Predicting Stock Prices basing on Money Supply and other Macroeconomic Variables

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Abstract

The level of stock market indices is determined by many macroeconomic factors and phenomena. The stock market situation, on the one hand, can reflect economic activity and consumer confidence, on the other hand, central bank policy and geopolitical tensions. This article examines the impact of the M2 money supply in the United States on the S&P 500 stock market index. In addition, it examines the relationship between the industrial production index, the Federal Reserve System interest rate (federal funds rate), energy commodity prices, the U.S. dollar index and the S&P 500 stock market index.

1 Review of the scientific literature

There is no consensus in the scientific literature about the direction of the effect of the money supply on the stock market. Keynesian theory says that there is a negative relationship between money supply and stock prices, while real activity theory indicates a positive relationship. The expectations of economic agents can play an important role in the effect of money supply on the stock market index. For example, Peter Sellin (2001) points out that the money supply will affect the stock market only if a change in the money supply leads to a change in investors' expectations. He states that an increase in the money supply leads to a tightening of expectations about future monetary policy. As a result, investors expecting a decrease in the money supply, take this into account in their decisions, which leads to an increase in the current interest rate, as well as an increase in the discount rate. This, in turn, leads to lower stock prices. Sellin (2001) also adds that an increase in interest rates weakens economic activity, which also depresses stock prices.

Real activity theorists take a different view (Maskay, 2007). They believe that a positive money supply shock will lead to an increase in stock prices. They argue that an increase in the money supply means an increase in the demand for money, which in turn signals increased economic activity. In turn, higher economic activity determines higher money flows in the economy, which positively affects stock market indexes.

Ben Bernanke and Kenneth Kuttner (2005) agree with this thesis. As they argue, a reduction in the money supply increases the interest rate and, at the same time, the discount rate, which lowers stock prices. Bernanke and Kuttner (2005) therefore point to a positive relationship between the money supply and the stock market index through the interest rate. In addition, they state that a reduction in the money supply lowers economic activity and reduces the potential for companies to generate high profitability. In such a situation, investors increase the risk premium, which reduces the attractiveness of stocks and lowers their price.

In considering the relationship between the money supply and the stock market index, Eric Sorensen's (1982) study should also be mentioned. He examined the impact between expected and unexpected changes in money supply and stock prices using a two-stage regression model. Sorensen (1982) finds that an unexpected change in the money supply has a greater impact on stock indexes than an expected

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change in the money supply. It is worth noting that the empirical evidence from Sorensen's (1982) study supports the efficient market hypothesis, which assumes that all information is contained in the stock price, hence only an unexpected change in the money supply can affect stock market indexes. On the other hand, opponents of the efficient market hypothesis point out that stock prices do not contain all information (Corrado and Jordan, 2005). Therefore, even an expected change in the money supply can affect stock price indexes.

A key macroeconomic variable - linked to changes in the money supply - that affects stock prices can be the interest rate. Bernanke and Kuttner (2005) analyzed the impact of expected and unexpected changes in the federal funds rate (the main rate of the US central bank) on stock prices. The authors found that the stock market reacts more strongly to unannounced changes in Fed interest rates, which also supports the efficient market hypothesis. D'Agostino, Sala and Surico (2005) show that an unexpected Fed monetary policy tightening of 50 basis points causes the S&P500 index to fall by 4.7 percent. Huang, Mollick and Nguyen (2016), using weekly data from January 3. 2003 to March 27, 2015, find that the correlation between the real interest rate (in simple terms: nominal interest rate - inflation) and the return on US stock markets (S&P500, DJIA, NASDAQ) is different in the period up to January 28, 2009 and negative in the period after 2009. This is due to the fact that real interest rates became negative after 2009. Findings from the second period suggest consistency with the common view that a decline in the real interest rate leads to an increase in stock market indices. Similarly, Assefa, Esqueda and Mollick (2017), analyzing the period 1999-2013, find that declines in interest rates in developed countries led to a bull market in the stock market. At the same time, they prove that in developing countries, interest rate cuts did not affect the stock market (Assefa et al., 2017). Kurihara (2006) shows that the decline in interest rates during quantitative easing in Japan did not affect stock market indexes. Complementing this narrative is a study by Kimura and Small (2006), who find that quantitative easing in Japan increased the risk premium on corporate bonds and low-rated stocks, with the result that the stock market did not respond with increases.

The development of stock markets can also be determined by other macroeconomic variables such as the industrial production rate, GDP growth, energy commodity prices and the level of the exchange rate. In general, macroeconomic factors are fundamental to stock market indices. As King (1996) points out, macroeconomic phenomena explain the behavior of stock prices by an average of 50 percent. Clare and Thomas (1994) proved that there is a strong relationship between the price of oil, inflation, credit volume and the British stock market. Similar conclusions were reached by Gjerde and Saettem (1999) for the Norwegian stock market and by Cheung and Ng (1998) for the German, Italian and Japanese stock markets.

2 Data Description

We examine the relationship between macroeconomic variables and the stock market by analyzing monthly data on the M2 money supply, the industrial production index, the Fed interest rate, gasoline prices, gas prices, the U.S. dollar index and the S&P 500 stock market index for the period Jan'2000-Dec'2022. However, we exclude the price of gasoline in the model because there is too much correlation between the price of gasoline and the price of gas, which would negatively affect the model's results. The data source for the M2 money supply, the industrial production index, the Fed interest rate, gasoline prices, gas prices and the S&P 500 stock market index is Federal Reserve Economic Data (FRED), while the data source for the U.S. dollar index is Yahoo Finance.

The unit of M2 money supply is seasonally adjusted billions of U.S. dollars. The industrial production index is seasonally adjusted, and the base period is 2017=100. An increase in the index indicates an increase in industrial production over the period, while a decrease in the index indicates a decrease in industrial production. The Fed's effective federal funds rate is used as the interest rate in the model. The unit of gasoline price and gas price is US dollars per gallon seasonally adjusted. The US dollar index shows the value of the dollar against major currencies. An increase in the index indicates an appreciation of the dollar, while a decrease in the index indicates a depreciation of the dollar. The S&P 500 Index consists of 500 key companies in the US economy and covers 75 percent of US stocks. The figure below shows the monthly change in the analyzed macroeconomic indicators for the period January - December 2022.

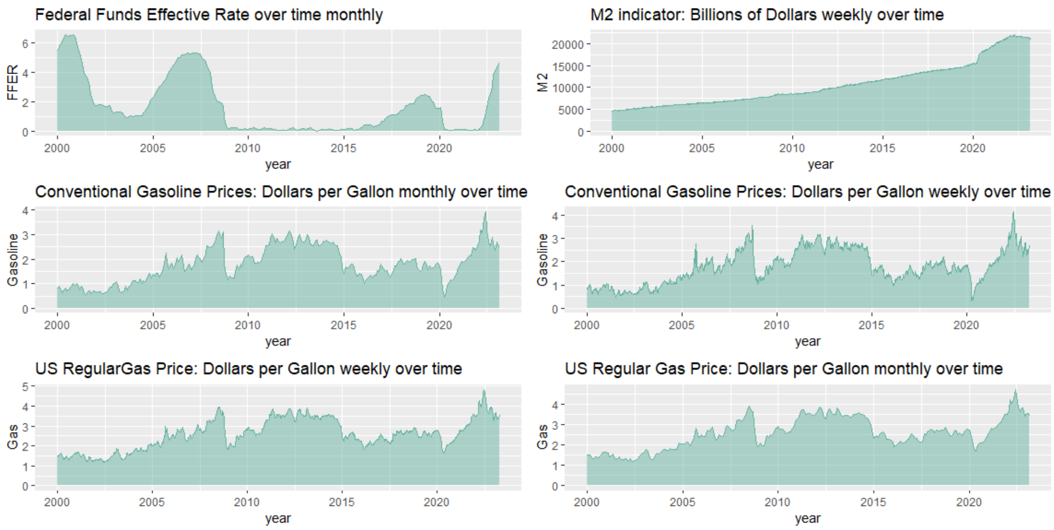

Figure 1: The level of macroeconomic variables in the perios January 2000 - December 2022

3 Methodology and Analysis

To carry out statistical analysis of the hypotheses for estimating stock prices basing on money supply and other macroeconomic indexes, we used a number of methods that are widely used by statisticians and econometricians around the world. Among them is linear regression, which will allow us to examine the relationship between the dependent variable (S&P 500) and independent variables mentioned in the previous sections. To consider excluding indicators that are not statistically significant we implemented the LASSO regression model to our data. Another way to predict the outcome variable is the so-called tree algorithms, based on a tree structure. We used one of them, namely the XGBoost algorithm, to model the S&P 500 value of interest.

3.1 Linear Regression

In statistics Linear Regression is a set of methods for modelling relationships between variables of interest. In particular, our goal is to minimize distance between dependent (y) and independent variables ($\boldsymbol{x}$) by estiamting unbiased estimators of coefficients in linear model which has following form

$$y_i = m\left(\boldsymbol{x}_i\right) + \varepsilon_i$$

, where $m\left(\boldsymbol{x}_i\right) = E_{\xi}\left(y_i \mid \boldsymbol{x}_i\right)$ and $m\left(\boldsymbol{x}_i\right)$ can take a parametric form such as $m\left(\boldsymbol{x}_i\right) = = x_i^{\top}\boldsymbol{\beta}$. By minimiziation residuals of the squared distance between linear predictors and y variable.

$$\sum_{i=1}^{n} \varepsilon_i^2 = \sum_{i=1}^{n} \left[y_i - m\left(\boldsymbol{x}_i\right)\right]^2 .$$

We get following estimators of coefficients, which lead to us to the final result of the model

$$\hat{\boldsymbol{\beta}} = \left(\sum_{i \in \mathcal{S}} \boldsymbol{x}_i \boldsymbol{x}_i^{\top}\right)^{-1} \left(\sum_{i \in \mathcal{S}} \boldsymbol{x}_i y_i\right),$$

where S is our sample.

3.2 Lasso Regression

In theoretical terms, Lasso Regression is a linear regression method that uses a penalty term to regularize the model and prevent overfitting. The goal of Lasso Regression is to find the set of regression coefficients that minimizes the sum of squared errors between the predicted and actual values, subject to a constraint that the sum of the absolute values of the coefficients is less than or equal to a predefined constant.

Mathematically, Lasso Regression can be expressed as minimisation of

$$\sum_{i=1}^{n} \left[y_i - m\left(\boldsymbol{x}_i\right)\right]^2 - \lambda \sum_{j=1}^{p} |\beta_j|$$

The penalty term (λ) in Lasso Regression shrinks the magnitude of the regression coefficients towards zero, resulting in a simpler model with fewer variables. This is known as "sparsity", and Lasso Regression can be used for feature selection by setting the coefficients of irrelevant features to zero.

3.3 eXtreme Gradient Boosting

The eXtreme Gradient Boosting (XGBoost) is a popular machine learning algorithm that uses an ensemble of decision trees to make predictions. XGBoost is an extension of the Gradient Boosting algorithm, which iteratively fits weak learners to the residuals of the previous iteration in order to improve the overall model accuracy.

In XGBoost, the algorithm builds an ensemble of decision trees, where each tree is trained to predict the residual errors of the previous tree. This is done by using a customized loss function that includes a regularization term to prevent overfitting. The regularization term consists of both L1 and L2 penalties on the weights of the trees, which help to control the complexity of the model and reduce the risk of overfitting.

XGBoost also incorporates several advanced features, such as the use of second-order gradient information for more accurate and efficient splitting of decision trees, and the ability to handle missing values in the data. Additionally, XGBoost includes a built-in mechanism for early stopping that allows the algorithm to automatically stop iterating once the model performance stops improving.

3.4 Arima Model

ARIMA (Autoregressive Integrated Moving Average) is a time series forecasting model that combines autoregressive (AR), integrated (I), and moving average (MA) components to make predictions about future values of a time series.

Autoregressive (AR) refers to a model that predicts future values of a time series based on its own past values. Integrated (I) refers to a technique used to remove trends or seasonality from a time series by differencing the series. Moving average (MA) refers to a model that predicts future values of a time series based on the average of its past values.

The ARIMA model is typically denoted as ARIMA(p,d,q), where p, d, and q represent the orders of the AR, I, and MA components, respectively. The AR component captures the autocorrelation in the time series, the I component captures the trend and seasonality, and the MA component captures the residual errors.

4 Result Analysis

4.1 Result Analysis tables

Table 1: RMSE error by the model

Interval	Linear Regression	XGBoost	LASSO
Monthly	375.3543	1136.186	405.1332
Weekly	398.8621	1369.678	428.7943

4.2 Result Analysis interpretation

Our analysis shows that among the models analyzed, the RMSE is lowest for data with a monthly interval for the linear regression model. Therefore, we choose monthly data for analysis.

Our analysis shows that the linear regression model will be the best for studying the impact of macroeconomic variables on the SP 500 stock index. We choose the linear regression model because it has a higher level of statistical significance for the macroeconomic variables analyzed.

Variance Inflation Flower for no variable exceeds 5, and the overall model fit to the data (adjusted R sqquared) is 0.97. Three variables are at the significance level of p = 0.001 (volume in million, m2sl, fedfunds). In contrast, one variable is at a significance level of p = 0.01 (gasregm). Two variables (usdxm close, indpro) are not statistically significant, but improve the model fit.

5 Summary

For each unit increase in the variable "m2sl" (money supply seasonally adjusted), the value of the dependent variable decreases by 0.2369 units.

For the "volume in mln" (variable means that for each unit increase in the "volumeinmln" variable, the value of the dependent variable (presumably resulting from this model) decreases by 0.005144 units.

For the "gasregm" variable means that for each unit increase in the "gasregm" variable, the value of the dependent variable decreases by 71.43 units.

For the fedfunds variable means that for each unit increase in the fedfunds variable, the value of the dependent variable increases by 100.4 units.

For the variable "usdxm close" means that the effect of this variable on the dependent variable is negative, but it is not statistically significant (t = -0.884, p = 0.3777).

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