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# Gold price volatility: A forecasting approach using the Artificial Neural Network–GARCH model

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ABSTRACT

One of the most used methods to forecast price volatility is the generalized autoregressive conditional heteroskedasticity (GARCH) model. Nonetheless, the errors in prediction using this approach are often quite high. Hence, continued research is conducted to improve forecasting models employing a variety of techniques. In this paper, we extend the field of expert systems, forecasting, and model by applying an Artificial Neural Network (ANN) to the GARCH method generating an ANN–GARCH. The hybrid ANN–GARCH model is applied to forecast the gold price volatility (spot and future). The results show an overall improvement in forecasting using the ANN–GARCH as compared to a GARCH method alone. An overall reduction of 25% in the mean average percent error was realized using the ANN–GARCH. The results are realized using the Euro/Dollar and Yen/Dollar exchange rates, the DJI and FTSE stock market indexes, and the oil price return as inputs. We discuss the implications of the study within the context of the discipline as well as practical applications.



## 1. Introduction

The ability to forecast the volatility of security prices is a major challenge given their economic and financial importance. In this context, the ability to predict gold price (spot and future) volatility with greater precision is important for commodity markets and for the world economy. The common method is to apply generalized autoregressive conditional heteroskedasticity (GARCH) models to forecast volatility. Nonetheless, the errors in prediction using this approach are often quite high. Resultant errors in forecasting have the potential to deliver great economic loss for those using a flawed model. Additionally, shortcomings in modeling approaches contribute to greater inefficiencies in the market. Hence, improved modeling approaches are continuously sought in order to reduce risk and improve market efficiencies.

Traditional research to reduce errors in models has sought to include variables that appear to be more important in explaining gold price volatility for the period studied thereby improving the explanatory power of a particular model; however, this approach typically lacks the capability to forecast outside of the sample period. This study innovates by changing the focus of the models to the capability to forecast future volatility as opposed to explaining. The results of this study are therefore more useful in the prediction of the gold spot price and the future gold price volatility. This should be important for government agents in countries with an economy related to the gold, and for investors wanting to make investment decisions in the commodity market (spot and future) to get a better asset allocation and portfolio diversification.

In an earlier study, Tully and Lucey (2007) modeled the price volatility of gold using an Asymmetric Power (AP) GARCH model, concluding that the most relevant variables influencing gold price volatility were oil prices and the FTSE. Kristjanpoller, Fadic, and Minutolo (2014) demonstrated that an expert system, in particular the ANN–GARCH, increases the accuracy of volatility forecasts predicted by GARCH models. The expert system is sensitive to behavior between variables such that the results are improved forecasts. The ANN–GARCH approach creates the possibility to determine the influences that variables exert the result of which is incremental improvements in the accuracy of forecasts as compared to the classical form of their relationship in the fit of the model. The ANN–GARCH approach incorporates as input to the ANN model the GARCH forecasts but allows for the possibility to incorporate other inputs variable into the ANN. Thus, financial variables that are significant for the price or the volatility of the price of gold in the classical models can be incorporated. This fact is very important, since the focus is not on the behavior *in*-sample, but the influence of the

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variables is measured according to its contribution in the forecast *out*-of-sample. Building on these previous works, this study employs an ANN–GARCH model to forecast volatility beyond the sample period to the out-of-sample population thereby improving current knowledge and abilities.

The significance of this current work is based on two findings. First, we determine the improvement of accuracy in forecasting using a hybrid model as opposed to traditional GARCH models. In particular, we demonstrate greater accuracy of the hybrid ANN–GARCH forecasts of gold price volatility for different periods and for spot and future gold prices over the GARCH alone. Second, the ability to include financial variables as inputs of the ANN allows for the determination of the influence that the variables have on the estimation of the gold price volatility, spot and future for different horizons. This work is important since improved accuracy of gold price estimations and of gold price volatility will result in investor decision making, improve the efficiency of the market, and contribute in the future price allocation.

The remainder of this work is divided into four additional sections. In the next section, we provide a brief review of the literature on forecast models, neural networks, and various applications that have analyzed gold spot prices and gold future prices for evidence of which macroeconomic and other economic variables influence them. In the following section the methodology is detailed and the data used are analyzed. The results are then presented and interpreted. Finally, the last section summarizes the main conclusions of this study.

## 2. Literature review

In recent years, authors have focused on modeling and forecasting volatility in financial series since it is crucial for the characterization of markets, portfolio optimization and asset valuation; the case of gold is no exception. There are numerous studies whose focus is on gold, whether it is in the analysis of its spot price, future price, or volatility. In this study, the volatility of the spot price and the future price of gold is modeled using an ANN–GARCH model to determine the important macroeconomic variables for forecasting.

Many types of models have been used to forecast volatility, but the most widely used are the ARCH models proposed by Engle (1982), and then generalized by Bollerslev (1986); they have led to significant improvements in the modeling of time series. Later Kroner, Kneafsey, and Claessens (1995) tried to predict the volatility of the daily price of cacao, corn, cotton, gold, silver, sugar, and wheat in the long term by using the combination of the GARCH model and the ISD (Implied Standard Deviation) model. In addition, Tully and Lucey (2007) investigated macroeconomic influences on gold using an AP–GARCH model. Their research examined the spot price and the future price of gold from 1983 to 2003 using macroeconomic variables. They paid special attention to two periods – around 1987 and 2001 – when there were shocks to the stock markets. The results showed that the AP–GARCH model delivered the most appropriate fit to the data, and the most important explanatory variable was the dollar.

Trück and Liang (2012) examined different models that can be used to predict volatility (GARCH, TARCH, TGARCH, ARMA) in order to study their behavior in the gold market and to evaluate the performance of these models. Their results showed that for prediction, both within and outside the sample period, the TARCH models provided the best results.

Finally, Creti, Joëts, and Mignon (2013) contributed to the field by studying the relationship between commodities and stocks. They focused on the dynamics of the correlation between both markets, and analyzed whether these correlations evolved according to the situation of "optimism or pessimism" in the stock market. The methodology they used was the dynamic conditional correlation approach (DCC) GARCH introduced by Engle (2002), which allows the assessment of changes over time in the correlations between returns on commodities and stocks.

Other tools used in the study of price volatility are Artificial Neural Networks. Several researchers have used them for the study of gold. For example, Grudnitski and Osburn (1993) studied the impact of general economic conditions and the expectations of the investors on the S&P 500 index and the prices of gold futures, modeling these prices like a neural network. Later on, Parisi, Parisi, and Díaz (2008) conducted a study in which they analyzed the Recursive Neural Network and the Rolling Neural Network as modifications to the traditional neural networks, and applied these new strategies to predict variations in the price of gold. Another study is that of Yazdani-Chamzini, Yakhchali, Volungevičienė, and Zavadskas (2012), who investigated the ability of the ANFIS (Adaptive Network Fuzzy Inference System) model to capture changes in the gold price, and then evaluated the model's performance compared to those of the ANN and the Autoregressive Integrated Moving Average (ARIMA) model. Their results showed that the ANFIS and ANN methods are powerful tools to model the price of gold and can produce better results than the ARIMA model.

Since we want to predict the future, it is necessary to consider the implied volatility of gold prices in addition to their realized volatility and history. Hamid and Iqbal (2004) predicted the volatility of prices of a group of commodities using a neural network, and then they compared their results to the implied volatility obtained by using the Barone-Adesi and Whaley options pricing model (1987) to contrast both predictions with the actual volatility. The conclusions of the article indicated that the predictions made by the neural network substantially improved the predictions obtained through the implied volatility.

Szakmary, Ors, Kyoung Kim, and Davidson (2003) also analyzed the implied volatility. Their work represents an important contribution because they used data from futures markets, where options about futures and underlying future contracts are traded on the same basis. The results obtained in the study indicated that even though the implied volatility performed well, it was not an unbiased forecaster of future volatility. Neely (2003) used high-frequency data (every 30 min) of future spot prices of gold as well as new econometric techniques, including long memory models, to examine why implied volatility is an inefficient and biased forecaster of actual volatility. According to his study, none of the suggested explanations previously mentioned in the literature (inaccurate estimation of volatility, overlapping samples, selection of the sample, etc.), can plausibly explain this bias and inefficiency.

Finally, it is necessary to know what other variables affect the gold market, since one of the requirements for using neural networks is the correct selection of explanatory variables. There are numerous studies that have analyzed the impact of macroeconomic variables on the price of gold; for example, Batten, Ciner, and Lucey (2010) examined the relationship between the volatility of four metals actively traded in the markets (gold, silver, platinum and palladium) with key macroeconomic factors in the global economy, such as the price of oil and inflation. These studies provide clear evidence that the same macroeconomic factors have an influence on the volatility of the series of precious metal prices, but there is limited evidence of the feedback from the price volatility of other commodities.

Shafiee and Topal (2010) analyzed the behavior of gold prices from all existing records to see what factors have helped increase its value, given that the gold market has attracted a lot of attention and its price is nearly the highest in history. The most important variables that explain gold price behavior are the price of oil and