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Granger Causality Effect of Macroeconomic Factors on Treasury Securities Yields in Kenya

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Abstract
Treasury securities are important financial instruments in any economy since their yields provide a benchmark interest rates for other securities. They are also key indicators of market expectations, risk perceptions and money conditions in an economy. Over the recent past years, Kenya has experienced unexpected great movements of the treasury securities yields which has presented a real risk to economic stability. Therefore, the main objective of this research is to determine the granger causality effect of macroeconomic factors on treasury securities yields in Kenya. The key macroeconomic factors considered in this research are inflation rate, monetary policy rate, Government debt and foreign exchange rate. This study finds that inflation rates significantly contribute more in explaining positive movements of short-term and medium-term treasury yields in Kenya. Similarly, monetary policy rates were found to have a significant, but relatively less, contribution in explaining negative movements of short-term and medium-term treasury yields in Kenya. Moreover, foreign exchange rates were significantly found to have more contribution in explaining positive movements of short-term treasury securities yields in Kenya. Finally, the study found that Kenyan government debt does not significantly contribute in explaining the movement of treasury security yields of all maturities in Kenya.
Keywords: Treasury Securities, Inflation Rate, Monetary Policy Rate, Government Debt, Foreign Exchange Rate, Granger Causality

1 Introduction

1.1 Background to the study

Treasury security yields play a vital role in an economy. From an economic policy point of view treasury yields are indicators of market expectations, risk perception and money conditions (Hovart, Kalman, Kocsis, & Ligeti, 2014). From investment point of view treasury yields provide as benchmark interest rates: they are vehicles for hedging interest rate risk; they are useful for position funding and liquidity management (Santosa & Sihombing, 2015). Therefore, accurate information extracted from macroeconomic causes of yield curve movement broadens the information base of economic policy makers and investors thereby contributing to sound decision-making.

Over many years, the relationship between macroeconomy and asset pricing has been a long-standing area of research (Laubach & wei, 2014). Given the impact of yield rates on security prices, financial analysts and policy makers have spent much time and effort trying to identify factors that affect interest rate movements overtime (Saunders & Cornet, 2012). Specifically, much attention has been given to interaction between the macroeconomy and treasury security yield rates.

Earliest researchers that sought to explain the movements in yields attributed the changes to a few unobservable factors (Dai & Singleton, 2000). Specifically, a model with three latent factors was first developed by Litterman and Scheinkman (1991). However, this and other models did not provide an insight into what the unobservable factors represent in an economy. This fact necessitated a move towards models that seeks to identify the underlying forces that drive yield changes or about their responses to macroeconomic variables.

Wu (2001) and Ang and Piazzesi (2005) were among the first economic and finance papers to include macroeconomic factors in modeling for determinants of yield curve changes. They included inflation and real economic activity to their models of determinants of bond yields. In their findings, including inflation and real activity into their model, proved to be more useful in explaining the movement of security yields.

Evans and Marshall (2006), unlike their predecessors, used a non-structural model approach in formulating a Variance Auto Regression (VAR) model with rich macroeconomic dynamics. The study sought to determine the effect of macroeconomic shocks on unobservable factors of yield curve. Their conclusion confirmed Wu (2001) and Ang and Piazzesi (2003) results. They find that a substantial portion of short-term and medium-term bond yields are driven by macroeconomic variables.

A more recent paper by Dua and Raje (2014), while confirming that security yields are affected by macroeconomic variables, they find that their impact differ depending on the maturities of the underlying securities. They suggest that for short-term and medium-term securities, factors affecting their yields include monetary policy, liquidity and demand and supply of credit, inflation rates and foreign exchange rates. For long-term interest rates, economic activity and expectation about government policy are relatively more important.

More current studies continue to show that macroeconomic factors are important drivers of treasury yield rates (Crump, Eusepi, & Moench, 2017). Studies such as Randionova (2010), Chee and Wah (2013), Hysing (2015) and Akram and Das (2017) have suggested some macroeconomic factors to be more significant in affecting treasury yields. These factors include inflation, economic growth, monetary policies, fiscal policies and foreign exchange rates. However, these studies have shown mixed empirical results under different target economies.

1.2 Statement of the Problem

Over the recent past years, Kenya has experienced unexpected great movements of the treasury yields which has presented real risk to economic stability (Parliamentary Budget Office, 2011). For example, the greatest movement was observed in the period between June 2015 to December 2015 (Central Bank of Kenya, 2016). The yield curve evolved from a normal positive sloping yield curve in early 2015 to an inverted negative sloping yield curve by October 2015. Such events would always puzzle economic and financial policy makers as to what contribute to such great yield movements. Understanding the evolution of treasury security yield rates is important for predicting future interest rates developments and asset returns (Gurkaynak & Wright, 2012).

A Central Bank of Kenya (2016) report suggested that the June 2015 to December 2015 yield curve movement was caused by intensive government borrowing and CBK's monetary intervention of raising its lending rate to stop depreciation of the Kenyan shilling. Moreover, the yield movements were credited to first half of 2015 experiences of rising inflationary expectations emanating from exchange rate depreciation, demand pressures and persistent global foreign exchange volatility. Notably, these and other similar propositions on how macroeconomic factors contribute to treasury yields movements in Kenya were not backed by any evidence of local empirical study.

However, macro-finance theories such as loanable fund theory (Robertson, 1934) and Investment Saving – Liquidity Preference Money Supply (IS-LM) Model (Hicks, 1937) have postulated that macroeconomic factors cause treasury yield movements. Moreover, recent empirical studies such as Chee and Wah (2013), Dua and Raje (2014), Hysing (2015) Santosa and Sihombing (2015) Akram & Das (2017) conducted in other economies have revealed that macroeconomic factors contribute to treasury securities yields movement. It was, therefore, important that this study was conducted to determine how different factors of macroeconomy can be used to explain the movements of treasury yields in Kenya.

1.3 Objectives of the Study

1. To determine the granger causality effect of inflation rate on treasury securities yields in Kenya.
2. To determine the granger causality effect of monetary policy rate on treasury securities yields in Kenya.
3. To determine the granger causality effect of government debt on treasury securities yields in Kenya
4. To determine the granger causality effect of foreign exchange rate on treasury securities yields in Kenya.

2 Literature Review

2.1 Theoretical Framework

Critical theories that inform this study are Loanable Funds Theory (Robertson, 1934), Investment Saving – Liquidity Preference Money Supply (IS-LM) Model (Hicks,1937), Expectation theory (Fisher, 1896) and Liquidity premium theory (Hicks, 1946).

2.1.1 Loanable Fund Theory

The loanable fund theory, developed by Robertson (1934), is a common economic model used in explaining interest rates and interest rate movements. The loanable fund theory of interest rate determination views the level of interest rates in financial markets as resulting from factors that affect the supply and demand of loanable funds in an economy (Saunders & Cornet, 2012). Supply of loanable funds are funds provided to the financial markets by net suppliers of funds while demand is the total net demand for funds by fund users.

Changes in the underlying factors that determine demand and supply of loanable funds could shift demand and/or supply curves hence changing the equilibrium interest rate (Mishkin, 2004). Factors that cause the supply of loanable funds to shift include wealth of supplies, monetary policy objectives, public sector deficit and inflation. On the other hand, factors that cause demand shift include the utility of consumption, restrictiveness of conditions on borrowing, and economic growth (Saunders & Cornet, 2012).

The significance of this theory for this research cannot be understated as it provides the theoretical relationship between market interest rates and macroeconomic factors in an economy. It explains how market yield rates are affected by macroeconomic conditions such inflation rate, economic growth, and government's monetary and fiscal policies (Matete, 2014). In this research, these macroeconomic factors are studied empirically to determine their effect on market interest rates of treasury securities in Kenyan economy.

2.1.2 IS-LM Model

IS-LM model, developed by Hicks (1937), explains how interest rates and total output produced in the economy (aggregate output) are determined, given a fixed price level (Bordo & Schwartz, 2004). IS-LM model is based on interaction of two macroeconomic curves; Investment Saving (IS) curve and Liquidity preference Money Supply (LM) curve. The IS curve traces out the combinations of the interest rate and aggregate output for which the goods market is in equilibrium, and the LM curve traces out the combinations for which the market for money is in equilibrium.

The simultaneous determination of output and interest rates occurs at the intersection of the IS and LM curves, where both the goods market and the market for money are in equilibrium (Saunders & Cornet, 2012). Factors that cause shift of IS curve are changes in consumer spending, investment spending, government spending, taxes, net exports. On the other hand, LM curve is shifted by changes in money supply and money demand. When these factors cause shifts in either LM or IS curve the equilibrium interest rate and output will also change (Mishkin, 2004).

According to Mishkin (2004) and Saunders and Cornet (2012) this model has been used to explain the effect of monetary and physical policies on interest rates in an economy. A rise in the money supply raises equilibrium output, but lowers the equilibrium interest rate. Expansionary fiscal policy (a rise in government spending or a fall in taxes) raises equilibrium output, but, in contrast to expansionary monetary policy, also raises the interest rate. The real interest rate is a key intertemporal relative price, which increases when there is greater expected growth in real activity and falls when the economy slows (King, 2000). The nominal interest rate is the sum of the real interest rate and expected inflation. Accordingly, a central bank pursuing an inflation-targeting policy designed to keep output near capacity must raise the nominal rate when the economy's expected growth rate of capacity output increases and lower it when the expected growth rate declines.

According to Bordo and Schwartz (2004) though this model has faced many criticisms in the past it has survived and prospered. Today it is at the heart of emphasis on low inflation as the key policy goal of the world's leading central banks. Improvement to the model, termed new IS-LM model, is same as IS-LM model only incorporating the principle of interest rate determination, which is an essential component of modern macroeconomics (King, 2000). This theory is relevant to this study because it demonstrates how the level of interest rates is affected by changes in investment spending as well as by changes in government's monetary and fiscal policy. The IS-LM model implies that an economy recovering from a temporarily low level of output would have a high real interest rate (Mishkin, 2004). A low real interest rate would be associated with an economy experiencing a temporarily high level of output. This implication is very useful in interpreting the co-movement of the real interest rate with cyclical fluctuations.

2.1.3 Expectation Theory and Liquidity Premium Theory

There is no consensus on the originator of expectation theory of the term structure of interest rate but most authors have credited it to Fisher (1896) (Guidolin & Thornton, 2008). According to this theory yield curve reflects the market's expectations of future short-term rates (Gurkaynak & Wright, 2012) . The intuition behind the theory is that long-term rates reflect the expectations of future short-term interest rates, which implies that the return on long term securities is the same as the expected return on a series of short term securities during the same period.
Liquidity Premium Theory developed by Hicks (1946) is an extension of expectation theory. This theory allows the long-term interest rate to positively deviate from the expected short-term rates (Guidolin & Thornton, 2008). This theory states that long-term rates are equal to geometric averages of current and expected short-term rates (as in expectation theory) plus liquidity risk premiums that increase with the maturity of the security (Saunders & Cornet 2012).

Not all authors have shown support for this theory from empirical analysis. Many early researchers of 1980s found little evidence of this theory especially those who used USA data (Mishkin, 2004). However, there are recent studies that still support this theory. For example, Guidolin and Thornton (2008) suggests that expectation theory failed previously because short-term interest rates were not predictable to any significant degree. Moreover, Brink (2010) finds that interest rates on markets outside the U.S. better comply to the implications of the expectations theory.

The relevance of this theories to our study, is that it supports the fact that if macroeconomic factors affects short term rates as suggested by other theories (e.g. IS-LM model) then it must also affect long term yield rates. Orphanides and Wei (2012) explains that endogenous response of monetary policy to inflation and economic conditions provides a strong link between macroeconomic factors and expected short-term yield rates. Therefore, if this expectation theory of yield term structure holds then long-term yield rates must also be linked with macroeconomic factors.

2.2 Empirical Review

2.2.1 Effect of Inflation Rate on Treasury Securities Yields

Rudebusch and Wu (2004) using US data of treasury yields presented the early empirical evidence that inflation was major factor that induces changes in long-term yield rates. Later papers by Evans and Marshall (2006) and Weise and Hardisty (2006) had similar results using US data but different sample periods. Also, Bekaert, Choo and Moreno (2010) paper finds that inflation target shock dominates the variation in the "level factor" of the yield curve affecting both short-term and long-term yield rates in the US.

A study outside the US economy by Diebold, Li and Yue (2008) conducted an empirical analysis of term structures of government bond yields for Germany, Japan, the UK and the US. They find that inflation to be economically important in explaining significant fractions of country yield curve dynamics, with interesting differences in across countries. Randionova (2010) and Hysing (2015) found similar results when investigating the behavior of the Russian government bond yields and Spanish government bonds respectively.

In Asian countries, Dua and Raje (2014) study examines the determinants of government yields in India and finds long-run relationship exists between yield rates and the inflation. Urahman (2016) focused on how T-bills are affected macroeconomic variables in Pakistan and results showed that when inflation increases, yields of T-bills also increase. Fan and Johansson (2009) analyzes the joint dynamic processes of macroeconomic and monetary variables and bond yields in China. Their results revealed that an increase in the inflation rate result in a rise in the yield curve.

However, there are studies that have found inflation rate to be insignificant in explaining treasury yields. An example is Fen et al. (2014) paper that examined the relationship between government bond yields and macroeconomic determinants in Malaysian economy. Also, Santosa and Sihombing (2015) study aimed at analyzing the contributions of the factors that influence the movement of the yield curve of government securities in Indonesia finds that inflation contribute less significantly to the movement of yields.

In Kenya and local region, Mwega (2014) paper analyses the relationship between the term structure and future changes in inflation in Kenya, using treasury bill rates spreads. The paper's findings are consistent with those obtained for other economies indicating that the slope of the term structure is a good predictor of expected inflation. Also, Ahmed and Ricci (2005) results showed that an expected inflation differential was key driver behind yield rates in South Africa.

2.2.2 Effect of Monetary Policy Rate on Treasury Securities Yields

A very early research by Piazzesi (2005) using US data finds that long yields are affected by monetary policy interest rate. Also, Charles and Marshall (2006) presented empirical evidence that adjustment of monetary policies of Federal Bank of US affect yield curves of treasury yields. Crump et al (2017) still using US data finds that monetary policy decisions, implemented through the short-term policy rate, aff ect the entire path of expected real rates as changes in the short-term real rate. However, Rudebusch and Wu (2004) found that treasury yields are less driven by monetary policies in US economy.

In Europe Chee and Wah (2013) paper studies the relationship between eight macroeconomic determinants and UK government bond yields. The results show that short term policy interest rates have a strong and negative impact on five-year, ten-year and twenty-year UK government bond yields. Also, Randionova (2010) investigated the behavior of the Russian government bond yields and its sensitivity to a selected range of macroeconomic factors. The results indicated a major significant role of changes in monetary factors.

In Asia, Fan and Johansson (2009) working paper analyzed the joint dynamic processes of macroeconomic and monetary variables and bond yields in China. This paper showed that monetary policy variable had a significant impact in capturing the variation in yields. Other studies by Dua and Raje (2014) and Santosa and Sihombing (2015) examines the determinants of government yields in India and Indonesia respectively. The empirical estimates exposed a long-run relationship between these interest rates and monetary policy rate.

2.2.3 Effect of Government Debt on Treasury Securities Yields

A study by Cebula (2015) provides current empirical evidence on the impact of net U.S. government borrowing (budget deficits) on treasury yields. Findings showed that federal budget deficit, expressed as a percent of GDP, exercised a positive and statistically significant impact on the nominal interest rate yields. Also, Ichiue & Shimizu (2012) paper examined the determinants of long-term bond yields through a panel data analysis in 10 developed countries (e.g.US and Japan). They confirm that government borrowings have a significant influence on long-term yields.

In Europe, Hysing (2015) paper applied demand and supply analysis to examine government bond yields in Spain. The study finds Spanish government bond yields to be positively associated with the government debt/GDP ratio. Also, Randionova (2010) investigated the behavior of the Russian government bond yields and its sensitivity to a selected range of macroeconomic factors. That research, however, finds that GDP and domestic debt growth are not significant factors.

In Asia, Akram and Das (2017) paper investigated the long-term determinants of Indian government bonds' nominal yields. It appraises whether the government finance variable, government debt-to-nominal income ratio, has an adverse effect on government bond yields. They find that the ratio of government debt and nominal income do not have any discernible adverse effect on yields over a long-run horizon. Similarly, Fen et al (2014) paper found government budget deficit to be insignificant in explaining government bond yields movements in Malaysian Economy.

Regionally and locally in Kenya, the available empirical literature show that government debt affects interest rates. For example, Ahmed and Ricci (2016) found that domestic government's debts tend to raise long-term yield rates in South Africa. Matete (2014) applied the loanable funds model to determine predictors of lending rates by forty-three commercial banks in Kenya and finds that government borrowing was significant predictor of lending rates by commercial banks in Kenya.

2.2.4 Effect of Foreign Exchange Rate on Treasury Securities Yields

Chee and Wah (2013) paper studied the relationship between eight macroeconomic determinants and the UK government bond yields. The results showed exchange rates to have had significant and positive relationship with UK government bond yields. Hysing (2015) paper applied demand and supply analysis to examine the government bond yield in Spain using 1999 to 2014 data. The study found that Spanish government bond yields were being negatively affected by the nominal effective exchange rate.

In Asia, Santosa and Sihombing (2015) study analyzed the contributions of the factors that influence the movement of the yield curve of government securities in Indonesia. They find that the movements of the exchange rate, contribute significantly to the movement of level of yield curve. Also, a paper by Randionova (2010) investigated the behavior of the Russian government bond yields and its sensitivity to a selected range of macroeconomic factors. The results of that empirical study, indicated a major significant role of foreign exchange rate as a risk factor.

Regionally, Ahmed and Ricci (2016) noted that long-term interest rates in South Africa were declining due to not only to internal macroeconomic factors but also external factors affecting the foreign exchange rate. In Kenya, Ogilo (2014) study sought to investigate the effect of selected macro-economic variables on bond market development in Kenya. The study showed that exchange rate had a positive effect on bond market in Kenya.

2.3 Critique of Existing Literature

Although there are several studies on factors affecting treasury yields, early researches such as Dai and Singleton (2000) and Litterman and Scheinkman (1991), focused only on latent factors of yield curves yet very early macroeconomic theories such as loanable fund theory (Robertson, 1934) and IS-LM model (Hicks, 1937) had shown that macroeconomic factors affect treasury yields. This was later confirmed by Ang and Piazzesi (2003) and Evans and Marshall (2006) using empirical data of US although they focused on only two macroeconomic factors (inflation and economic output).

Other researchers such as Ichiue & Shimizu (2012), Aime and Tanko (2016) employed simple regression models which ignore the dynamic relationship between yield rates and macroeconomic factors. Previous researches such as Diebold et al (2005) Evans and Marshall (2006) Diebold et al (2008) had suggested that VAR models produced better results than simple regression models.

Some studies, such as Ahmed and Ricci (2016) and Aime and Tanko (2016), conducted within African economies have ignored foreign exchange as a factor affecting treasury yields yet emerging economies are known to be affected by external factors. Cialorne, Piselli and Trebeschi (2007) and Eichengreen, Hausman and Panizza (2003) had suggested that treasury yields in emerging economies are affected by foreign exchange as they largely depend on external borrowing.

2.4 Research Gap

Although various studies globally that have been undertaken to determine the effects of macroeconomic factors on treasury yields securities, a few have been specific to Kenya and Africa at large. Moreover, these global studies have shown mixed results under different target economies. For example, Diebold, Li and Yue (2008) conducted an empirical analysis of term structures of government bond yields for several European countries and US. They find significant differences in results among those countries.

Fen et al (2014) finds contradicting results when they find inflation rate to be insignificant in explaining yields movements in Malaysian economy. This was contradicting other researches that show inflation rate as the most significant. Also, Rudebusch and Wu (2004) results contradicted Charles and Marshall (2001) and Crump et al (2017) when they find that treasury yields are less driven by monetary policies using data from same economy.

3 Research Methodology

This research employed Causal/explanatory research design to determine the granger causality effect among research variables. The study also employed quantitative research method with use of quantitative time series data. The target population for this research was yields of the entire treasury securities offered by Kenyan government. This included all T-bills (with maturities of 91 days, 182 days and 364 days), treasury bonds (with maturities of more than one year). However, a sample frame period from September 2000 to September 2017 was used in this study to ensure availability of data of both the treasury yields and macroeconomic factors recorded within the same period. Within the sampling frame period, census of all monthly data from January 2000 to September 2017, providing a maximum of 203 observations. This research utilized secondary data collected from Central Bank of Kenya and World Bank.

Statistical diagnostic test comprising of unit root test, cointegration analysis were carried out to check for stationarity and cointegration of these variables. This study tested for the stationarity of the variables to avoid spurious regression. Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) tests were used for unit root testing while Kwiatkowski-Phillip-Schmidt-Shin (KPSS) test was used to confirm stationarity results of unit root tests. Since, granger causality methodology is known to be sensitive to the lag length used, this research used Akaike's information Criteria(AIC) to select the optimal length of the VECM model. Johansen Cointegration test was used to test for cointegration among research variables. Two types of Johansen cointegration test were applied in testing for cointegration i.e. unrestricted cointegration rank test (Trace) and unrestricted cointegration rank test (Maximum eigen Value). These tests estimated the number of cointegrating equations from the research variables at 5% level of significance.

This study applied the Vector Auto Regressive (VAR) modelling popularized in econometrics by Sims (1980) to determine the effects of macroeconomic factors on treasury yields. However, due to presence of cointegration among research variables, VECM, which is a restricted form of Vector Autoregressive (VAR), was used in this study. The main advantage of modelling in a VAR/VECM framework, is that all variables of the model are treated as endogenous variables. This allows for more possible dynamic relationships between variables which is ignored in the simple regression framework. The VECM was estimated with nine equations for each of the nine endogenous variables, namely 91-day bill yields, 182-day bill yields, 364-day bill yields, 10-year bond yields, 15-year bond yields, inflation rate, money policy rate, government debt and foreign exchange rate. However, this research was interested in only five equations of dependent variables namely 91-day bill yields, 181-day bill yields, 364-day bill yields, 10-year bond yields, 15-year bond yields.

Therefore, all the nine research variables were modelled as endogenous. The model equation is shown below.

$$Y_t = \beta_0 + \beta_1 Y_t + \beta_2 Y_{t-1} + \cdots + \beta_{k+1} Y_{t-k} + u_t$$

Where, Y_t is a 9×9 vector of the nine research variables at time t

? $2_{1,}$? 2_2, …? 2_{k+1} are 9×9 vectors of parameter coefficients estimated

u_t is a 9×1 vector of error terms at time t

? 2_0 is 3×1 vector of constant parameter estimated

k is the number of lags

Within the framework of the VAR/VECM system of equations, the significance of all the lags of each of the individual variables were examined jointly using granger causality test. For granger causality tests, the null hypotheses are that a given variable does not granger cause another variable. On the other hand, the alternative hypotheses are that a given variable granger cause another variable. Therefore, a rejection of null hypothesis meant presence of granger causality effect among variables. This research tested the significance of granger causality effect of macroeconomic factors on treasury yields at 5% to 10% level of significance. Granger causality test cannot, by construction, explain the extend of the relationship between variables. Therefore, to further determine the granger causality effect of the macroeconomic factors on treasury yield securities, impulse response and variance decompositions were estimated from the VECM model.

4 Research Findings and Discussion

4.1 Statistical Diagnostic Tests

4.1.1 Stationarity Test

Table 4.1: Summary of unit root tests and stationarity tests results

Variables	Level			1st difference			Stationarity
	ADF test	PP test	KPSS Test	ADF test	PP test	KPSS Test	
91-Day Bill Yields	Reject H0	Reject H0	N/A	N/A	N/A	N/A	Stationary at level
182-Day Bill Yields	Do not Reject H0	Reject H0	Reject Ho	Reject Ho	Reject Ho	N/A	Stationary at 1st difference
364-Day Bill Yields	Do not Reject H0	Do not Reject H0	N/A	Reject Ho	Reject Ho	N/A	Stationary at 1st difference
10-Year Bond Yields	Do not Reject H0	Do not Reject H0	N/A	Reject Ho	Reject Ho	N/A	Stationary at 1st difference
15-Yields Bond Yields	Reject H0	Reject Ho	N/A	N/A	N/A	N/A	Stationary at level
Inflation Rate	Reject H0	Do not Reject H0	Do not Reject H0	N/A	N/A	N/A	Stationary at level
Money Policy Rate	Reject H0	Do not Reject H0	Do not Reject H0	N/A	N/A	N/A	Stationary at level
Government Debt	Do not Reject H0	Do not Reject H0	N/A	Do not Reject H0	Reject Ho	Do not Reject H0	Stationary at 1st difference
Foreign Exchange Rate	Do not Reject H0	Do not Reject H0	N/A	Reject Ho	Reject Ho	N/A	Stationary at 1st difference

The results show that 91-day bill yields, 15-year bond yields, inflation rate and money policy rate are stationary at level order. On the other hand, 182-day bill yields, 364-day bill yields, 10-year bond yields, government debt and foreign exchange rate are stationary at first differencing. Therefore, to avoid spurious regressions, 182-day bill yields, 364-day bill yields, 10-year bond yields, government debt and foreign exchange rate variables were first transformed by first differencing to make them stationary before using them in the cointegration test and VAR model.

4.1.2 Cointegration Test

Table 4.2: Unrestricted Cointegration rank test (Trace) results

Hypothesized Number of Cointegrating Equations	Eigen Value	Trace Statistic	0.05 Critical Value	Probability Value
None *	0.666551	362.9266	197.3709	0.0000
At most 1 *	0.565245	270.6722	159.5297	0.0000
At most 2 *	0.536528	200.7025	125.6154	0.0000
At most 3 *	0.383116	136.1057	95.75366	0.0000
At most 4 *	0.342802	95.52743	69.81889	0.0001
At most 5 *	0.271814	60.26681	47.85613	0.0023
At most 6 *	0.223918	33.62217	29.79707	0.0173
At most 7	0.106990	12.32836	15.49471	0.1419
At most 8	0.033050	2.823141	3.841466	0.0929

Table 4.3: Unrestricted Cointegration rank test (Maximum eigen value) results

Hypothesized Number of Cointegrating Equations	Eigen Value	Maximum Eigen Value	0.05 Critical Value	Probability Value
None *	0.666551	92.25437	58.43354	0.0000
At most 1 *	0.565245	69.96968	52.36261	0.0004
At most 2 *	0.536528	64.59682	46.23142	0.0002
At most 3 *	0.383116	40.57828	40.07757	0.0439
At most 4 *	0.342802	35.26061	33.87687	0.0340
At most 5 *	0.271814	26.64464	27.58434	0.0656
At most 6 *	0.223918	21.29381	21.13162	0.0475
At most 7	0.106990	9.505223	14.26460	0.2465
At most 8	0.033050	2.823141	3.841466	0.0929

Table 4.2 and Table 4.3 presents the results of both two types of Johansen cointegration tests. The results from both test show that there are at least six significant cointegrating equations among the research variables. This means that, from research data, linear combinations of at least six research variables are stationary despite those variables being individually non-stationary. Therefore, to avoid spurious regression, this study converted a VAR model to VECM by first differencing all the research variables before applying them to the model.

4.1.3 Model Optimal Lag Length

Table 4.4: Model optimal lag length results

Lag length	**0**	**1**	**2**	**3**	**4**
Akaike Information Criterion	21.34473	10.96718	7.283039	7.273880*	7.408356

The results of AIC, shown in table 4.4 above, selects 3 lags as the optimal lag length given the data available for this research. This means that optimal length of time that macroeconomic factors granger-cause movements in treasury yields is 3 months. Therefore, this research estimated a VECM model with 3 lags.

4.2 Vector Error Correction Model Analysis

Table 4.5: Vector error correction model analysis results

	Dependent Variable Equations				
	91-Day Bill Yield	182-Day Bill Yields	364-Day Bill Yields	10-Year Bond Yields	15-Year Bond Yields
R-squared	0.778184	0.757421	0.745284	0.576324	0.801930
Adj. R-squared	0.640072	0.606381	0.586688	0.312525	0.678604

The results, shown in table 4.5 above, show that all the five equations are significant in explaining the movement of the targeted dependent variables. The goodness of fit statistics (R-Squared) showed that these five estimated equations explained about 77%, 75%, 74%, 57% and 80% for dependent variables 91-day bill yields, 182-day bill yields, 364-day bill yields, 10-year bond yields and 15-year bond yields dependent variables respectively.

4.3 Granger Causality effect

4.3.1 Granger Causality Effect of Inflation Rate on Treasury Yields

Table 4.6: Granger causality effect of inflation rate on treasury yields results

	91-Day Bill Yields	182-Day Bill Yields	364-Day Bill Yields	10-Year Bond Yields	15-Year Bond Yields
Chi-Square Statistic	8.355829	7.593486	5.589115	11.24892	4.961514
Degrees of freedom	3	3	3	3	3
Probability	0.0392	0.0552	0.1334	0.0105	0.1746

For 91-day bill yields, 182-day bill yields, 364-day bill yields and 10-year bond yields the null hypothesis is rejected at 5% to 6% level of significance while for 15-year bond yield the null hypothesis is not rejected at 5% level of significance. Therefore, the results, as displayed on table 4.6, show that inflation rate significantly granger-cause yields of 91-day bills, 182-day bills, 364-day bills and 10-year bonds while it does not significantly granger-cause yields of 15-year bonds.

4.3.2 Granger Causality Effect of Monetary Policy Rate on Treasury Yields

Table 4.7: Granger causality effect of monetary policy rate on treasury yields results

	91-Day Bill Yields	182-Day Bill Yields	364-Day Bill Yields	10-Year Bond Yields	15-Year Bond Yields
Chi-Square Statistic	9.305395	8.423232	6.807198	8.959182	3.661855
Degrees of freedom	3	3	3	3	3
Probability	0.0255	0.0380	0.0783	0.0298	0.3004

For 91-day bill yields, 182-day bill yields, 364-day bill yields and 10-year bond yields the null hypothesis was rejected at 5% to 8% level of significance while for 15-year bond yield the null hypothesis is not rejected at 5% level of significance. Therefore, the results show that monetary policy rate significantly granger-cause yields of 91-day bills, 182-day bills, 364-day bills and 10-year bond while it does not significantly granger-cause yields of 15-year bonds.

4.3.3 Granger Causality Effect of Government debt on Treasury Yields

Table 4.8: Granger causality effect of government debt on treasury yields test results

	91-Day Bill Yields	182-Day Bill Yields	364-Day Bill Yields	10-Year Bond Yields	15-Year Bond Yields
Chi-Square Statistic	3.555340	3.568718	3.635570	3.68367	3.793294
Degrees of freedom	3	3	3	3	3
Probability	0.3137	0.3120	0.3036	0.2974	0.2847

For all the treasury securities, namely, 91-day bill yields, 182-day bill yields, 364-day bill yields, 10-year bond yield and 15-year bond yields the null hypothesis was not rejected at 5% level of significance. Therefore the results show that Government debt does not significantly granger-cause yields of 91-day bills, 182-day bills, 364-day bills, 10-year bonds and 15-year bonds.

4.3.4 Granger Causality Effect of Foreign Exchange Rate on Treasury Yields

Table 4.9: Granger causality effect of foreign exchange rate on treasury yields test results

	91-Day Bill Yields	182-Day Bill Yields	364-Day Bill Yields	10-Year Bond Yields	15-Year Bond Yields
Chi-Square Statistic	30.86396	25.39591	30.10425	5.238637	0.778314
Degrees of freedom	3	3	3	3	3
Probability	0.0000	0.0000	0.0000	0.1551	0.8546

For 91-day bill yields, 182-day bill yields, 364-day bill yields the null hypothesis was rejected at 5% level of significance while for 10-year bond yields and 15-year bond yields the null hypothesis was not rejected at 5% level of significance. Therefore, the results on table 4.9 show that foreign exchange rate significantly granger-causes yields of 91-day bills, 181-day bills and 364-day bills while it does not significantly granger-cause yields of 10-year bonds and 15-year bonds.

4.4 Impulse Response

4.4.1 Impulse Response of 91-Day Bill Yields

Table 4.10: Impulse response of 91-day bill yields results

Period	Inflation rate	Monetary policy rate	Government debt	Foreign exchange rate
1	0.000000	0.000000	0.000000	0.000000
2	0.401902	-0.000261	0.197296	0.473875
3	0.138453	-0.049914	0.192877	0.428182

Impulse response results on table 4.10 show that in 3 lags 91-day bill yields responds negatively to granger causality effects of monetary policy rate. Conversely, impulse response results show that in 3 lags 91-day bill yields respond positively to granger causality effects of inflation rate, government debt and foreign exchange rate.

4.4.2 Impulse response of 182-Day Bill Yields

Table 4.11: Impulse response of 182-day bill yields results

Period	Inflation rate	Monetary policy rate	Government debt	Foreign exchange rate
1	0.000000	0.000000	0.000000	0.000000
2	0.369078	-0.090004	0.193677	0.523006
3	0.144710	-0.169874	0.206967	0.318316

Impulse response results on table 4.11 show that in 3 lags 182-day bill yields respond negatively to granger causality effects of monetary policy rate. Conversely, impulse response results show that in 3 lags, 182-day bill yields respond positively to granger causality effects of inflation rate, government debt and foreign exchange rate.

4.4.3 Impulse Response of 364-Day Bill Yields

Table 4.12: Impulse response of 364-day bill yields results

Period	Inflation rate	Monetary Policy rate	Government debt	Foreign exchange rate
1	0.000000	0.000000	0.000000	0.000000
2	0.314785	-0.020319	0.084624	0.474394
3	0.111379	-0.231381	0.178002	0.479389

Impulse response results on table 4.12 show that in 3 lags 364-day bill yields respond negatively to granger causality effects of monetary policy rate. Conversely, impulse response results show that in 3 lags, 364-day bill yields respond positively to granger causality effects of inflation rate, government debt and foreign exchange rate.

4.4.4 Impulse Response of 10-Year Bond Yields

Table 4.13: Impulse response of 10-year bond yields results

Period	Inflation rate	Monetary policy rate	Government debt	Foreign exchange rate
1	0.000000	0.000000	0.000000	0.000000
2	0.023945	-0.071142	-0.002068	0.166911
3	0.004085	-0.134305	-0.079008	0.244565

Impulse response results on table 4.13 show that in 3 lags 10-year bond yields respond negatively to granger causality effects of monetary policy rate and government debt. Conversely, impulse response results show that in 3 lags 10-year bond yields respond positively to granger causality effects of inflation rate and foreign exchange rate.

4.4.5 Impulse Response of 15-Year Bond Yields

Table 4.14: Impulse response of 15-year bond yields results

Period	Inflation rate	Monetary policy rate	Government debt	Foreign exchange rate
1	0.000000	0.000000	0.000000	0.000000
2	-0.009052	-0.027380	-0.012790	0.049446
3	-0.040095	-0.055664	-0.029067	0.097307

Impulse response results on table 4.14 show that in 3 lags 15-year bond yields respond negatively to granger causality effects of inflation rate, monetary policy rate and government debt. Conversely, impulse response results show that in 3 lags 15-year bond yields respond positively to granger causality effects of foreign exchange rate.

4.5 Variance Decomposition

4.5.1 Variance Decomposition of 91-Day Bill Yields

Table 4.15: Variance decomposition of 91-day bill yields results

Period	Inflation rate	Monetary policy rate	Government debt	Foreign exchange rate
1	0.000000	0.000000	0.000000	0.000000
2	6.435713	2.720006	1.550937	8.947137
3	5.674670	0.078243	2.390765	12.80992

The variance decomposition results on table 4.15 show that, in 3 lags, inflation rate and foreign exchange rate explains relatively more of variation in 91-day bill yields with total of about 12% and 20% respectively. On the other hand, monetary policy rate and government debt explains relatively less of variation of 91-day bill yields with a total of about 3% and 4% respectively.

4.5.2 Variance Decomposition of 182-Day Bill Yields

Table 4.16: Variance decomposition of 182-day bill yields results

Period	Inflation rate	Monetary policy rate	Government debt	Foreign exchange rate
1	0.000000	0.000000	0.000000	0.000000
2	5.645419	0.335723	1.554582	11.33635
3	5.314263	1.249706	2.716848	12.67570

The variance decomposition results on table 4.16 show that in 3 lags inflation rate and foreign exchange rate explains relatively more of variation in 182-day bill yields with total of about 11% and 24% respectively. On the other hand, monetary policy rate and government debt explains relatively less of variation of 182-day bill yields with a total of about 1% and 4% respectively.

4.5.3 Variance Decomposition of 364-Day Bill Yields

Table 4.17: Variance decomposition of 364-day Bill yield results

Period	Inflation rate	Monetary policy rate	Government debt	Foreign exchange rate
1	0.000000	0.000000	0.000000	0.000000
2	5.373099	0.022388	0.388314	12.20321
3	4.153472	2.009784	1.447104	16.94480

The variance decomposition results on table 4.17 show that in 3 lags inflation rate and foreign exchange rate explains relatively more of variation in 364-day bill yields with total of about 10% and 29% respectively. On the other hand, monetary policy rate and government debt explains relatively less of variation of 364-day bill yields with a total of about 2% each.

4.5.4 Variance Decomposition of 10-Year Bond Yields

Table 4.18: Variance decomposition of 10-year bond yield results

Period	Inflation rate	Money policy rate	Government debt	Foreign exchange rate
1	0.000000	0.000000	0.000000	0.000000
2	0.159903	1.411481	0.001193	7.769536
3	0.108055	4.230072	1.143906	16.05499

The variance decomposition results on table 4.18 show that in 3 lags, foreign exchange rate explains relatively more of variation in 10-year bond yields with total of about 24%. On the other hand, inflation rate, monetary policy rate and government debt explains relatively less of variation of 10-bond bonb yields with a total of about 1%, 5% and 1% respectively.

4.5.5 Variance decomposition of 15-Year Bond Yields

Table 4.19: Variance decomposition of 15-year bond yields results

Period	Inflation rate	Monetary policy rate	Government debt	Foreign exchange rate
1	0.000000	0.000000	0.000000	0.000000
2	0.154845	1.416580	0.309115	4.619971
3	1.556324	3.544717	0.928970	10.97409

The variance decomposition results on table 4.19 show that in 3 lags foreign exchange rate explains relatively more of variation in 15-year bond yields with total of about 15%. On the other hand, inflation rate, monetary policy rate and government debt explains relatively less of variation of 15-year bond yields with a total of about 2%, 5% and 1% respectively.

5 Summary, Conclusions and Recommendations

5.1 Summary

This study explored the effect of macroeconomic factors on treasury securities yields in Kenya. The key macroeconomic factors considered in this research are inflation rate, monetary policy rate, Government debt and foreign exchange rate. The target population for this research was limited to yields of the treasury securities offered by Kenyan government. Specifically yields of 91-day bills, 182-day bills, 364-day bills, 10-year bonds and 15-year bonds was used.

5.1.1 Effect of inflation rate on treasury securities yields

The findings of this research show that inflation rate significantly granger-causes the yields of 91-day bill yields, 182-day bill yields, 364-day yields and 10-year bond yields while it does not significantly granger cause yields of 15-year bonds. Moreover, granger causality effect of inflation rate is positive. Variance decomposition results show that inflation rate explains more variation in 91-day bills yields, 182-day bill yields, 364-day bill yields and explains less variation in 10-year bond yields.

This result agrees with those of earlier studies by Diebold et al (2008), Randionova (2010) and Hysing (2015) who conducted empirical analysis of term structures of government bond yields in other economies (i.e. Germany, Japan, the UK and the US). They had found Inflation to be economically important in explaining significant fractions of country yield curve dynamics. Also, this study's results correspond to Fan & Johansson (2009) analysis that revealed inflation rate to have a positive impact on treasury yield curve in China.

5.1.2 Effect of Monetary Policy Rate on Treasury Securities Yields

This study finds that, monetary policy rate significantly granger-causes yields of 91-day bills, 182-day bills, 364-day bills and 10-year bond while it does not significantly granger-cause yields of 15-year bonds. Also, the granger causality effect is negative for those yields that are affected by monetary policy rate. Moreover, monetary policy rate explains relatively less variation on treasury yields it granger causes, namely, 91-day bill yields, 182-day bill yields, 364-day bill yields and 10-year bond yields.

These results match those of Fan and Johansson (2009) paper that showed that monetary policy variable had a significant impact in capturing the variation of yields in China. This result also parallels Rudebusch and Wu (2004) study that found out that treasury yields are less driven by monetary policies in the US economy. However, these results disagree with Randionova (2010) that indicated a huge significant role of changes in monetary factors in explaining Russian government bond yields.

5.1.3 Effect of Government Debt on Treasury Securities Yields

The results of this study show that Government debt does not significantly granger-cause all types of treasury yields, namely, 91-day bill yields, 182-day bill yields, 364-day bill yields, 10-year bond yields and 15-year bond yields. Likewise, the results show that, if government debt was significant in granger causing treasury yields, its effect would explain very less of treasury yield movement of all maturities. Moreover, its effect would be positive for short-term treasury yields and negative for long-term treasury yields.

The results are similar to Akram and Das (2017) paper results that showed the ratio of government debt and nominal income as not having any discernible adverse effect on yields over a long-run horizon in India. The results are also analogous to Fen et al (2014) paper that found government budget deficit to be insignificant in explaining government bond yields movements in Malaysian Economy.

5.1.4 Effect of Foreign Exchange Rate on Treasury Securities Yields

The findings of this research show that foreign exchange rate significantly granger-causes yields of 91-day bills, 182-day bills, 364-day bills while it does not granger cause yields of 10-year bonds and 15-year bonds. Additionally, the granger causality effect is positive for those yields it affects. Also, foreign exchange rate explains relatively more variation on 91-day bill yields, 182-day bill yields and 364-day bill yields.

The findings correspond to those of Santosa and Sihombing (2015) study that found movements of the exchange rate to be contributing significantly to the movement of level of yield curve in Indonesia. Also, a paper by Randionova (2010) had similar results that indicated a major significant role of foreign exchange rate as a risk factor on Russian government bond yields. Chee and Wah (2013) paper also showed that exchange rates have significant and positive relationship with UK government bond yields.

5.2 Conclusions

This study concludes that inflation rate, monetary policy rate and foreign exchange rate have a significant granger causality effect on treasury securities in Kenya. However, this research finds that government debt does not have a significant granger causality effect on treasury yields in Kenya. The optimal length of time the macroeconomic factors in Kenya granger-cause treasury yield is found to be three months. Also, the findings of this research show that VECM is statistically significant in modelling for dynamic effects of macroeconomic variables on treasury yields in Kenya.

Specifically, this study finds inflation rate as having more and positive granger causality effect on short-term treasury yields than on medium-term treasury yields. Also, monetary policy rate has a less and positive granger causality effect on short-term and medium-term treasury yields. Moreover, foreign exchange rate has more and positive granger causality effect on short-term treasury yields. Lastly, government debt has no granger causality effect on treasury yields of all maturities.

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