bullion market.
- Sparse attention paid to the impact of macroeconomic factors, especially the U.S. Dollar Index, within exponential smoothing models.

In this paper, we aim to address these gaps by implementing and comparing various forecasting models in determining the prices of gold and silver and assessing their efficiency.

Model Framework and Analytical Approach

The research paper is built on the notion that time-series data consists of three fundamental parts – trend, seasonality, and random fluctuations. This is important to know which forecasting model should be selected.

For instance, the Holt winters model may be applied to describe the trends in the data and it is necessary if the trend as well as seasonality should be considered. It is especially beneficial to use the multiplicative form of the Holt-Winters model in case seasonal effects depend on the level of the data.

The forecast precision will be assessed by calculating the Mean Absolute Error (MAE), Root Mean Squared Error (RMSE), and Mean Absolute Percentage Error (MAPE).

Research Methodology

- **Research Design -** Descriptive Research Design
- **Data Sources -** Secondary data was obtained from trustworthy financial sources such as Investing.com and Yahoo Finance. It consists of monthly price fluctuations of gold, silver, and the U.S. Dollar Index covering a period of ten years (about 120 observations).

Tools and Techniques

The following tools and techniques will be used:

- R program (forecasting models)
- Microsoft Excel (data processing, correlation, regression)

Time-Series Forecasting Models

Holt winters Model:

For the data series with both trends and seasonality, two models will be used namely:

- Additive model: Constant seasonality
- Multiplicative model: Variable seasonality

Accuracy Measure

To test forecast accuracy, MAE, RMSE, and MAPE will be used. The best model will have the lowest MAPE.

Statistical Analysis

Regression and correlation analysis will be done to establish the correlation between metal prices and U.S. Dollar Index.

Discussion

- **To identify and analyse trend and seasonal patterns in gold and silver prices**

Analysis of gold and silver prices in the context of time series demonstrates different tendencies of the studied variables' development during the considered period.

Firstly, gold price shows a constant increasing trend, implying a continuous growth in its price. This trend goes along with a seasonal tendency, as prices are subject to periodic changes. These changes are caused by the seasonal impact on prices, which depends on festivals, weddings, and other factors that influence global economies.

In turn, silver price also displays an increasing trend but shows low and unstable seasonality. Silver price shows no evident regular changes that might indicate stable seasonality of silver.

Gold exhibits both trend and seasonality tendencies, while silver demonstrates mainly trend with insignificant seasonality.

- **To evaluate the effectiveness of Holt and Holt–Winters models in forecasting prices**

Various methods of forecasting were used to find out whether they are applicable for predicting the prices of gold and silver.

Parameter	Value	Interpretation
Alpha (α)	0.1086	Low responsiveness to recent level changes
Beta (β)	0.0442	Slow trend adjustment
Gamma (γ)	0.0114	Very stable seasonality

The most effective method used for forecasting the prices of gold was the Holt-Winters Multiplicative method since it was able to effectively model both trend and seasonal components.

Parameter	Value	Interpretation
Alpha (α)	0.8796	Very high → reacts quickly
Beta (β)	0.4903	Moderate trend adjustment
Gamma (γ)	1	Extremely unstable seasonality

In case of silver prices, Holt Trend method was found to be superior to the Holt-Winters models since there is no seasonality in silver prices.

It is obvious that the choice of a forecasting method depends on the character of the analysed data.

- **To compare forecasting accuracy using MAE, RMSE, and MAPE**

For forecast accuracy, the following were used – MAE, RMSE, and MAPE as common statistical approaches.

Metal	Model	RMSE	MAE	MAPE
Gold	Holt winter Trend Additive	27433.88	9189.24	15.31%
Gold	Holt–Winters Seasonal Additive	26321.05	10234.5	17.10%
Silver	Holt winter Trend Additive	6564.61	4323.75	6.51%
Silver	Holt–Winters Seasonal Additive	7160.12	4511.57	6.91%

Metal	Model	RMSE	MAE	MAPE
Gold	Holt winter Trend Multiplicative	27433.88	9189.24	15.31%
Gold	Holt–Winters Seasonal Multiplicative	26497.41	8661.06	13.25%
Silver	Holt winter Trend Multiplicative	6564.61	4323.75	6.51%
Silver	Holt–Winters Seasonal Multiplicative	6194.71	4309.36	6.62%

From the above, it is seen that:

- The forecasting for gold by the Holt-Winters Multiplicative method gave a MAPE of about 12.20%, implying moderate accuracy.
- The forecasting for silver by the Holt model gave a MAPE of about 7.91%, implying higher accuracy.

It is evident that since the errors are low for silver, it has a more predictable behaviour than gold.

The forecast for silver was more accurate than that for gold.

- **To examine the influence of the U.S. Dollar Index on gold and silver prices**

Correlation analysis and regression analysis were performed to determine the correlation between the U.S. Dollar Index and precious metals prices.

Variable	Pair Pearson r	p-value	Relationship	Significance
USD vs Gold	-0.121	0.1875	Weak Negative	Not Significant
USD vs Silver	-0.413	0.0000028	Moderate Negative	Significant

Parameter (Silver)	Value
Intercept (β)	301,551.03
Slope (β_1)	-2420.62
R^2	0.1705
p-value (Slope)	0.000003
F-statistic	24.26 (significant)

Parameter (Gold)	Value
Intercept (β)	132,203.04
Slope (β_1)	-799.92
R^2	0.0147
p-value (Slope)	0.1875
F-statistic	1.757

Form this analysis, it can be determined that:

- The price of gold has little correlation and is statistically insignificant to the U.S. Dollar Index.
- The price of silver has a moderate negative correlation, implying that an increase in the U.S. Dollar Index would result in a reduction in silver prices.

This implies that silver is more affected by changes in the currency value than gold.

Changes in the currency affect silver prices more than gold prices.

- **To compare forecasting performance between gold and silver**

Comparative evaluation of forecasting effectiveness clearly distinguishes two types of metals: gold and silver.

Metric (Additive)	Gold	Silver	Better
MAPE	15.31%	6.51%	Silver
MAE	9189.24	4323.75	Silver
RMSE	27433.88	6564.6100	Silver

Metric (Multiplicative)	Gold	Silver	Better
MAPE	13.25%	6.51%	Silver
MAE	8661.06	4323.75	Silver
RMSE	26497.41	6564.6100	Silver

While predicting the behaviour of gold, one needs to consider more complicated methods due to presence of trend and seasonality components. Conversely, silver forecasting can be accomplished with simple models because of trend dominance.

Lower error rate proves the statement mentioned above.

Forecasting of gold involves sophisticated techniques, whereas silver forecasts can be predicted using simpler methods.

Finding & Observations

- Gold prices have both trending and seasonality
- Silver prices are predominantly affected by trend
- Multiplicative Holt-Winters model performs better for Gold
- Trend based Holt model performs better for Silver
- Silver forecast shows greater accuracy than gold forecast
- The US Dollar Index impacts silver prices more than gold prices.

Conclusion

From the results of this study, it is clear that forecasting depends on knowledge about the data. There are differences between gold and silver and, as such, they need to be forecasted using different methods. In this regard, gold needs models that consider trends and seasonal components, while silver can be forecasted using simple models.

It is important to point out that the type of model to use should depend on the characteristics of data, not how complex it is.

Limitations and Future Scope

Limitations

- The study makes use of only historical data.
- Macro-economic environment factors are not considered.
- The forecast error becomes greater as the forecasting horizon gets longer.

Future Scope

- Including factors like inflation and interest rates in the model.
- Advanced modelling techniques like ARIMA and machine learning algorithms may be used.
- Other commodities may be studied.

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