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Effects of Interest rates and Inflation Rates on Stock Price Volatility: A Granger Causality Approach

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Abstract: This paper deals with the Granger Causality analysis to review the impact of U.S. interest rates and various inflation rates on the different companies' stock price volatilities and the explicit correlation between them. The interest rates are used as they are important indicator of volatility measurement and inflation rates are used to be a measure of implicit estimate of the stock price movement. After performing the test using R package the results make it essential to understand how the different interest rates and inflation rates behave over time especially granger causes each other. The data set that we used is extracted from the St. Louis Fed are all daily sector data over the period of June 2008 to December 2017 and the technique of autoregressive lag model (ARLM) are applied in investigating the trend behavior of the interest rates as well as the inflation rates over any influence on the stock indices. The result indicates that interest rate and the inflation rate Granger Causes each other quite significantly whereas inflation rates have not Granger causes the stock price volatility. However, interest rates establish a causal relationship among those stock price volatilities and the inflation rates.

Keywords: Granger Causality; Interest Rate; Inflation Rate; Stock Volatility

JEL classification: JEL: C22

1. Introduction

It is a debatable issue among the economists regarding theoretical as well as empirical relationship between the interest rate and inflation rate. According to Fisher effect under the quantity theory of money, an increase in real interest rate is necessarily causes a deflationary situation in the economy and vice-versa. This is on other hand causes the home country's currency to appreciate and thereby helps to avoid many adverse economic consequences. In general, when the interest rates are low, many people can borrow more money from the financial institutions. This causes a boom in the money supply of the economy where the consumers have more money to spend. This will cause expansionary pressure within the economy to grow and inflation to increase. The opposite holds true for an increase in nominal interest rates.

For several reasons, a high interest rate policy is thought to be important. First, it tells the market forces about the sharp exchange rate movement and the expectations of the market given the state of the economy and thereby reduce the inflationary pressure and prevent the vicious cycle of inflation and exchange rate depreciation. Secondly, by

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increasing the attractiveness of domestic financial assets, capital inflows are generated, thus limiting the depreciation of the exchange rate. Thirdly, the reduction of domestic demand results not only in an improvement in the balance of payments position, but also reduces imports.

Interest rate and inflation rate are two significant economic and financial indicators that affect not only the common stock value but also the capital accumulation and capital inflow or outflow situation of a country. On the other hand, financial analyst defines stock volatility as a measure of the relative rate at which the prices of a security move up and down. Volatility is found by calculating the annualized standard deviation of daily change in price. If the price of a stock moves up and down rapidly over short time periods we call it has high volatility. On the other hand, if the price almost never changes it has low volatility. In finance, volatility means as a measure for variation of price of a financial instrument over time that is how far, and fast stock prices can move.

Over the years, several market volatility indicators have been developed to track the status of broad market volatility and help investors decide when to buy or sell. These include the S&P 500 Volatility Index, the NASDAQ Volatility Index, and the Russell 2000 Volatility Index. Most of the time, stock prices move up and down, sometimes even trending in a positive or negative direction.

Interest rate, which reflects the price of money, has a clear and substantial effect on different indicator variables in money and capital market instruments. The interest rates indirectly affect the valuation of the stock prices and stock volatility directly creates a shift between the money market and capital market instruments. Inflation rate is another major source of macroeconomic uncertainty that directly and indirectly affects the stock volatility. High inflation rate influences the value of the stock since the future cash flows of the firm will change and hence affect their investment plan on stock or bond.

This paper takes the daily data on Chicago Board Options Exchange(CBOE)'s several companies stock volatility which are CBOE NASDAQ 100 Volatility Index, CBOE S&P 500 3-month volatility index, CBOE Gold ETF Volatility Index. Daily rates of three type of inflation rates have been taken these are 5-Year Breakeven Inflation Rate, 5-Year Forward Inflation Expectation Rate, and10-Year Breakeven Inflation Rate. Inflation expectation of these few influential rates are most connected with the United States business and exchange. For the interest rates four different types of daily rates such as Effective Federal Funds Rate, 3-Month Treasury Constant Maturity Rate, Bank Prime Loan Rate, and 3-Year Treasury Constant Maturity Rate are taken carefully through the R command. The findings show that interest rate and inflation rate Granger causes each other quite significantly but inflation rate has a minimal Granger causality impact on Stock price volatilities.

2. Ex-ante Discussion

The Granger testing procedure requires one set up and test two equations. In each equation, the current value of one variable (X_t or Y_t) is a function of the set of other variables and the function of its own level with the previous time periods or lagged values. The intuition behind the Granger test is that-if previous values of a variable X_t significantly affects the current values of the other variable Y_t, then it can be said that X

Causes *Y*. As mentioned earlier this paper takes three volatility indices of different measurement and therefore run the autoregressive distributed lag regression under the canned R command for to see whether the interest rate and the inflation rate has any Granger causality effects on the volatility indices. That is if interest rate or inflation rate causes any changes in volatility indices, then one can observe that changes in interest rate or inflation rate will cause a precede changes in stock volatility indices. The functional form of equations that are used in this process are follows:

$$\mathbf{Y_t = \beta_0 + \beta_1 Y_{t-1} + \beta_2 Y_{t-2} + \delta_1 X_{t-1} + \delta_2 X_{t-2} + \varepsilon_t}$$

$$\mathbf{X_t = \alpha_0 + \alpha_1 X_{t-1} + \alpha_2 X_{t-2} + \mu_1 Y_{t-1} + \mu_2 Y_{t-2} + \theta_t}$$

Due to the internationalization of the stock market, the liberalization of capital flows, and a large amount of foreign investment in the US stock market, stocks and all other major macroeconomic markets have become increasingly interdependent. Several financial and currency crises around the world, as well as the recent 2008-2009 fiscal year crisis in the US financial sector and different emerging markets around the world, prompted academicians and experts to re-examine the volatility spillover between stocks and different macroeconomic sectors.

Researchers have seen a large correlated movement resulting in market contamination (Mishra et al., 2007). It has been observed that interest rates have been used to explain the behavior of stock prices, assuming that company earnings tend to respond to any fluctuations in future forecasts and turning points (Kim, 2003). This paper uses three important inflation rates in the expectation to see how the 5-Year Breakeven Inflation Rate and 10-Year Breakeven Inflation Rate Granger causes stock volatility indices such as NASDAQ 100 Volatility Index or S&P 500 3-Month Volatility Index. From the past literature it can be discovered that the relationship between interest rate and stock volatility has been widely examined by the researchers. According to one of the studies, short- term interest rates and stock returns have a relationship with the level of market volatility. It was found that the nominal yield on one-month T-bills has a significant positive correlation with variance in the market, but it leads to negative correlation with future stock returns (Dimitrova, 2005).

A study conducted by Cifter and Ozun (2007) looked at how interest rate changes affect the closing values of the Istanbul Stock Exchange 100 index and the compounded interest rates on daily closing values to examine the causal effects of interest rate changes on stock returns. Accordingly, they concluded that the effect of interest rate on stock returns increases with increasing time scales. Their tests began with a nine-day time-scale effect of the ISE 100 index.

A similar study has been conducted by Salimullah (2016) in which the another uses the Granger Causality techniques on interest rate and exchange rate over the return behavior of the stock price volatilities. Using the daily sector data over the period of 2007-2012 and establishing a two-way causal relationship the study shows that there is strong statistical evidence between the stock volatility and the interest rate which exists only to some extent and, in some cases, demonstrates no relationship among them. However, the Granger Causality test was applied to the other two variables, exchange rates and stock volatility, which proved unidirectional causality running from interest rates to stock returns and from exchange rates to stock returns, but in the opposite cases the bi-directional effect did not support any significant results

3. Methodology

The methodology that is used in this paper is the Granger Causality approach that is applied through producing R-commands in which a special and systematic use of *F*-statistic has been formulized. Any time series trends or variables (i.e. daily, quarterly, monthly, or yearly data) are found suitable for this type of test. Usually most of the time series are non-stationary or produce a random walk. When a time series is found stationary, then the Granger test could be performed by using the level values of two (or more) variables. On the other hand, if the trend variables are found non-stationary, then the test is done only after by testing for a unit root (whether a series is stationary or non-stationary). The augmented Dickey-Fuller (ADF) test is used for detection of a unit root. The null hypothesis for ADF test is that the series is a non-stationary; if the p-value is low enough then we do reject the null hypothesis and accept the alternative views of the series is stationary. If the p-value is higher than any significance level (conventionally we use 1%, 5% or 10% level of significance) then we cannot reject but to accept the null hypothesis and trying to transform the series to a better one.

Typically, the first difference of a time series will be stationary. The number of lags included in an analysis will be determined with the help of information criterion, such as the Akaike information criterion (AIC) or the Schwarz information criterion. If any lag value of the variable is significant according to the t-test, it is retained in the regression, and according to the F-test, other lag values of the variable together add explanatory power to the model. The null hypothesis of no Granger causality will be created if and only if the lag value of the explanatory variable is not retained in the regression. In empirical techniques, it is very possible to find that neither of the two variables Granger-causes the other variable, or each of the two variables causes the other variable Granger-causes the other.

4. Data

This paper uses the data series from the Federal Reserve Bank of St. Louis namely as St. Louis Fed economic data. From the bunch of series at first, the researcher choses the variables that would be the best fit for the empirical model and then the author took the daily time point from June 2008 to December 2017. This restriction technique ends up with a total of **2,379** observations. The volatility indices that I have chosen are the most demonstrative financial indicators for the stock market under Chicago Board Options and Exchange (CBOE). These indices are based on the common stock prices of top publicly traded American companies stock and bond.

The choice variables for the stock volatilities are CBOE Gold ETF Volatility Index (Ticker-GVZCLS) measures the market's expectation of 30-day volatility of gold prices by applying the VIX methodology to options on SPDR Gold Shares. The other daily rates that have taken are CBOE NASDAQ 100 Volatility Index (Ticker-VXNCLS) and CBOE S&P 500 3-Month Volatility Index (Ticker-VXVCLS). VXNCLS is a key measure of market expectations of near-term volatility conveyed by NASDAQ-100 Index (NDX) option prices. While VXVCLS is designed to be a constant measure of 3-month implied volatility of the S&P 500® (SPX) Index options.

The interest rate variables that have been used in this research are the daily rates of Effective Federal Funds Rate (Ticker-DEF), 3-Month Treasury Constant Maturity Rate (Ticker- DGS3MO), 3-Year Treasury Constant Maturity Rate (Ticker-DGS3), and Bank Prime Loan Rate (Ticker-DPRIME). As the daily data are accepted for this study so that the other interest rates which are sounds predominant cannot be used as they have monthly or quarterly data. For the case of inflation rate I have chosen 5-Year Breakeven Inflation Rate (Ticker-T5YIE), 5-Year, 5-Year Forward Inflation Expectation Rate (Ticker-T5YIFR), and 10-Year Breakeven Inflation Rate (Ticker-T10YIE). The preliminary analysis of the data for all the series displays that interest rates and the stock volatilities are persistent with their respective mean values.

The mean or average values for the inflation rates are not consistent for three different rates. The mean for 10-Year Breakeven Inflation Rate is negative which is -0.00023 and has a lower standard deviation i.e. 0.0386. All three volatility indices have the higher level of implied volatility with mean around 21.167 and the standard deviation of 8.675 (almost 867%). The mean and the standard deviation for the interest rates are found much closer on average. The overall mean for the four interest rates is 1.261 and the standard deviation is 0.4283 (almost 42%). The other descriptive statistics for those variables are shown in the following Table 1.

Table 1: Summary Statistics

Variable Name	Mean	Standard Dev.	Median	Min	Max	Lags	P-value
GVZCLS	20.454	7.6847	18.54	10.16	64.53	22	0.020603
VXNCLS	21.481	9.6306	18.40	10.31	80.64	25	0.010000
VXVCLS	21.567	8.7124	18.99	11.85	69.24	17	0.023206
T5YIE	1.613	0.5309	1.710	-2.240	2.720	48	0.060523
T5YIFR	2.267	0.4063	2.330	0.430	3.050	33	0.010000
DFF	0.3169	0.4258	0.1500	0.0400	2.9700	46	0.010000
DGS3MO	0.249	0.3435	0.100	0.000	2.070	47	0.010000
DPRIME	3.442	0.4148	3.250	3.250	5.000	49	0.016054
DGS3	1.037	0.5291	0.980	0.280	3.380	16	0.033465
T10YIE	-0.0002271	0.0386	0.0000	-0.3600	0.3300	45	0.294031

Source: Author's own calculation

5. Results and Discussion

After running the standard statistical package R and modifying the necessary codes accordingly by including all of the observed variables and the related data set from the St. Louis Fed and using the R command install.Packages ("fImport") and library fImport, this paper comes up with the following results. To make the data set stationary this paper also performed the unit root test (R command adf.test). The entire Table 2 shows the first part of the Granger Causality result for all of the observed variables. In this following Table 2 the significance of the generated Granger causality test is accompanied by the

long run multiplier and its respective probability values. The null hypotheses and the alternative hypotheses for this test are:

H_0: variable X does not cause variable Y ($X \nRightarrow Y$).

H_a: variable X causes variable Y ($X \Rightarrow Y$)

Table 2 shows the outcomes of the estimation results. CBOE Gold ETF Volatility Index (GVZCLS) establishes positive Granger Causality on VXNCLS and VXVCLS but has negative Granger Causality on T5YIE, T5YIFR, T10YIE, DEF, and DGS3MO. But it has no causal relationship with DPRIME and DGS3. CBOE NASDAQ 100 volatility Index (VXNCLS) positively Granger causes GVZCLS, and VXVCLS. But it shows some negative Granger Causality over T5YIE, T5YIFR, T10YIE, and DGS3MO. However, VXNCLS shows zero Granger Causality over DEF, DPRIME and DGS3. CBOE S&P 500 3-Month Volatility Index (VXVCLS) generates negative Granger Causality over GVZCLS, VXNCLS, T5YIE, T5YIFR, T10YIE, and DGS3MO. VXVCLS produces zero causality over DEF, DPRIME, and DGS3. All of these causal relationship between the stock volatilities are found statistically significant by the value of the test statistic of long run multiplier with having a lower level of p-values. 5-Year Breakeven Inflation Rate (T5YIE) positively Granger causes GVZCLS, T5YIFR, T10YIE, and DGS3MO. However, it shows negative Granger Causality over VXNCLS, VXVCLS, DEF, DPRIME, and DGS3. 5-Year Forward Inflation Expectation Rate (T5YIFR) shows positive relation with GVZCLS, VXNCLS, VXVCLS, and T5YIE. But T5YIFR negatively Granger causes T10YIE, DEF, DGS3MO, DPRIME, and DGS3.

10-Year Breakeven Inflation Rate (T10YIE) has a negative causal relationship with T5YIE, T5YIFR, DEF and DGS3. However, T10YIE shows positive Granger Causality with all the volatility indices such as GVZCLS, VXNCLS, and VXVCLS. It also creates positive causal relationship with two interest rates namely, DGS3MO and DPRIME. However, some of these relationship are found insignificant as the value of the long run multiplier is lower than the critical value of this test statistic. Effective Federal Funds Rate (DEF) positively affects all the three stock price volatilities as expected. The probability values for GVZCLS, VXNCLS, and VXVCLS are found very low that confirms the statistical significance of their relationship with DEF. It also has a positive effect on T10YIE, DGS3MO and DPRIME. However, DEF has a negative Granger Causality with T5YIE, T5YIFR and DGS3.

3-Month Treasury Constant Maturity Rate (DGS3MO) has a positive causal relationship with CBOE Gold ETF Volatility Index, NASDAQ 100 Volatility Index, S&P 500 Volatility Index and 10-Year Breakeven Inflation Rate. But it shows negative causality with T5YIE, T5YIFR, DEF, DPRIME and DGS3. One of the major interest rates Bank Prime Loan Rate (DPRIME) shows positive causal relationship with GVZCLS, VXNCLS, VXVCLS, T10YIE, and DGS3MO. There is found some negative Granger Causality with T5YIE, T5YIFR, DEF, and DGS3. 3-Year Treasury Constant Maturity Rate (DGS3) constructs positive effect with T5YIE, T5YIFR, T10YIE, DEF, DGS3MO, and DPRIME. But in case of all three stock volatility indices i.e. GVZCLS, VXNCLS, and VXVCLS, 3-Year Treasury Constant Maturity Rate shows negative Granger Causality. The test statistic which is the value of the long run multiplier has the significant results with the lowest probability values.

Table 2: Two-way Granger Causality test results for the selected number of variables

Variable X	Variable Y	p-value	Long Run Multiplier	pvLRM	Label	Sign
GVZCLS	VXNCLS	0	0.00147	0.00026	H0: CBOE Gold ETF Volatility Index -/-> CBOE NASDAQ 100 Volatility Index	1
GVZCLS	VXVCLS	0	0.00191	0	H0: CBOE Gold ETF Volatility Index -/-> CBOES&P5003-MonthVolatilityIndex	1
GVZCLS	T5YIE	0	-1.00E-05	0.01116	H0: CBOE Gold ETF Volatility Index -/-> 5-Year Breakeven Inflation Rate	-1
GVZCLS	T5YIFR	0.00113	-1.00E-05	0.13307	H0: CBOE Gold ETF Volatility Index -/-> 5-Year,5-YearFrwrdInfltnExpcttnRt	-1
GVZCLS	T10YIE	0	-2.00E-05	0.00735	H0: CBOE Gold ETF Volatility Index -/-> 10-Year Breakeven Inflation Rate	-1
GVZCLS	DFF	0.00674	-1.00E-05	0.07516	H0: CBOE Gold ETF Volatility Index -/-> Effective Federal Funds Rate	-1
GVZCLS	DGS3MO	0	-1.00E-05	0.00429	H0: CBOE Gold ETF Volatility Index -/-> 3-MonthTreasuryConstantMaturityRt	-1
GVZCLS	DPRIME	0	0	0.26296	H0: CBOE Gold ETF Volatility Index -/-> Bank Prime Loan Rate	0
GVZCLS	DGS3	8.00E-05	0	0.39927	H0: CBOE Gold ETF Volatility Index -/-> 3-YearTreasuryConstantMaturityRat	0
VXNCLS	GVZCLS	0	0.00015	0.31509	H0: CBOE NASDAQ 100 Volatility Index -/-> CBOE Gold ETF Volatility Index	1
VXNCLS	VXVCLS	0	0.00401	0.01838	H0: CBOE NASDAQ 100 Volatility Index -/-> CBOES&P5003-MonthVolatilityIndex	1
VXNCLS	T5YIE	0	-1.00E-05	0.00748	H0: CBOE NASDAQ 100 Volatility Index -/-> 5-Year Breakeven Inflation Rate	-1
VXNCLS	T5YIFR	0	-1.00E-05	0.21021	H0: CBOE NASDAQ 100 Volatility Index -/-> 5-Year,5-YearFrwrdInfltnExpcttnRt	-1
VXNCLS	T10YIE	0	-1.00E-05	0	H0: CBOE NASDAQ 100 Volatility Index -/-> 10-Year Breakeven Inflation Rate	-1

Variable X	Variable Y	p-value	Long Run Multiplier	pvLRM	Label	Sign
VXNCLS	DFF	0.01628	0	0.05031	H0: CBOE NASDAQ 100 Volatility Index -/-> Effective Federal Funds Rate	0
VXNCLS	DGS3MO	0	-1.00E-05	NA	H0: CBOE NASDAQ 100 Volatility Index -/-> 3-MonthTreasuryConstantMaturityRt	-1
VXNCLS	DPRIME	0.00881	0	0.22344	H0: CBOE NASDAQ 100 Volatility Index -/-> Bank Prime Loan Rate	0
VXNCLS	DGS3	0.00071	0	0.47792	H0: CBOE NASDAQ 100 Volatility Index -/-> 3-YearTreasuryConstantMaturityRat	0
VXVCLS	GVZCLS	0	-1.00E-05	0.49374	H0: CBOES&P5003-MonthVolatilityIndex -/-> CBOE Gold ETF Volatility Index	-1
VXVCLS	VXNCLS	0	-0.00191	0.09826	H0: CBOES&P5003-MonthVolatilityIndex -/-> CBOE NASDAQ 100 Volatility Index	-1
VXVCLS	T5YIE	0	-1.00E-05	0.00522	H0: CBOES&P5003-MonthVolatilityIndex -/-> 5-Year Breakeven Inflation Rate	-1
VXVCLS	T5YIFR	0	-1.00E-05	0.34388	H0: CBOES&P5003-MonthVolatilityIndex -/-> 5-Year,5-YearFrwrdInfltnExpcttnRt	-1
VXVCLS	T10YIE	4.00E-05	-1.00E-05	1.00E-05	H0: CBOES&P5003-MonthVolatilityIndex -/-> 10-Year Breakeven Inflation Rate	-1
VXVCLS	DFF	0.01239	0	0.00352	H0: CBOES&P5003-MonthVolatilityIndex -/-> Effective Federal Funds Rate	0
VXVCLS	DGS3MO	0	-1.00E-05	0.01196	H0: CBOES&P5003-MonthVolatilityIndex -/-> 3-MonthTreasuryConstantMaturityRt	-1
VXVCLS	DPRIME	0.03714	0	0.11853	H0: CBOES&P5003-MonthVolatilityIndex -/-> Bank Prime Loan Rate	0
VXVCLS	DGS3	0.01807	0	0.33965	H0: CBOES&P5003-MonthVolatilityIndex -/-> 3-YearTreasuryConstantMaturityRat	0
T5YIE	GVZCLS	0.00013	0.00327	0.19517	H0: 5-Year Breakeven Inflation Rate -/-> CBOE Gold ETF Volatility Index	1
T5YIE	VXNCLS	0	-0.00011	0.49142	H0: 5-Year Breakeven Inflation Rate -/-> CBOE NASDAQ 100	-1

Variable X	Variable Y	p-value	Long Run Multiplier	pvLRM	Label	Sign
					Volatility Index	
T5YIE	VXVCLS	0	-0.00107	0.34407	H0: 5-Year Breakeven Inflation Rate -/-> CBOES&P5003-MonthVolatilityIndex	-1
T5YIE	T5YIFR	0	2.00E-04	0.24015	H0: 5-Year Breakeven Inflation Rate -/-> 5-Year,5-YearFrwrdInfltnExpcttnRt	1
T5YIE	T10YIE	0	0.00013	0.00172	H0: 5-Year Breakeven Inflation Rate -/-> 10-Year Breakeven Inflation Rate	1
T5YIE	DFF	0	-4.00E-05	0.16266	H0: 5-Year Breakeven Inflation Rate -/-> Effective Federal Funds Rate	-1
T5YIE	DGS3MO	0	5.00E-05	0.13362	H0: 5-Year Breakeven Inflation Rate -/-> 3-MonthTreasuryConstantMaturityRt	1
T5YIE	DPRIME	0	-4.00E-05	0.08581	H0: 5-Year Breakeven Inflation Rate -/-> Bank Prime Loan Rate	-1
T5YIE	DGS3	0	-0.00042	6.00E-05	H0: 5-Year Breakeven Inflation Rate -/-> 3-YearTreasuryConstantMaturityRat	-1
T5YIFR	GVZCLS	0.00549	0.00418	0.02652	H0: 5-Year,5-YearFrwrdInfltnExpcttnRt -/-> CBOE Gold ETF Volatility Index	1
T5YIFR	VXNCLS	0.03976	0.00339	0.266	H0: 5-Year,5-YearFrwrdInfltnExpcttnRt -/-> CBOE NASDAQ 100 Volatility Index	1
T5YIFR	VXVCLS	0.00038	0.00695	0.20705	H0: 5-Year,5-YearFrwrdInfltnExpcttnRt -/-> CBOES&P5003-MonthVolatilityIndex	1
T5YIFR	T5YIE	0	0.00025	0.04197	H0: 5-Year,5-YearFrwrdInfltnExpcttnRt -/-> 5-Year Breakeven Inflation Rate	1
T5YIFR	T10YIE	5.00E-05	-0.00013	0.08438	H0: 5-Year,5-YearFrwrdInfltnExpcttnRt -/-> 10-Year Breakeven Inflation Rate	-1
T5YIFR	DFF	0.00014	-0.00013	3.00E-05	H0: 5-Year,5-YearFrwrdInfltnExpcttnRt -/-> Effective Federal Funds Rate	-1
T5YIFR	DGS3MO	0	-6.00E-05	0.01665	H0: 5-Year,5-YearFrwrdInfltnExpcttnRt -/-> 3-MonthTreasuryConstantMaturityRt	-1

Variable X	Variable Y	p-value	Long Run Multiplier	pvLRM	Label	Sign
T5YIFR	DPRIME	0.00036	-0.00016	0.00401	H0: 5-Year,5-YearFrwrdInfltnExpcttnRt -/-> Bank Prime Loan Rate	-1
T5YIFR	DGS3	0	-0.00042	0.00971	H0: 5-Year,5-YearFrwrdInfltnExpcttnRt -/-> 3-YearTreasuryConstantMaturityRat	-1
T10YIE	GVZCLS	0	0.01339	0.01268	H0: 10-Year Breakeven Inflation Rate -/-> CBOE Gold ETF Volatility Index	1
T10YIE	VXNCLS	0	0.01038	0.00044	H0: 10-Year Breakeven Inflation Rate -/-> CBOE NASDAQ 100 Volatility Index	1
T10YIE	VXVCLS	0	0.00893	0.01211	H0: 10-Year Breakeven Inflation Rate -/-> CBOES&P5003-MonthVolatilityIndex	1
T10YIE	T5YIE	0	-0.00023	0.00029	H0: 10-Year Breakeven Inflation Rate -/-> 5-Year Breakeven Inflation Rate	-1
T10YIE	T5YIFR	0	-0.00025	2.00E-05	H0: 10-Year Breakeven Inflation Rate -/-> 5-Year,5-YearFrwrdInfltnExpcttnRt	-1
T10YIE	DFF	0	-0.00034	0.38239	H0: 10-Year Breakeven Inflation Rate -/-> Effective Federal Funds Rate	-1
T10YIE	DGS3MO	0	9.00E-04	NA	H0: 10-Year Breakeven Inflation Rate -/-> 3-MonthTreasuryConstantMaturityRt	1
T10YIE	DPRIME	0	5.00E-05	0.37514	H0: 10-Year Breakeven Inflation Rate -/-> Bank Prime Loan Rate	1
T10YIE	DGS3	0	-0.00035	0.10741	H0: 10-Year Breakeven Inflation Rate -/-> 3-YearTreasuryConstantMaturityRat	-1
DFF	GVZCLS	0	0.01073	0.02221	H0: Effective Federal Funds Rate -/-> CBOE Gold ETF Volatility Index	1
DFF	VXNCLS	0	0.00954	0.00333	H0: Effective Federal Funds Rate -/-> CBOE NASDAQ 100 Volatility Index	1
DFF	VXVCLS	0	0.00789	0.13542	H0: Effective Federal Funds Rate -/-> CBOES&P5003-MonthVolatilityIndex	1
DFF	T5YIE	0	-0.00027	0.01516	H0: Effective Federal Funds Rate -/-> 5-Year Breakeven Inflation	-1

Variable X	Variable Y	p-value	Long Run Multiplier	pvLRM	Label	Sign
					Rate	
DFF	T5YIFR	0	-0.00011	0.04785	H0: Effective Federal Funds Rate -/-> 5-Year,5-YearFrwrdInfltnExpcttnRt	-1
DFF	T10YIE	0	0.00191	1.00E-04	H0: Effective Federal Funds Rate -/-> 10-Year Breakeven Inflation Rate	1
DFF	DGS3MO	0	0.00052	0.05941	H0: Effective Federal Funds Rate -/-> 3-MonthTreasuryConstantMaturityRt	1
DFF	DPRIME	0	2.00E-05	0.4382	H0: Effective Federal Funds Rate -/-> Bank Prime Loan Rate	1
DFF	DGS3	0	-0.00037	0.00739	H0: Effective Federal Funds Rate -/-> 3-YearTreasuryConstantMaturityRat	-1
DGS3MO	GVZCLS	0	0.01304	0.04944	H0: 3-MonthTreasuryConstantMaturityRt -/-> CBOE Gold ETF Volatility Index	1
DGS3MO	VXNCLS	0	0.01272	NA	H0: 3-MonthTreasuryConstantMaturityRt -/-> CBOE NASDAQ 100 Volatility Index	1
DGS3MO	VXVCLS	0	0.01259	NA	H0: 3-MonthTreasuryConstantMaturityRt -/-> CBOES&P5003-MonthVolatilityIndex	1
DGS3MO	T5YIE	0	-0.00025	1.00E-05	H0: 3-MonthTreasuryConstantMaturityRt -/-> 5-Year Breakeven Inflation Rate	-1
DGS3MO	T5YIFR	0	-0.00033	NA	H0: 3-MonthTreasuryConstantMaturityRt -/-> 5-Year,5-YearFrwrdInfltnExpcttnRt	-1
DGS3MO	T10YIE	0	0.00311	0.00025	H0: 3-MonthTreasuryConstantMaturityRt -/-> 10-Year Breakeven Inflation Rate	1
DGS3MO	DFF	0	-1.00E-05	0.4351	H0: 3-MonthTreasuryConstantMaturityRt -/-> Effective Federal Funds Rate	-1
DGS3MO	DPRIME	0.00042	-5.00E-05	0.38836	H0: 3-MonthTreasuryConstantMaturityRt	-1

Variable X	Variable Y	p-value	Long Run Multiplier	pvLRM	Label	Sign
					-/-> Bank Prime Loan Rate	
DGS3MO	DGS3	0	-0.00048	1.00E-05	H0: 3-MonthTreasuryConstantMaturityRt -/-> 3-YearTreasuryConstantMaturityRat	-1
DPRIME	GVZCLS	1.00E-05	0.00399	0.12957	H0: Bank Prime Loan Rate -/-> CBOE Gold ETF Volatility Index	1
DPRIME	VXNCLS	0	0.01038	0	H0: Bank Prime Loan Rate -/-> CBOE NASDAQ 100 Volatility Index	1
DPRIME	VXVCLS	0	0.01008	0.0188	H0: Bank Prime Loan Rate -/-> CBOES&P5003-MonthVolatilityIndex	1
DPRIME	T5YIE	0	-0.00026	0.00462	H0: Bank Prime Loan Rate -/-> 5-Year Breakeven Inflation Rate	-1
DPRIME	T5YIFR	0	-1.00E-04	0.05074	H0: Bank Prime Loan Rate -/-> 5-Year,5-YearFrwrdInfltnExpcttnRt	-1
DPRIME	T10YIE	0	4.00E-05	0.18915	H0: Bank Prime Loan Rate -/-> 10-Year Breakeven Inflation Rate	1
DPRIME	DFF	0	-1.00E-05	0.27615	H0: Bank Prime Loan Rate -/-> Effective Federal Funds Rate	-1
DPRIME	DGS3MO	0	3.00E-05	NA	H0: Bank Prime Loan Rate -/-> 3-MonthTreasuryConstantMaturityRt	1
DPRIME	DGS3	0	-0.00025	4.00E-05	H0: Bank Prime Loan Rate -/-> 3-YearTreasuryConstantMaturityRat	-1
DGS3	GVZCLS	0	-0.46865	0.00085	H0: 3-YearTreasuryConstantMaturityRat -/-> CBOE Gold ETF Volatility Index	-1
DGS3	VXNCLS	0.00292	-0.05389	0.37721	H0: 3-YearTreasuryConstantMaturityRat -/-> CBOE NASDAQ 100 Volatility Index	-1
DGS3	VXVCLS	2.00E-05	-0.15841	0.18522	H0: 3-YearTreasuryConstantMaturityRat -/-> CBOES&P5003-MonthVolatilityIndex	-1
DGS3	T5YIE	0	0.00704	0.1689	H0: 3-YearTreasuryConstantMaturityRat -/-> 5-Year Breakeven Inflation Rate	1

Variable X	Variable Y	p-value	Long Run Multiplier	pvLRM	Label	Sign
DGS3	T5YIFR	8.00E-05	0.00308	0.37859	H0: 3-YearTreasuryConstantMaturityRat -/-> 5-Year,5-YearFrwrdInfltnExpcttnRt	1
DGS3	T10YIE	0	0.00898	3.00E-05	H0: 3-YearTreasuryConstantMaturityRat -/-> 10-Year Breakeven Inflation Rate	1
DGS3	DFF	0.00309	0.0014	0.09863	H0: 3-YearTreasuryConstantMaturityRat -/-> Effective Federal Funds Rate	1
DGS3	DGS3MO	0	0.002	0.01388	H0: 3-YearTreasuryConstantMaturityRat -/-> 3-MonthTreasuryConstantMaturityRt	1
DGS3	DPRIME	0.00058	0.00393	0.07626	H0: 3-YearTreasuryConstantMaturityRat -/-> Bank Prime Loan Rate	1

6. Ex-Post Discussion

The results in Table 2 also produce a Flowchart using the R-command. This visual representation of the sequence of steps incorporating each of the variables with a node and each link establishes a causal relationship. This study shows some import illustrations from this flow chart. The ‘black’ color node shows positive Granger Causality and the ‘red’ color node represents negative Granger Causality. The 3-Year Treasury Constant Maturity Rate (DGS3) has shown three unique Granger causality with DEF, T5YIFR, T10YIE, and DGS3MO. 3-Month Treasury Constant Maturity Rate (DGS3MO) shows positive Granger causality to T5YIFR but in response T5YIFR has a negative Granger Causality with DGS3MO. 5-Year Forward Inflation Expectation Rate (T5YIFR) shows negative Granger Causality to Effective Federal Funds Rate (DEF) but in reply DEF shows positive causal effect on T5YIFR.

This T5YIFR shows positive causality with S&P 500 3-Month Volatility Index (VXVCLS) but in response VXVCLS has a negative Granger causality to T5YIFR. DEF and VXVCLS both negatively Granger causes each other which is established with that of the red color nodes. 5-Year Breakeven Inflation Rate (T5YIE) and Bank Prime Loan Rate (DPRIME) shows negative causal relationship with each other. However, T10YIE positively Granger causes GVZCLS but in opposite direction GVZCLS has a negative effect on T10YIE. Besides, no other inflation rates, interest rates, and stock volatility indices builds any form of strong granger causality between them as portrayed from the following flow chart.

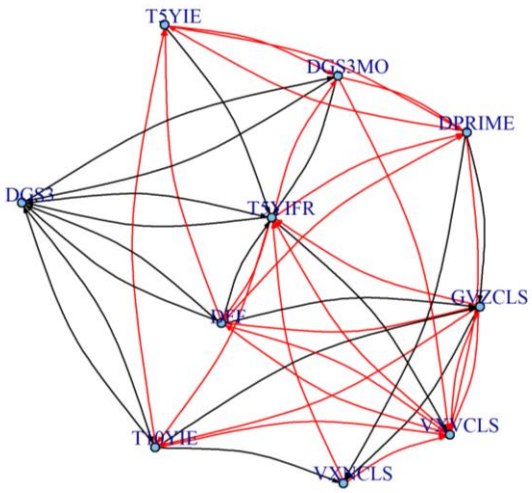

Figure 1: The Flow Chart

For example, VXNCLS has a negative Granger causality on VXVCLS but not the reverse is true. On the other hand, T10YIE do a positive granger causes on VXNCLS but there is zero causality in reverse. GVZCLS has a negative Granger Causality over DPRIME but the reverse causality is absent here in this diagram. Therefore, the study can make a decision that interest rate has a clear Granger causal effects on inflation rate and to some extent with stock volatilities. However, stock volatilities could not make any prominent causal effects on interest rates in reverse. This chart is therefore, in most cases establishes a negative causal relationship with the stock volatilities and the inflation rates but the reverse is not true always. Thus, the findings of this study therefore, verify that interest rate has the strong impact on inflation rate and vice-versa. Inflation rate although did not create any workable impact on volatilities but it creates in a shorter extent some negative impacts on stock price changes.

The interest rate however in a broad sense has significant effect on the stock volatilities. This result could be more interesting if a number of appropriate inflation rate (such as CPI) can be included and this will surely cause stock volatility, that's why I opened it up for further research and I welcome everyone to do similar type of research with more fitting inflation rates and interest rates and investigate the influence of them on stock price volatilities.

7. Conclusion

This paper empirically examines the Granger Causality test between the stock price volatilities, interest rates and inflation rates in tems of auto regressive and distributed lag effects. Daily data from June 2008 to December 2017 are used for the various interest rates and the major inflation rates to investigate the two-way causality under the Granger procedure between stock volatilities and among those indices. The probability value for the long run multiplier within that set range of time periods helps to identify the significant Granger causality test results. Considering the overall results, this study

therefore examines the causality sign to see how each of these variables affects the others within this procedure. The empirical findings from the causality tests therefore reveals that there is a strong statistical relationship between the interest rate and inflation rate and also there exists causality between interest rates and stock volatilities to some extent. It also shows, in many cases, there is no relationship among the stock volatilites and the inflation rates. Hence, the Granger Causality test proves unidirectional and bi-directional causality running from interest rates to inflation rates to stock returns and also from inflation rates to stock returns to interest rates. However, a different scenario could be established between them if the number of interest rates and inflation rates is no longer controlled.

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