TIME SERIES MODELING OF THE DYNAMICS OF THE DOW AND S&P 500 INDEXES OVER TIME

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ABSTRACT

Performance of the stock market affects many individuals and corporations and is of importance for the economy of the country. Therefore, it is of prime importance to be able to determine variables that relate to stock returns and develop models that can predict the behavior of the stock market over time. In this study, from a set of nine macroeconomic variables, we developed linear time series models (using transfer function and auto-regression time series analyses) relating the DOW index and the S&P 500 index as dependent variables to the GDP as the independent variable. For both indexes, the index at time t was a function of its lag at time t-1 and the GDP at time t and its lag at time t-1. This simple model gave an excellent fit to the data for pre and post the 2008 recession. Forecasts from the model were good for the pre-2008 recession but underestimated somewhat the observed indexes for 2017 and 2018. This could be attributed to outside intervention due to deregulation (or in anticipation of) during the Trump presidency. GDP seems to be a good predictor of the DOW and S&P behaviors over time under normal circumstances, barring any intervention, such as recessions, regulations or deregulations, or world political events.

INTRODUCTION

The stock market in the US is of major importance for the economy of the country. More than fifty percent of individuals in the United States are invested in the stock market. In addition, corporations are heavily invested in the stock market and many people depend for their retirement on the stock market. Therefore, performance of the stock market affects many individuals and corporations and hence is of importance for the economy of the country. Movement and volatility in the stock market are indicative of changes in macroeconomic variables that have a bearing on the economy.

Many studies in the literature show that stock market returns are related to certain macroeconomic variables such as interest rate, bond rate, GDP, inflation, and industrial production. Most of the studies used cointegration analysis to determine short and long-term effects of macroeconomic variables on stock returns. Of importance is to develop models that can predict the performance of the stock market returns from macroeconomic variables. Few models using ordinary least square regression were used to develop predictive models in developing countries. These models were weak predictors of stock market performance. Ordinary least squares is known not to be the proper methodology for time series data. The best approach for model development is the use of multiple time series methodology that addresses the autocorrelation in the errors and allows for the detection of feedback between the dependent and independent variables and the determination of lags in the dependent as well as each of the independent variables in the model.

In this study, we extend the present research in the literature by attempting to build models, using time series methodology, for out of sample prediction of the US DOW JONES and S&P 500 stock market indexes.

LITERATURE REVIEW

In a study of the effects of macroeconomic variables on the stock exchange in Romania, Sabău-Popa et al. (2014) using the grey incidence analysis technique, reported that there was a significant relationship between the Bucharest stock exchange index and each of the following variables: GDP, 5-year bond interest rate, the RON/USD exchange rate, and inflation rate. GDP has the largest impact of all the variables studied. It was concluded that economic growth, currency appreciation, low interest rate, and low inflation rate contribute to a robust stock market.

Pian and Smith (2013) applied nonparametric dimension-reduction techniques to study the effects of macroeconomic variables on monthly stock returns of 25 portfolios between 1960 and 2008. Authors used inverse regression to extract from the 15 macroeconomic variables three variates that were significant and explained 95% of the variation in the stock returns. The first variate represented low inflationary expectations and low credit-risk. The second variate was strong economic indicators; the third variable related to inflation shocks and gave a small contribution to the model.

Naifar (2016) reported on economic factors affecting the global Islamic index using quantile regression. Of the variables studied it was found that conventional stock market returns, stock market volatility and future economic conditions (deduced from the slope of the yield curve) were significant for all the quantiles. In addition, the credit risk factor was significant with a positive coefficient. Oil prices and investor sentiment indicator had a positive effect, but only for the lower quintiles.

Chakraborty and Gupta (2017) using ordinary least squares regression studied the effects of money supply, gold prices, exchange rate, GDP, and inflation on the Bombay Stock Exchange. Results indicated that none of the macroeconomic variables had any significant effect on the stock market returns.

In a study on the effect of macroeconomic factors on the Indian stock market, Bhattacharya (2014) using factor analysis and regression on factor scores, reported that three factors had an effect on the stock market returns for the time 2000-2010. One factor was termed a domestic macroeconomic factor, the second a money market factor which includes interest rate, and the third a foreign involvement factor. After correcting for autocorrelation by using the Cochrane and Orcott regression technique, it was found that factor one was positively related to stock returns and factors 2 and 3 were negatively related to stock returns.

Hassan and Al Refai (2012) investigated the long run relationship between macroeconomic variables and equity returns using cointegration analysis. Results indicated that trade surplus, foreign exchange reserves, the money supply, and oil prices were important macroeconomic variables that had long run relationship with the Jordanian stock market. Kudyba (1999) using ordinary least square regression examined the effect of 30-year treasury yield as the independent variable on the daily close of the S&P and NSDQ indices as the dependent variables. The author reported that more than 50% of the variability in each index was attributed to the T-bond yield. In addition, the relationship between T-bond yield and index was nonlinear in the sense that the elasticity varied with yield. For yields above 6.4%, the inverse relationship between yield and index was observed. The rise in yield in the range 5.6% - 6.4% accounted for 30% decrease in the corresponding stock index.

In a study on the effects of macroeconomic variables (industrial production index, consumer price index, money supply, exchange rate, foreign portfolio investment, Treasury bill rates, and oil prices) on the stock market monthly returns for the period 1998-2008 in Pakistan, Hasan and Tariq (2009), using Granger causality test and cointegration, reported that equity market returns were causally effected by exchange rate, T-Bill, money supply and the consumer price index. Cointegration analysis revealed the presence of four cointegration vectors among the variables. Industrial production, oil price, and foreign investment had no significant impact on the equity market. However, inflation, Treasury bill rate and exchange rate were major contributors to the volatility of the equity market.

Misra (2018) investigated the effects of Index of Industrial Production (IIP), inflation, interest rate, price of gold, rate of exchange, foreign institutional investment (FII) and supply of money for the period April 1999-March 2017 on the Bombay stock exchange, namely BSE Sensex. Results of the Johansen Cointegration analysis and the Vector Error Correction Model (VECM) revealed that there was a long-term relationship between the macroeconomic factors and BSE Sensex. In addition, a short-term relationship existed between BSE Sensex, inflation, and money supply. Also, BSE Sensex had an effect on exchange rate, money supply, FII, gold price, and IIP.

Ratanapakorna and Sharma (2007) investigated the effect of six macroeconomic variables on the S&P500 index in the US over the period 1975-1999. Based on the Johansen cointegration analysis and the Vector error Correction Model (VECM) results showed that stock prices were negatively related to the long-term interest rate and positively related to industrial production, money supply, inflation, exchange rate, and short-term interest rate. Furthermore, every economic variable Granger causes the stock prices in the long-term, but not in the short-term.

Kwon and Chin (1998) investigated cointegration and causality between macroeconomic variables and stock market returns in Korea. The data was monthly stock prices on the Korea Composite Stock Price Index (KOSPI) and Small-size Stock Price Index (SMLS) for the period, January 1980 to December 1992. Results from the cointegration test and the Vector Error Correction Model, showed that both stock market indices were cointegrated with the production index, exchange rate, trade balance, and money supply. This indicated that both market indices had long-run equilibrium with these four macroeconomic variables. While the macroeconomic variables had an effect on predicting the stock market prices, the reverse was not true.

Flannery and Protopapadaki (2002) using the GARCH (1, 1) model and 17 macroeconomic conditions to investigate the effect of the macroeconomic variables on the NUSE_AMEX_NASDAQ stock market daily index for the period 1980-1996. Results indicated that six of the 17 variables had effects on the stock market index. Two inflation measures (CPI and PPI) had an effect on the level of the market returns.

Balance of trade, employment and housing starts had an effect on the returns' volatility. Monetary Aggregate had an effect on return level and volatility. Also, the same variables increased the stock market trading volume. It was interesting to find that real GNP and industrial production had no effect on the stock market index.

Sousa et al. (2016) investigated the predictability of stock market returns from macroeconomic, macro-financial and US/global variables in the BRICS countries: Brazil (BR), Russia (RS), India (IN), China (CH) and South Africa (SA), over the period 1995Q1–2013Q2 employing quarterly data. Using ordinary least square regression, their analysis shows that overall there was very little evidence for out of sample predictability using macro-finance variables (Consumption–wealth ratio, wealth-income ratio and equity price scaled by GDP) that seem to have predictability in developed markets. Variables that showed signs of out of sample predictability for equity returns were the output gap to GDP variable, the central bank rate and the change in the exchange rate with regard to the US dollar. In general, for the 2005-2013 out of sample period, empirical evidence for predictability of stock returns for the BRICS countries was limited

Rjoub et al. (2009) investigated the effects of macroeconomic factors on the returns of 193 stocks in the Istanbul stock market using monthly data for the period January 2001 to September 2005. The six macroeconomic variables chosen for the study were the term structure of the interest rate, unanticipated inflation rate, risk premium, exchange rate, money supply, and unemployment rate. Using ordinary least square regression, results showed that there was a significant relationship between stock market returns and inflation, interest rate, money supply and risk premium. However, it was noted that the regression model was a weak predictor of stock returns indicating that there were other macroeconomic factors affecting stock returns that were not included in the model.

Kashif and Hasan (2016) investigated the effect of macroeconomic variables on stock returns in the Pakistan stock market. The data used was monthly for the period January 2000 to December 2015. The data was analyzed using the Garch model. Results indicated that an increase in interest rate had a negative effect on stock returns and a positive effect on volatility. Also, oil price was negatively related to volatility and positively related to stock returns.

Literature shows that certain macroeconomic variables had an effect on stock returns and in some cases volatility. However, most of the studies were done in developing countries. Few studies were for developed countries or in particular the United States. Furthermore, almost none of the studies attempted building models to predict stock returns. In this study, we extend this research by attempting to build a model using time series methodology for out of sample prediction of the US stock market index for the DOW JONES and S&P 500 stock markets.

DATA

Time series data on macroeconomic variables were obtained from the Federal Reserve Economic Data Base (https://fred.stlouisfed.org). Data was quarterly from the first quarter 1970-1 to the fourth quarter 2018-4. The economic variables were GDP in billions, consumer price index (CPI), saving deposits at commercial banks in billions, 10-year bond yield, Central bank interest rate, federal debt in millions, unemployment rate, industrial production index, and money supply in billions.

METHODS

In order to develop a model that can predict the performance index for the DOW and the S&P 500 two analytical procedures (transfer function in time series, and auto-regression) were utilized using the SAS software. The quarterly data were analyzed for two periods, before and after the 2008 recession. The first period was from 1970-1 – 2006-4 and the second period, after the recession, was from 2009-1 to 2016-4.

Time Series: Transfer function

The transfer function approach is one of the methods used in relating one or two input time series to an output time series. This time model relating a stationary output series y_t to a stationary input series x_i is expressed as

$$y_t = v(B)\, x_t + a_t, \tag{1}$$

where $v(B) = w(B)B^c/d(B)$.

Here, $w(B) = w_0 – w_1B - \ldots -w_sB^s$

$d(B) = 1-d_1B- \ldots -d_rB^r$.

and c represents the time delay (or lag) until the input variable x_t produces an effect on the output variable y_t.

We assume that the input series follows an ARMA process, $\frac{\varphi(B)}{\theta(B)}$ x_t. The function v(B) with its lags is determined from the cross correlations between the white noise input series $\frac{\varphi(B)}{\theta(B)}$ x_t and the filtered output series $\frac{\varphi(B)}{\theta(B)}$ y_t , namely the significance at a given lag and the pattern of the cross correlations over lags (Wei, 2006). For instance, if the correlation is significant at only lag 0, then Equation (1) becomes

$y_t = w_0x_t + a_t$. On the other hand, if the correlation is significant at only lag 1, then one has

$y_t = w_0x_{t-1} + a_t$

Once v(B) is identified, one can express a_t in Eq. (2) as

$$a_t = y_t – v(B)\ x_t \tag{2}$$

and identify the appropriate time series model for Eq. (2). With a_t known, one can determine the final model in Eq. (1).

Auto regression

The auto-regression model employed takes the form

$$y_t = a + bx_t + n_t \tag{3}$$

Where n_t was an auto-regressive process of the first order

$$n_t = \theta n_{t-1} + e_t\ (|\theta|< 1), \tag{4}$$

where e_t is random error. The order was determined by the Durbin-Watson statistic.

This auto-regression analysis is a proper method to use for time series data where the errors are auto-correlated. The estimation procedure corrects for the autocorrelation in the errors.

RESULTS AND DISCUSSION

Auto regression analysis: Period 1970-1 – 2006-4

DOW

All nine macroeconomic variables were entered first in the model and a backward elimination scheme was performed which deleted one at a time the variable that was least significant

(Montgommary et al., 2001). The three significant variables that remained in the final model were consumer price index (CPI) measuring inflation, saving deposits at commercial banks and GDP (Table 1A).

As expected, saving deposits and CPI had a negative effect on the DOW index and GDP a positive effect as presented in Table 1A. The model is given in Equation (5). The errors are represented by a first order autoregressive model, AR (1). Replacing Z in Equation (5) by its value, E_t / (1- 0.89B), and simplifying, one arrives at the conclusion that the DOW index is a function of its own lag and of CPI, Savings, GDP and their own lags. Figure 1 shows a plot over time of the observed quarterly DOW index and its predicted values from Equation (5). It is seen that there is a good agreement between observed and expected for the period 1970 to 2006. The model has an R-squared value of 0.9928. It is seen from the out of sample prediction that the model predicted the observed values for 2007-1 t0 2008-3 fairly well as shown in Table 1B. The observed quarterly index was within the 95% confidence limits of the predicted value. The prediction for 2008-4 was not as good due to the plunge in the market because of the 2008 recession. This points to the fact that a model can predict the market under normal conditions when there is no outside intervention such as a recession, market deregulation or political events.

TABLE 1. AUTO REGRESSION ANALYSIS

A. DOW is dependent variable, GDP, CPI, and Savings are the independent variables. Data, first quarter of 1970 (1970-1) till the fourth quarter of 2016 (2016-4)

Variable	DF	Estimate	Error	t Value	Pr > |t|
Intercept	1	1980	884.3758	2.24	0.0267
CPI	1	-236.2610	50.9471	-4.64	<.0001
Savings	1	-2.8948	0.9586	-3.02	0.0030
GDP	1	2.8935	0.4506	6.42	<.0001
AR1	1	-0.8925	0.0386	-23.11	<.0001

B. Observed and predicted values of the DOW index with predicted lower and upper 95% confidence limits (LCL and UCL) for out of sample data

Quarter	Observed	Predicted	LCL	UCL
2007-1	12621.69.	12201.23	10803.27	13599.18
2007-2	13862.91	12502.72	10987.31	14018.12
2007-3	13211.99.	12721.68	11106.01	14337.35
2007-4	13930.01.	12663.59	10977.52	14349.66
2008-1	12650.36	12336.55	10605.34	14067.77
2008-2	12820.13	12237.74	10431.79	14043.69
2008-3	11378.02	11950.82	10104.76	13796.88
2008-4	9325.01	11300.54	9304.35	13296.73

Model based on the estimates in Table 1A.

$$DOW_t = 1980 - 236.26\ CPI_t - 2.89\ Savings_t + 2.89\ GDP_t + Z_t \qquad (5)$$

where $Z_t = E_t / (1 - 0.89B)$

Here B is the backshift operator ($BX_t = X_{t-1}$) and E is random error or noise.

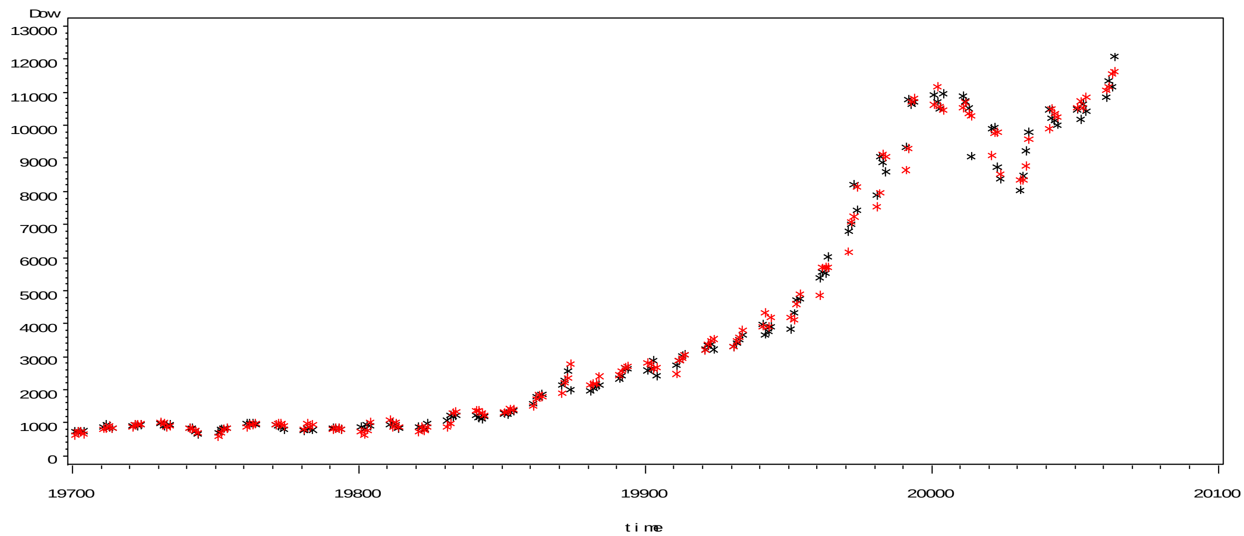

FIGURE 1. DOW INDEX AND ITS PREDICTED VALUE OVER TIME. OBSERVED INDEX IS BLACK COLOR AND PREDICTED IS RED COLOR. MODEL USED IS THAT OF EQUATION (5).

As seen from the results in Table 2 A, GDP alone was found to be as good a predictor of the DOW index as the model in Equation (5). In other words, CPI and Savings although significant in the model did not contribute substantially to the total R-squared. When deleted from the model, GDP alone had an R-squared of 0.9922. The model is presented in Equation (6). It expresses the DOW index at time t as a function of its lag value at time t-1 and the GDP at time t and its lag at time t-1. Table 2 B shows that the prediction of out of sample observations over the quarters 2007-1 to 2008-3 is as good as that for model (5).

S&P 500

Table 3A presents the model estimates for the S&P 500. The variables in the model that were significant were the same as for the DOW model in Equation (5). They were CPI, Saving deposits, and GDP. From the estimates in Table 3A, the model, expressing the S&P 500 as a function of the independent variables, is given in Equation (7). The plot in Figure 2 shows a good fit between observed and predicted from Equation (7). The R-squared was 0.9932.

As in the case of the DOW Jones index, the out of sample S&P 500 predicted values for the quarters 2007-1 to 2008-3 were rather good when compared to the observed values. The 2008-4 value was lower than predicted due to the great recession.

As seen in Table 4A, GDP alone is as good a predictor of the S&P 500 index as CPI, Savings and GDP together. The model for the GDP is given in Equation (8). As in the case of the DOW analysis, the S&P 500 at time t is expressed as a function of its own lag at time t-1 and the GDP at time t and its lag at time t-1. The model predicts the out of sample observation over the quarters 2007-1 to 2008-4 fairly well. The R-squared value for the model is 0.9922.

TABLE 2 AUTO REGRESSION ANALYSIS

A. DOW is dependent variable and GDP is the independent variable. Data, first quarter of 1970 (1970-1) till the fourth quarter of 2016 (2016-4).

Variable	DF	Estimate	Error	t Value	Pr > |t|
Intercept	1	-1380	948.7888	-1.45	0.1479
GDP	1	0.9471	0.1179	8.03	<.0001
AR1	1	-0.9597	0.0220	-43.53	<.0001

B. Observed and predicted values of the DOW index with predicted lower and upper 95% confidence limits (LCL and UCL) for out of sample data

Quarter	Observed	Predicted	LCL	UCL
2007-1	12621.69	12233.14	9940.77	14525.52
2007-2	13862.91	12406.84	9993.67	14820.01
2007-3	13211.99	12541.23	10026.05	15056.42
2007-4	13930.01	12645.81	10043.32	15248.30
2008-1	12650.36	12625.06	9965.66	15284.46
2008-2	12820.13	12757.37	10019.61	15495.13
2008-3	11378.02	12781.41	9990.29	15572.52
2008-4	9325.01	12499.68	9712.52	15286.83

Model based on the estimates in Table 2A.

$$DOW_t = -1380 + .947\ GDP_t + Z_t \qquad (6)$$

where $Z_t = E_t / (1- 0.96B)$

TABLE 3. AUTO REGRESSION ANALYSIS

A. S&P is the dependent variable, GDP, CPI, and Savings are the independent variables. Data, first quarter of 1970 (1970-1) till the fourth quarter of 2016 (2016-4).

Variable	DF	Estimate	Error	t -Value	Pr > |t|
Intercept	1	281.6529	121.3900	2.32	0.0217
CPI	1	-32.3457	6.4070	-5.05	<.0001
Savings	1	-0.4927	0.1180	-4.17	<.0001
GDP	1	0.3950	0.0551	7.17	<.0001
AR1	1	-0.9237	0.0317	-29.11	<.0001

B. Observed and predicted values of the S&P (SP) index with predicted lower and upper 95% confidence limits (LCL and UCL) for out of sample data.

Quarter	Observed	Predicted	LCL	UCL
2007-1	1438.24	1400.82	1105.04	1696.59
2007-2	1482.37	1425.42	1116.39	1734.46
2007-3	1455.27	1450.03	1129.24	1770.82
2007-4	1549.38	1455.58	1126.07	1785.10
2008-1	1378.55	1433.73	1099.65	1767.81
2008-2	1385.59	1443.46	1100.68	1786.25
2008-3	1267.38	1422.03	1073.63	1770.42
2008-4	968.75	1406.78	1059.52	1754.05

Model based on the estimates in Table 3A.

$$SP_t = 281.65 - 32.34\ CPI_t - 0.493\ Saving_t + 0.395\ GDP_t + Z_t \qquad (7)$$

where $Z_t = E_t / (1 - 0.924B)$

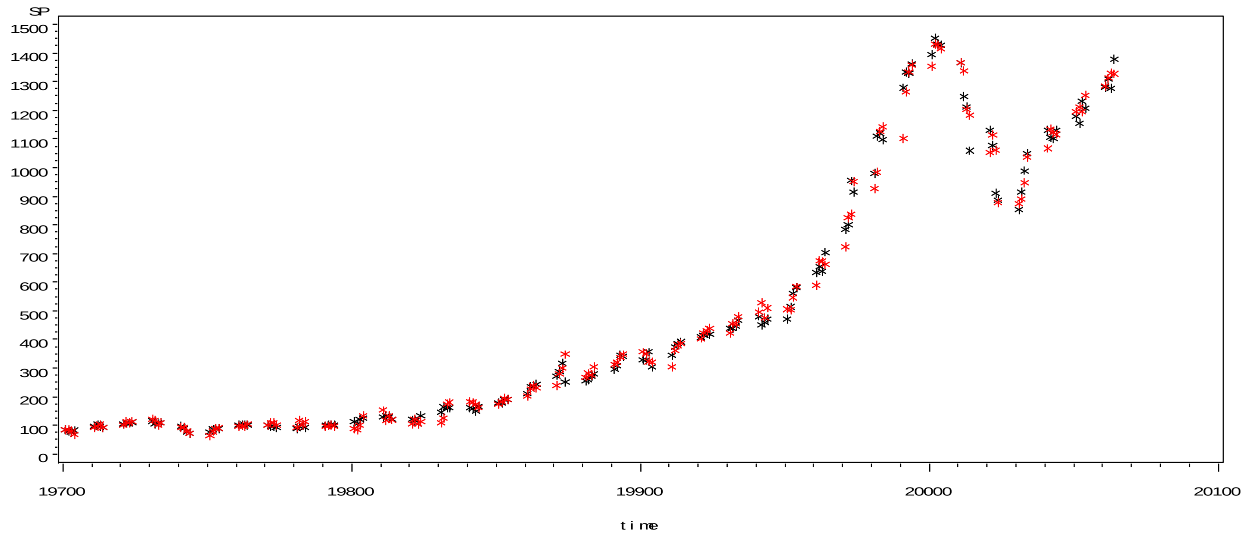

FIGURE 2. S&P INDEX AND ITS PREDICTED VALUE OVER TIME. OBSERVED INDEX IS BLACK COLOR AND PREDICTED IS RED COLOR. MODEL USED IS THAT OF EQUATION (7).

TABLE 4. AUTO REGRESSION ANALYSIS

A. S&P (SP) is the dependent variable and GDP is the independent variable. Data, first quarter of 1970 (1970-1) till the fourth quarter of 2006 (2006-4).

Variable	DF	Estimate	Error	t Value	Pr > |t|
Intercept	1	-166.7866	127.2197	-1.31	0.1919
GDP	1	0.1126	0.0154	7.32	<.0001
AR1	1	-0.9658	0.0203	-47.56	<.0001

B. Observed and predicted values of the S&P (SP) index with predicted lower and upper95% confidence limits (LCL and UCL) for out of sample data.

Quarter	Observed	Predicted	LCL	UCL
2007-1	1438.24	1398.06	1100.62	1695.50
2007-2	1482.37	1420.64	1109.31	1731.97
2007-3	1455.27	1438.47	1115.31	1761.64
2007-4	1549.38	1452.70	1119.32	1786.07
2008-1	1378.55	1451.96	1112.12	1791.79
2008-2	1385.59	1469.35	1120.03	1818.66
2008-3	1267.38	1473.81	1118.14	1829.48
2008-4	968.75	1441.86	1087.27	1796.45

Model based on the estimates in Table 4A.

$$SP_t = -166.78 + 0.113\ GDP_t + Z \tag{8}$$

Where Z = E/(1- 0.966B)

Time Series Analysis: Transfer Function (Period 1970-1 – 2006-4)

Tables 5 and 6 present the analyses for the DOW and the S&P 500 using the transfer function analysis. It is interesting to note that the analysis gave rise to the same results as those of the auto-regression analysis, namely that the independent variables that were significantly related to the DOW index or the S&P 500 index were CPI, Savings, and GDP. CPI and Savings had negative effects on the DOW and S&P 500 and GDP had a positive effect. The variables, both dependent and independent were first differenced to make them stationary. The out of sample predictions were rather good and similar to those from the auto-regression analysis above. The error in Table 5A (AR1,1 and AR1,2) is represented by an autoregressive model where "a" in Equation 1 is $a_t\,(1-0.155B^2 + .154B^3) = e$. Also, the error in Table 6A (AR1,1) is represented by $a_t\,(1+0.314B^3) = e$

Because all the models presented were equally adequate predictors, one may recommend using the simplest models for the DOW and GDP as well as for the S&P and the GDP, which are presented in Equations (6) and (8).

As can be seen below, the GDP model was also the best model for predicting the DOW and the S&P 500 for the period after the 2008 recession.

TABLE 5. TIME SERIES MODEL

A. DOW is the dependent variable, GDP, CPI, and Savings are the independent variables. Data, first quarter of 1970 (1970-1) till the fourth quarter of 2006 (2006-4).

Parameter	Estimate	Error	t Value	Pr > |t|	Lag	Variable	Shift
AR1,1	-0.15504	0.08529	-1.82	0.0712	2	Dow	0
AR1,2	0.15455	0.08411	1.84	0.0683	3	Dow	0
NUM1	2.48173	0.53827	4.61	<.0001	0	GDP	0
NUM2	-200.51012	76.92167	-2.61	0.0101	0	CPI	0
NUM3	-2.48860	1.19847	-2.08	0.0397	0	Savings	2

B. Forecasts for the Dow index with the 95% confidence limits.

Quarter	Observed	Predicted	Std Error	95% Confidence Limits	
2007-1	1438.24	12488.3199	343.2771	11815.5092	13161.1306
2007-2	1482.37	12448.7330	497.1240	11474.3878	13423.0782
2007-3	1455.27	12570.0908	604.5984	11385.0996	13755.0819
2007-4	1549.38	12716.6240	729.5675	11286.6980	14146.5499
2008-1	1378.55	12775.9598	851.2886	11107.4648	14444.4547
2008-2	1385.59	12849.6477	962.8577	10962.4812	14736.8142
2008-3	1267.38	12932.0769	1074.7188	10825.6668	15038.4871
2008-4	968.75	12999.7058	1185.2456	10676.6671	15322.7445

TABLE 6. TIME SERIES MODEL

A. S&P is the dependent variable, GDP, CPI, and Savings are the independent variables. Data first quarter of 1970 (1970-1) till the fourth quarter of 2006 (2006-4).

Parameter	Estimate	Error	t Value	Pr > |t|	Lag	Variable	Shift
AR1,1	0.31460	0.08120	3.87	0.0002	3	SP	0
NUM1	0.33395	0.06182	5.40	<.0001	0	GDP	0
NUM2	-33.14021	9.69929	-3.42	0.0008	0	CPI	0
NUM3	-0.30880	0.13890	-2.22	0.0278	0	Savings	0

B. Forecasts for the S&P index with the 95% confidence limits

Quarter	Observed	Predicted	Std Error	95% Confidence Limits	
2007-1	1438.24	1407.1662	39.3586	1330.0247	1484.3077
2007-2	1482.37	1411.8170	58.1690	1297.8077	1525.8262
2007-3	1455.27	1440.8273	74.6551	1294.5060	1587.1487
2007-4	1549.38	1452.1562	95.0075	1265.9448	1638.3675
2008-1	1378.55	1457.8318	113.4886	1235.3982	1680.2654
2008-2	1385.59	1472.8150	130.7478	1216.5540	1729.0760
2008-3	1267.38	1481.3357	148.4113	1190.4550	1772.2165
2008-4	968.75	1487.7219	165.2374	1163.8626	1811.5813

Auto regression analysis for the period 2009-1 to 2016-4

DOW Jones

The auto regression analysis for the period after the 2008 recession showed that only the GDP was related to the DOW index and the S&P 500 index. The DOW model based on the estimates in

Table 7A is given in Equation (9). The Total R-Square = 0.9728. Figure 3 showed a good fit between observed and predicted over the period 2009-1 – 2016-4. In addition, the model gave fair predictions for out of sample observation for the first three quarters of 2017 but fell short for 2017-4 and 2018-1 quarters. In general, the model underestimated the observed out of sample values. This may be due to outside intervention through deregulations (or in anticipation of) in the Trump presidency that caused the markets to soar.

S&P 500

Similar results to the DOW were obtained from the S&P analysis.as shown in Tables 8A and Figure 4. The model in Equation (10) gave a good fit to the data as seen from Figure 4. The Total R-Square = 0.9793. As seen in Table 8B, the model underestimated the out of sample S&P 500 observed values due to what may be termed outside intervention (market deregulation or in anticipation of) during the Trump presidency.

TABLE 7. AUTO REGRESSION MODEL

A. The DOW index is the dependent variable and GDP the independent variable. Data are quarterly, from 2009 to 2016

Variable	DF	Estimate	Error	t Value	Pr > |t|
Intercept	1	-22023	2845	-7.74	<.0001
GDP	1	2.1726	0.1722	12.62	<.0001
AR1	1	-0.6458	0.1535	-4.21	0.0002

B. Observed and predicted values of the DOW index with predicted lower and upper 95% confidence limits (LCL and UCL) for out of sample quarters

Quarter	Observed	Predicted	LCL	UCL
2017-1	19864.09.	18795.07	17257.17	20332.98
2017=2	20940.51.	19420.88	17685.40	21156.37
2017=3	21891.12.	20099.67	18253.15	21946.19
2017=4	23377.24.	20737.19	18813.80	22660.58
2018-1	26149.39	21240.78	19263.15	23218.41

Model based on the estimates in Table 7A.

$$DOW_t = -22023 + 2.1726\ GDP_t + Z \qquad (9)$$

where Z = E/(1-.646B)

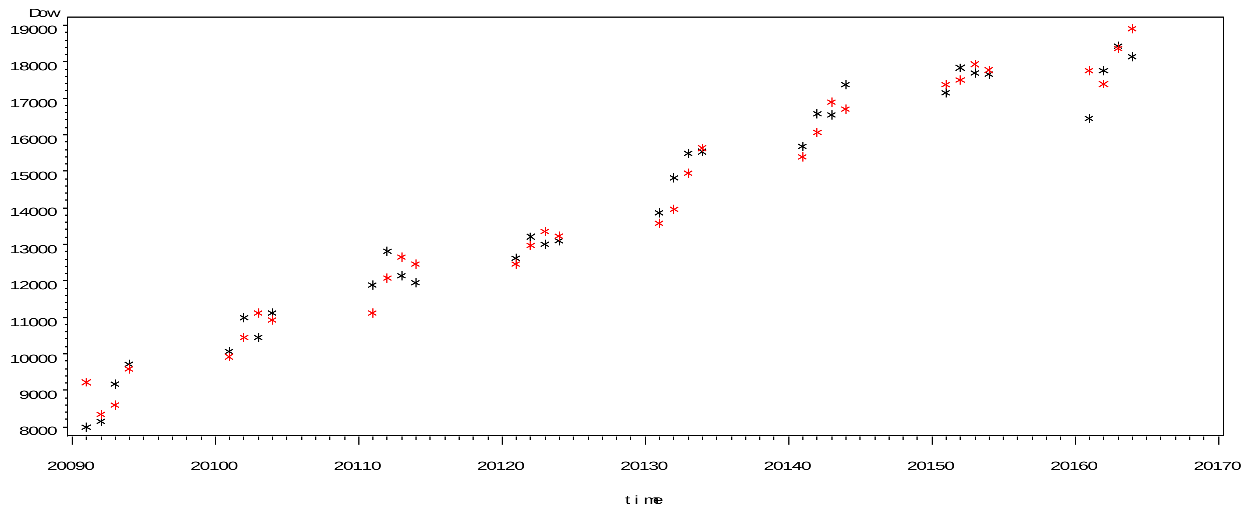

FIGURE 3. DOW INDEX AND ITS PREDICTED VALUE OVER TIME FROM MODEL (9). OBSERVED INDEX IS BLACK COLOR AND PREDICTED IS RED COLOR. DATA IS QUARTERLY FROM 2009 TO 2016

TABLE 8. AUTO REGRESSION MODEL

A. The S&P index is the dependent variable and GDP the independent variable. Data are quarterly, from 2009 to 2016

Variable	DF	Estimate	Error	t Value	Pr > |t|
Intercept	1	-3152	322.3851	-9.78	<.0001
GDP	1	0.2846	0.0195	14.59	<.0001
AR1	1	-0.6427	0.1530	-4.20	0.0002

B. Observed and predicted values of the S&P index with predicted lower and upper 95% confidence limits (LCL and UCL) for out of sample quarters

Quarter	Observed	Predicted	LCL	UCL
2017-1	2278.87	2205.83	2030.57	2381.08
2017-2	2384.20	2283.93	2086.20	2481.67
2017-3	2470.30	2370.27	2160.01	2580.54
2017-4	2575.26	2452.07	2233.17	2670.98
2018-1	2823.81	2516.90	2291.90	2741.90

Model based on the estimates in Table 8

$$SP_t = -3152 + 0.285\ GDP_t + Z \qquad (10)$$

where $Z = E/(1-.643B)$

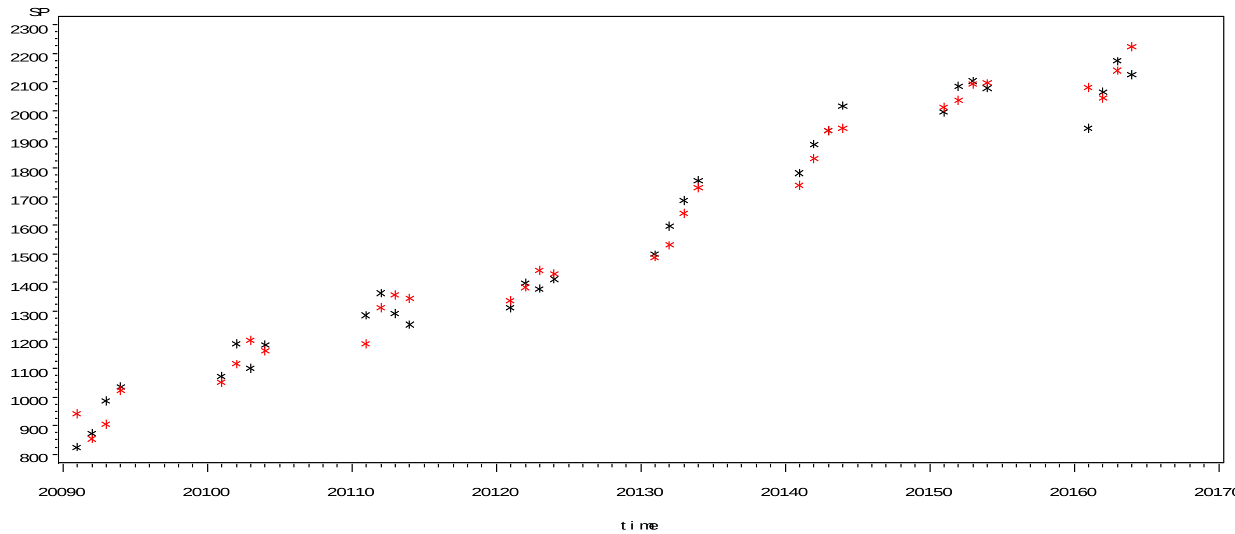

FIGURE 4. S&P INDEX AND ITS PREDICTED VALUE OVER TIME FROM MODEL (10). OBSERVED INDEX IS BLACK COLOR AND PREDICTED IS RED COLOR. DATA ARE QUARTERLY FROM 2009 TO 2016

CONCLUDING REMARKS

In this study, we used time series analyses (transfer function and auto-regression) to develop a model that can predict the DOW Jones and S&P 500 indexes over time from macroeconomic variables. The variables used to develop the models were: consumer price index (CPI), saving deposits at commercial banks, 10-year bond yield, Central bank interest rate, federal debt, unemployment rate, industrial production index, and money supply.

Out of the nine variables, the only variables that were significant and remained in the model were GDP, CPI, and saving deposits. GDP, as expected, had a positive effect on the DOW and S&P 500 indexes. On the other hand, CPI and savings had negative effects on both indexes. Of interest was the fact that GDP was the predominant variable. When CPI and saving deposits were deleted from the model, GDP alone was as good a model as all three variables together. The fact that the GDP model was simpler than the rest to use, makes it the choice model for predicting and forecasting the dynamics of the DOW index or the S&P 500 index over time. The models in Equations (6) (8) (9) and (10) gave an excellent fit to the DOW and S&P indexes over time for the time series data, pre and post the 2008 recession. The dependent variable (Dow or S&P index) at time t is a function of GDP at time t. Therefore, for forecasting the DOW or S&P index at time t one must know the

GDP value at time t. This can be obtained from the US Congressional Budget Office forecast of GDP at time t.

Out of sample forecasts of the indexes were fairly good for the first four quarters or more. Where the model underestimated the observed values of the DOW and S&P indexes was for the quarters in 2017 and 2018. This could be attributed to outside intervention because of deregulation, or in anticipation of, during the Trump presidency. There are studies in the literature (Bolanle & Adefemi, 2019; Malik et al., 2012; Ramdhan et. al., 2018; Sabäu-Popa et. al., 2014) pointing to the fact that the stock market is positively influenced by the GDP. However, the present study quantifies this relationship by developing models that give the functional relation between the DOW index as well as the S&P index and the GDP. The models were all of the same function in which the index (DOW or S&P) at time t was a function of its lag at time t-1 as well as the GDP at time t and its lag at time t-1. This simple model explained over 99% of the variation in the index and was a good predictor of the stock markets, barring any outside intervention.

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