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THE CONTEMPORANEOUS RELATIONSHIP BETWEEN STOCK PRICES AND MONETARY POLICY IN KENYA

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DECLARATION

I declare that this work has not been previously submitted and approved for the award of a degree by this or any other University. To the best of my knowledge and belief, the Research Proposal contains no material previously published or written by another person except where due reference is made in the Research Proposal itself.

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This Research Proposal has been submitted for examination with my approval as the Supervisor.

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Contents

List of Figures

List of Tables

List of Abbreviations

CBK	Central Bank of Kenya
CBR	Central Bank Rate
CIR	Cox, Ingersoll and Ross
CPI	Consumer Price Index
NSE	Nairobi Securities Exchange
NSE-20	Nairobi Securities Exchange 20-Share Index
RS	Rigobon and Sack

Abstract

Movements in the stock market can have a significant impact on the macroeconomy and stock prices are therefore likely to be an important factor in monetary policy decisions. In view of the raging debate on whether central banks should react directly to asset price movements, this paper attempts to measure the contemporaneous response relationship between stock prices and monetary policy in Kenya applying the procedure of Rigobon and Sack (2003) to identify and estimate a VAR in the presence of heteroskedasticity of stock returns. The study finds a significant positive policy response with a 1% percent rise (fall) in the NSE-20 share index, a proxy for stock prices, increasing the likelihood of a 1.97% tightening (easing) of the short-term interest rate which captures monetary policy actions by the CBK.

Keywords: asset prices, stock prices, monetary policy, interest rates, endogeneity

1. INTRODUCTION

1.0. Background

The aim of many central banks has mainly been to keep inflation low while promoting sustainable real growth and this objective is supported by a wide consensus in macroeconomic literature that monetary policy can influence the real economy. For instance, (Taylor, 1995) reported that monetary policy actions can cause real output movements that last for over two years. However, there is less agreement on the relationship between stock price movements and monetary policy, and in particular on the impact of the former on money demand and in turn on economic activity. (Caporale & Soliman, 2013) Over time, this relationship between stock prices and monetary policy, if any, has begged two questions: Is the demand for money independent from asset price movements? Should central banks react directly to stock price movements, especially at times of very volatile stock prices? If "yes" to the latter, some scholars have argued that this direct response to asset prices by monetary authorities can improve macroeconomic performance, (Lansing, 2003). On the contrary, it has been contended that even if a central bank takes into consideration asset prices e.g. stock prices and is successful in stabilizing prices, it may be unsuccessful in creating financial stability and may promote financial instability, (Bean, 2003)

While central bankers have predominantly been concerned with price stability by controlling the interest rate which is now low and stable in developed economies e.g. the USA and Canada ((Andolfatto, 2014) & (Desroches & Francis, 2007)), focus has turned on stabilizing prices of assets within the financial systems. This issue of financial stability has often been linked to business cycles and has been widely discussed in academic literature and the press. In a study of aggregate financial imbalances involving 34 countries that included all the G10 countries, (Borio & Lowe, 2002) found two complete boom-bust cycles in asset prices for the period 1970-2002. The study found these cycles to be growing in amplitude and length and being characterized by increasing volatility of equity prices than real estate prices (both commercial and residential). The large swings have been linked to strains in the real economy and financial sector.

Being the case, the debate on this monetary policy-financial stability nexus has yielded much empirical work in different countries to establish if the relationship- if any- between stock prices and monetary policy instruments is simultaneous. Consequently, this has raised the question of whether central banks should react to asset prices, ((Akram, Bardsen, & Eitrheim, 2006) & (Bernanke & Gertler, 2001))

1.1. Motivation of the study

Developments in asset markets can have a significant impact on both inflation and real economic activity. History is replete with examples in which large swings in stock, housing and exchange rate markets coincided with prolonged booms and busts for example the Wall Street's 1929 crash and the Tokyo housing and equity bubble in the late 1980s. While it is difficult to state with certainty the causal relationship between such economic phenomena and fluctuations in asset prices, there is extant evidence that asset price booms and busts have been associated repeatedly with the emergence of serious economic imbalances. According to (Borio, Kennedy, & Prowse, 1994), the boom-bust nature of asset price fluctuations exacerbates business cycles, fuelling the upswing, magnifying the downswing and slowing down the recovery process. Much more, the disruption caused to balance sheets of economic agents, notably banks, results in widespread financial distress.

In Kenya, (Misati & Nyamongo, 2012) used VAR methodology to study the impact of stock prices on monetary policy in Kenya using quarterly data spanning 1996q1-2009q2. The study used the Nairobi Securities (NSE) market index as a proxy for asset prices and short-term rates namely, repo rate, interbank rate and Central Bank rate (CBR) to capture Monetary Policy. The authors found mixed results on the existence of the asset price channel in Kenya. Secondly, while the authors find no significant effect of monetary policy on stock price volatility, they note that instability in monetary variables was linked to volatility in asset prices. Hence they inferred that the stock market might be important in predicting business cycles.

In light of the foregoing study and the recent developments in asset markets, this research aims to explore the relationship between monetary policy and stock prices in Kenya using a different VAR approach. To the best of my knowledge, the research by (Misati & Nyamongo, 2012) is the only study on the contemporaneous relationship between asset prices and monetary policy in Kenya

1.2. Problem Statement

There exists a gap in the study of the contemporaneous impulse responses between monetary policy and stock prices in Kenya. Studies done in Kenya involving asset prices and monetary policy have focused on the unidirectional effect of interest rates or other macroeconomic variables on asset prices. For example, (Durevall & Ndung'u, 1997), using Kenyan data during 1974–1996, find that exchange rates, foreign prices, and terms of trade have long-term effects on prices, while interest rates and money supply have short-term effects. (Cheng, 2006) studied the effect of the Repurchase Agreement (REPO) rate on real output, prices and the nominal effective exchange rate using data for the period 1997-2005. The result was that variations in the short-term interest rate accounted for around one-third of the fluctuations in prices and half of the fluctuations in the nominal exchange rate, while accounting for around 10 percent of the output variation. This study aims at addressing this research gap.

As earlier stated, the study by (Misati & Nyamongo, 2012) on the effect of stock prices on monetary policy is the sole research on this issue in Kenya. The study uses VAR methodology as it is regarded as most appropriate for the analysis of policy shocks on macroeconomic variables and employs a recursive approach that makes use of restrictions to identify the VAR. However, (Rigobon & Sack, 2003) contend that the common approaches of using restrictions or instrumental variables in achieving identification are not adequate in appropriately separating the response of monetary policy to the stock market from the endogenous reaction of the stock market to interest while using VAR. As a solution, (Rigobon & Sack,

2003) propose an alternative identification technique by analyzing the heteroskedasticity found in interest rates and stock market returns so as to identify the reaction of monetary policy to the stock market. This study makes use of this technique as it considers the issue of endogeneity more precisely in establishing the relationship between stock prices and monetary policy in Kenya within a VAR framework. This is the contribution of this study on an empirical front.

1.3. Research Objectives

The objective of this study are as follows:

1. To find out if stock prices react to monetary policy in Kenya
2. To find out if there is a response to stock prices by monetary policy in Kenya

1.4. Research Hypothesis

The research hypotheses are:

H_{O1}: There is no reaction to monetary policy by stock prices in Kenya

H_{A1}: There is a reaction to monetary policy by stock prices in Kenya

H_{O2}: There is no response to stock prices by monetary policy in Kenya

H_{A2}: There is a response to stock prices by monetary policy in Kenya

1.5. Importance of the research

In view of this ongoing debate on the monetary-policy-financial stability debate, there is need to understand the relationship that may exist between monetary policy and asset prices. This research interest has been intensified by the recent global financial crisis. Undoubtedly, a critical outcome is to ask, therefore, whether central banks, in this case the CBK, can improve their effectiveness - and lessen the likelihood of economic instability - by taking asset price shifts into account explicitly in their decision-making. It is hoped that the results of this study will provide these answers.

2. LITERATURE REVIEW

2.0. An overview of the literature review

This chapter starts by discussing how asset prices affect the macroeconomy as this provides a basis for the study of the relationship between asset prices (stock prices) and monetary policy decisions. The existence and nature of this relationship as presented by varying studies has led to opposing views in academic literature on whether central bankers should be concerned about asset prices in their policy decisions. Whilst presenting these contrasting views, this chapter also discusses the endogoneity problem which is a key concern in the determination of the relationship between monetary policy and asset prices. In analyzing this relationship, empirical studies have used different variables hence the choice of variables is discussed which includes a discussion on the alternative use of inflation in place of interest rates to proxy monetary policy as suggested by some academic literature. In view of the foregoing, the chapter offers rationale from literature of how a response function involving stock prices and short term interest rates as policy instruments captures inflation.

In establishing this relationship between stock prices and monetary policy, it is worth noting that various econometric methodologies have been used. Being the case, the various approaches detailed in academic literature are discussed and a justification of the preferred methodology for this particular study is provided. At the conclusion of the literature review, a limitation of this study is offered

2.1. Asset prices affect the macroeconomy

The impact of the stock market on the macroeconomy could be through various channels: The first is that movements in stock prices influence aggregate consumption through the wealth channel (the wealth effect). According to (Rigobon & Sack, 2003), the central bank reacts indirectly to stock prices because of their wealth effects on aggregate demand. The stock price movements also affect the cost of financing to businesses. In addition to these, policy makers could view equity price movements as a signal of future economic activity, reflecting either private information in the hands of investors or simply revisions to investors' expectations about economic prospects. Being so, the near-term path of monetary policy –short-term rates- might respond to equity price movements because of the information contained in equity price movements and not merely owing to the wealth effect or change in the cost of borrowing (Rigobon & Sack, 2003).

(Maki & Palumbo, 2001) also provided evidence that there is a significant impact of asset price swings on aggregate demand through a wealth effect on consumption, a Tobin's Q and financial accelerator effects on investment. Hence, if a low response to asset prices by monetary policy is justified by a lower forecasting power for inflation, a larger stock market wealth effect should call for a higher response. This view is supported by (Kontonikas & Montagnoli, 2006) who argues that in the presence of wealth effects and inefficient markets, asset price misalignments from their fundamentals should be included in the optimal interest rate reaction function.

Interestingly, empirical evidence has supported the importance of the wealth effect coming from the housing sector with (Case, Quigley, & Shiller, 2005), (Ludwig & Slok, 2004), (Carroll, Otsuka, & Slacalek, 2006) having found that the real estate wealth effect is increasing over time and higher than of the equities. A study by (Furlanetto, 2008) finds evidence that the lower response to stock prices in a period of financial instability in the US is compensated by a higher response by the prices of real estate. Nevertheless, this study sticks to the study of stock prices and not real estate prices.

2.2. Support for central banks to be concerned about asset prices

Among the proponents of the notion that central banks should be concerned about asset prices, the popular consensus has been on "flexible" inflation-targeting. Within this inflation-targeting policy framework, the central bank announces to the public medium-term inflation targets that are the monetary policy nominal anchors whilst allowing for flexibility by then bank in the short-run to help stabilize the real economy, (Bernanke & Mishkin, 1997). Thus the central bank is primarily concerned about changes in expected inflation in its use of instrument interest rates. Thus, as regards the relationship between asset prices and monetary policy, the argument is that changes in asset prices should only influence monetary policy to the extent that they affect central bank's forecast of inflation within an inflation-targeting policy (Bernanke & Gertler, 2001). Alan Greenspan, a similarly a strong proponent, upholds the notion through his argument that policy-makers should respond to stock prices to the extent warranted by their impact on the economy in accordance with their influence on the outlook for output and inflation, (Greenspan, 2002).

Of core contribution to this proposition is the study by (Bernanke & Gertler, 2001) who used a new Keynesian model with nominal rigidities to show that the most stabilizing rule is one that responds strongly to inflation and not variations in asset prices. The argument is that the response to asset prices has destabilizing effects because it is almost impossible to know whether a change in asset prices is due to fundamental factors. In the study, they concluded that there was little if any marginal gains from allowing a response to the level of asset prices by central banks if the inflation forecast is not affected. More so, they consider worrisome an attempt to purely influence asset prices (without considering their inflationary or deflationary pressure) owing to the negative effects on market psychology of such a move. In their conclusion, (Bernanke & Gertler, 2001) emphatically assert that central banks should only respond to shocks that change the natural real rate of interest even if from the stock market i.e. shocks to stock prices (from either a bubble or from technology). The emphasis is thus on responding aggressively to underlying inflationary pressures but not singling out stock market prices in monetary policy determination as this would have no additional benefit.

An alternative perspective to this position is that monetary policy should remain focused on achieving the macroeconomic goals and should seek to do no more than deal with the fall-out from the eventual unwinding of an asset price bubble, a view supported by (Crockett, 2003), (Borio & Lowe, 2002), (Cecchetti, Genberg, Lipsky, & Wadhwani, 2000) and (Bordo & Jeanne, 2002). Put differently, Inflation targeting central banks automatically accommodate productivity gains that lift stock prices, while offsetting purely speculative increases or decreases in stock values whose primary effects are through aggregate demand.

A counter-argument to the foregoing first view is advanced by (Cecchetti, Genberg, Lipsky, & Wadhwani, 2000) who argue that a central bank is likely to achieve better performance by acting not only in response to its forecast of future inflation and the output gap but to asset prices as well. The reasons is that reaction to asset prices in the course of policy making will reduce the likelihood of asset price misalignments coming about in the first place and this reduces the likelihood of asset price bubbles forming. A further support for this argument is that, as inflation forecasts depend on assumptions about asset prices, they must depend on views about the size of asset price misalignments.

Whilst (Cecchetti, Genberg, Lipsky, & Wadhwani, 2000) agree that estimating asset prices misalignments is difficult and has been rendered impractical, they reason that these difficulties are not substantially different from those of estimating theoretical constructs such as potential GDP or the equilibrium real interest rate. The difficulties in question also entail distinguishing prices volatility owing to fundamental factors and those arising from non-fundamental factors as pointed out by (Bernanke & Gertler, 2000).

2.3. Argument against reaction to asset prices

A number of arguments have been advanced against central bank reacting directly to asset prices. (Tymoigne, 2006) argument is that it is irrelevant for a central bank to pursue price stability and it should focus primarily on maintaining financial stability. Thus, a central bank should abstain from any other economic problems which can be handled by other specialized public institutions. After all, central banks have a limited direct effect on inflation because they cannot have full control over the supply of reserves and supply of money and, most importantly, inflation is not necessarily a pure monetary phenomenon, (Keynes, 1936) & (Fazzari, Hubbard, & Petersen, 1988). More so, (Iacoviello, 2005) shows that reacting to real estate inflation causes little gain in terms of inflation and output volatility with the optimal coefficient in the reaction function being around 0.1. The view by (Tymoigne, 2006) has however been opposed by (Akram, Bardsen, & Eitrheim, 2006) who provides examples where a more proactive policy has stabilizing effects on the economy.

(Bean, 2003) offers an interesting view that even if a central bank takes into consideration asset prices and are successful in stabilizing prices, it may not be successful in creating financial stability and, on the contrary, may promote financial instability. This is because, output-price stability and solid growth may lead to the development of bullish expectations in the financial market. That generate optimistic views about the future. This results in an increase in the value of collateral which may in turn trigger a credit boom that highly reinforces the bullish financial market and causes instability in the markets. Finally, it has been argued that asset prices are too volatile to be of much use in determining policy and that misalignments of asset prices are close to impossible to identify, let alone correct.

2.4. The endogeneity problem

As movements in the stock market can have a significant impact on the macro economy, it is likely that they are, or should be, an important factor in monetary policy formulation. A key problem in identifying the monetary policy response to the stock market is the endogeneity problem as stock markets endogenously respond to monetary policy as depicted in the figure below (adopted from (Rigobon & Sack, 2003)

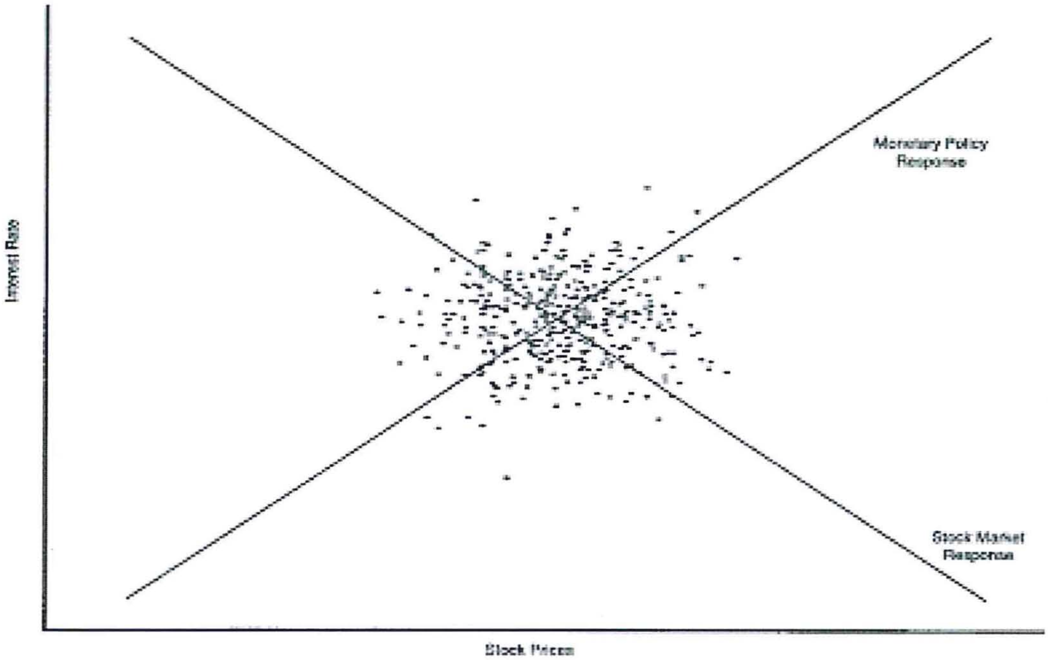


Figure 1: The simultaneous determination of interest rates and stock prices

In the figure above, *ceteris paribus*, higher interest rates are associated with lower stock market prices, given the higher discount rate for the expected stream of dividends. At the same time, the policymakers may react to higher prices in the stock by raising interest rates. The intersection of the two schedules determines the stock prices and interest rates without a clear reading of whether the policy reaction function is upward sloping in stock prices.

Using instrumental variables to solve the endogeneity problem proves a challenge as it is difficult to conceive of any instrument that would affect the stock market without affecting interest rates. The greatest difficulty lies in the fact that any instrument related to the macroeconomic outlook certainly would not be applicable. Much more, even variables specifically related to firm profits e.g. earnings surprises would likely have information about the macroeconomic outlook as well making them correlated with interest rate changes, (Rigobon & Sack, 2003). In addition to the endogeneity problem, the co-movements between stock market returns and interest rate changes could be influenced by other factors e.g. news about the economy.

2.5. The choice of variables for the impulse reaction function

In determining the relationship that exists between monetary policy and stock returns, there arises the questions of what variables to use in the econometric methodology as noted by (Reinhart, 1998). There has been consensus in using equity returns as a relative measure over the level prices and for these studies, the daily NSE-20 returns are used as proxies of stock prices. Nevertheless, there has been use of different variables in some studies

(Caporale & Soliman, 2013) use actual stock prices in an impulse response analysis for the UK, US and Germany. The demand for real money balances is expressed as a function of the interest rates, real income and real stock price indices all expressed in natural logarithm except the interest rates. Real stock prices are constructed using the Consumer Price Index. More so, the analysis distinguishes carefully between short-term and long-term interest rates. The finding is that a decrease in the short term interest rate (a monetary contraction) leads to a decline in asset prices and in the demand for money in all countries under study. With the long-term rate, differences are observed in the response across countries.

A study by (Tatom, 2009) uses the PE ratio for the S&P 500 index. The PE ratio is based on an average of quarterly data, which are the end-of-quarter stock price relative to the past four quarters' earnings. As the earnings are largely predetermined, the movements in the yield reflect the change in stock prices. The study also proposes use of the earnings yield, the inverse of the PE-ratio, as an alternative which is more readily comparable to other yields. The rationale of these variables is that it is movements in stock prices relative to earnings that are of interest in assessing price movements that are of concern to investors or to policy-makers. In relating this approach to that which uses stock returns, (Tatom, 2009) points out a strong negative correlation of -0.74 between annual changes in the S&P stock price index (logarithm of average of daily figures) and annual changes in the earnings yield (-0.74). The study establishes a strong negative correlation between the federal funds rate and the PE ratio which he attributes the significant correlation of each to inflation.

For this study, short term rates will be used to proxy monetary policy as they reflect a near term expectation of monetary policy. The study employs the interbank rate in place of the more popular CBR. While the latter may remain static for a long while, the interbank rate adjusts daily and is a short-term rate which the CBK could easily influence, (Gichuki, Oduor, & Kosimbei, 2012). It is worth noting that the Central Bank of Kenya has over the years used 2 instruments, interest rates and reserve money, to stabilize both inflation and output. In a study of the suitability of the instruments (Gichuki, Oduor, & Kosimbei, 2012) established that the use of interest rates would be a better instrument policy strategy if the bank desired one isolated policy instrument. This is because, while using an error correction model (ECM), interest rates resulted in minimum losses in output compared to the reserve money. This further justifies the choice of policy instrument for this study.

2.5.1. The use of inflation in place of policy instruments

Questions have also arisen as to whether asset prices be included directly in the measure of inflation in place of relating them to monetary policy instruments. This is because at the core of this debate is the relationship of stock prices to inflation which is of concern to the central bank. (Alchian & Klein, 1973) were the first to advance a case for this on the premise that the goal of central bank policy is to maintain the stability of the purchasing power of money. According to them, a stable purchasing power refers not only to the price of what is currently consumed, but also to future goods and services. As many asset prices actually refer specifically to the latter, they should be included together with the consumer price index as the central bank's target. This notwithstanding, a study by (Furlanetto, 2008) on monetary policy and asset prices using US found out that large stock market swings had no significant impact on CPI inflation.

An alternative method to this pioneer approach has been the calculation of inflation based on a statistical criterion designed to discover the core rate of inflation in the economy based on the idea that inflation affects all nominal prices including stocks and housing. For example, by using this approach, (Cecchetti, Genberg, Lipsky, & Wadhwani, 2000) calculate the core inflation of 12 countries using data from (Goodhart & Hofmann, 2000). There is much consensus however that inclusion of equity prices is likely to create more problems. Specifically, equity prices contain too much noise (with their variance hundreds of times that of conventional inflation measure) to be useful in inflation measurement, (Cecchetti, Genberg, Lipsky, & Wadhwani, 2000)

This research alludes to the proposition that the place of inflation in the study of the relationship between stock prices and monetary policy instruments is captured in the use of short term interest. This follows the early postulates of (French, 1975), (Schwert & Fama, 1977) and (Jaffe & Mandelker, 1976). Being the case, the change in expected inflation is simply measured as the change in the short-term interest rate.

2.6. Models used in measuring the contemporaneous reaction

Firstly, we have had methodological approaches that aim at integrating asset pricing with models from monetary economics e.g. CIR. For example, in a study by (Bakshi & Chen, 1996) that aimed at determining the price level, inflation, asset prices, and the real and nominal interest rates endogenously simultaneously, they related them in the spirit of (Cox, Ingersoll, & Ross, 1985a). Many other such models have been used to parsimoniously relate asset prices and interest rates to underlying economic variables. They include the term structure models of (Constantinides, 1992), the consumption-based CAPM of (Breeden D., 1979), (Sun, 1992) and (Longstaff & Schwartz, 1992). More so, we have had models that have addressed asset pricing issues and allowed a role for money while endogenizing the price level and inflation together with stock prices e.g. (Foresi, 1990) and (Danthine & Donaldson, 1986)

(Pesaran & Smith, 1998) advocated for *generalized impulse response* analysis for unrestricted vector autoregressive (VAR) and cointegrated VAR (CVAR) models as it does not require shocks to be orthogonalised and is invariant to the ordering adopted. However, Wickens and Motto (2001), pointed that though a feasible approach, it is not possible to give an economic interpretation to the response of the error correction terms to shocks to the disturbances of the CVAR. They suggested an alternative which incorporates estimating a VAR model in first differences for the exogenous variables of the CVAR, and adopting a VECM specification, which incorporates long-run restrictions derived from economic theory, for the endogenous variables. This approach, which assumes that it is possible to distinguish between endogenous and exogenous variables, was used by (Caporale & Soliman, 2013) to study the relationship between stock price movements, demand for money and monetary policy in the UK, the US and Germany, (Caporale & Soliman, 2013).

As in the Structural VAR approach, an alternative has been to impose a priori restrictions on the covariance matrix of the structural errors and the contemporaneous and/or long-run impulse response functions themselves. However, this method assumes that the errors are uncorrelated, which is not plausible in many cases, and requires a high number of restrictions. (Garratt, Lee, Pesaran, & Shin, 2003) attempted to tackle the identification problem by restricting the cointegrating space and then using a constrained maximum likelihood estimator instead of the standard Johansen estimator. However, the problem of identifying the shocks is unsolved.

Co-integrated VAR models have been employed in recent studies such as (Caruso, 2006), (Masih & De Mello, 2009) to examine the long-run relationship between stock price movements and demand for money. This methodology has been objected, for example by (Caporale & Soliman, 2013) on the issue of misspecification because of omission of important variables. Also, there is the issue of identification of the structural parameters with the standard approach being imposition of restriction on the interest rates, prices and real income and then assume there is simultaneous feedback only from the interest rate, prices and real per capita income (or wealth) to money demand (and not vice versa). The impulse response functions are then computed by employing the Choleski decomposition that orthogonolises the disturbances. (Pesaran & Smith, 1998) had pointed out two problems of this approach. First, the use of orthogonalised errors, and not the structural or even reduced form errors. Secondly, as the procedure involves a particular ordering of variables, estimates of the impulse responses depend on the ordering adopted.

2.6.1. The VAR approach using the Rigobon and Sack Procedure[1]

An improvement to the traditional VAR literature as regards the objective of this research was a study by (Rigobon & Sack, 2003) that measures the reaction of monetary policy to stock prices using a Vector Autoregression (VAR) model taking into account the endogeneity issue by using an appropriate identification technique based on heteroskedasticity present in the daily data of stock market returns. The rationale is that since shifts in the variance of stock market shocks relative to monetary policy shocks affect the covariance between interest rates and stock prices in a manner that depends on the responsiveness of the interest rate to equity prices, the response of the short-term rate can be computed based on the observed shifts in that covariance matrix.

Results by (Rigobon & Sack, 2003) exhibit a positive and significant reaction of monetary policy to the stock market in the US over the period 1985-1999. Using the same model, (Bohl, Siklos, & Werner, 2007) find a reaction that is not significant for Germany in the period 1985-1999. (Furlanetto, 2008) measures the reaction of monetary policy to the stock market in the US, UK, Japan and the EU using the RS procedure. Whilst taking into account that interest rates and stock returns are endogenous, they find no reaction in the Japan and the EU but a positive and significant reaction in the US and the UK.

This is the choice model for this study as its rationale ensures that the issue of endogeneity, which is at the core of the research, is properly considered without making overly-critical assumptions. For instance, the study by (Rigobon & Sack, 2003) strongly challenges the policy rule proposed by (Bernanke & Gertler, 2000) within a VAR framework arguing that it is hard to conceive any instrument which

[1] (Rigobon & Sack, 2003)

is highly correlated with changes in stock prices without affecting changes in the interest rate.

2.7. Limitations of the study

Empirical findings of a response to asset prices by monetary policy does not imply that a country's central bank is, or should be, targeting stock prices or reacting to misalignment in stock prices and there's much academic debate on the effectiveness of such a policy approach. (Misati & Nyamongo, 2012) note that, even in cases where it is clear that financial stability should be central bank's objective, it is not yet obvious how to attain the objective given that most central banks have at their disposal a single tool, usually used in the pursuit of price stability and the scenario is complicated when the source of instability is from the asset prices.

3. METHODOLOGY

3.0. Data type and sources

The daily returns and daily volatility of the NSE-20 are used as indicators of asset prices. This study employs high frequency data (daily) to allow for more accurate definition of heteroskedasticity of the shocks as prescribed by (Rigobon & Sack, 2003). Data on the stock market index will be obtained from the Nairobi Securites Exchange (NSE).

The short-term interest rates in Kenya are namely the Repo rate, the CBR, the interbank rate, the CBK overdraft rate and the 91-day treasury bills. The study will use the interbank rate rather than the CBR which is most popular. While the CBR may remain static for a long while, the interbank rate adjusts daily and may reflect expectations of future variations in CBR. Hence, it is a good reflection of near term expectations of future monetary policy. Data on the short-term interest rates will be obtained from the Central Bank of Kenya.

The study will uses quarterly data on Kenya covering the period 1996q1-2014q2.

3.1. The model set up

The model is based on the Rigobon and Sack (2003) (RS) Procedure. In relating the interest rates and stock prices, the structure of the simplest VAR is the following:

$$A\begin{bmatrix} i_t \\ s_s \end{bmatrix} = C(L)\begin{bmatrix} i_{t-1} \\ s_{t-1} \end{bmatrix} + B\begin{bmatrix} \varepsilon_t \\ \eta_t \end{bmatrix}$$

Where i_t is the interbank rate, s_t are NSE-20 returns, A is a 2x2 matrix that describes contemporaneous relations among the variables, $C\ (L)$ is a finite order lag polynomial, ε_t and η_t are structural disturbances. B is a $2x2$ matrix in which non-zero off-diagonal elements allow some shocks to affect both endogenous variables.

The usual assumptions to achieve identification in this kind of model are to impose a triangular form to matrix A (Cholesky decomposition) and a diagonal structure to matrix B. In this way the model is exactly identified. But a triangular matrix A implies that one of the two variables does not react contemporaneously to the other, an assumption that is inappropriate in this case, though reasonable in other contexts. In our application, each shock to one of the variables has an immediate effect on the other in the financial markets.

RS do not impose a triangular structure on matrix A and build an identification procedure relying on the heteroskedasticity that is present in the data and that usually is not considered in VAR studies. The thirty-day rolling volatility of daily changes in the NSE-20 stock market index and daily changes in the interest rate will be observed to check for rich patterns that may highlight the importance of modelling heteroskedasticity. It is expected that shifts in volatility affect the correlation between interest rates and NSE-20 returns. The RS procedure exploits these shifts in covariance to identify the model without imposing inappropriate exclusion restrictions (as in the traditional approach).The use of daily data thus becomes crucial in exploiting fully the heteroskedasticity present in the data. In fact, heteroskedasticity diminishes a lot in lower frequency data.

Realizations of interest rates and stock returns can be seen as the intersection between two schedules. The first is the reaction function of asset prices to changes in the interest rate (supposed to be downward sloping because an increase in the interest rate lowers the discounted value of future dividends, i.e. the value of the asset). The second is the reaction of the interest rate to the evolution of the stock market. The objective of the procedure is to estimate the slope of this second schedule which is the interest of the study.

Because of heteroskedasticity, endogeneity and unobservability of a common shock z_t, introduced below, OLS estimates are biased. Thus, we find a variable (an instrument) that shifts the stock market curve without affecting the monetary policy response. As an increase in the variance of the stock market shock changes the covariance between NSE-20 returns and the interest rate, this change plays the role of an instrument.

RS estimate the following VAR:

$$i_t = \beta s_t + \theta x_t + \gamma z_t + \varepsilon_t$$

$$s_t = \alpha i_t + \phi x_t + z_t + \eta_t$$

Where i_t is the Interbank rate s_t is the daily return on the NSE 20 share index, x_t includes lags of the two endogenous variables (say 5 lags) and some macroeconomic shocks (measured as monthly releases of some macro indicators and subtracting the value expected by market participants, as in RS (2003)), and z_t represents some unobserved shocks affecting both it and s_t. The common shock takes into account any macroeconomic shock not included in x_t or shifts in risk preferences of the agents[2]. ε_t is a monetary policy shock and η_t is a stock market shock.

Whilst the structure of the model is quite rich, the objective is very simple: To estimate the coefficient β that measures the response of the interest rate to the stock market return.

The assumption on the correlation structure of the shocks is the following: the shocks ε_t and η_t and the unobserved shock z_t are supposed to be orthogonal and at this stage, all three can be heteroskedastic. The orthogonality of ε_t and η_t does not imply that disturbances are uncorrelated: In fact, the presence of z_t induces correlation.

The structural form of the VAR can be re-written in the following way:

$$\begin{bmatrix} 1 & -\beta \\ -\alpha & 1 \end{bmatrix} \begin{bmatrix} i_t \\ s_t \end{bmatrix} = \begin{bmatrix} \theta \\ \phi \end{bmatrix} x_t + \begin{bmatrix} \gamma z_t + \varepsilon_t \\ z_t + \eta_t \end{bmatrix}$$

This system cannot be estimated directly, because of the endogeneity problem discussed above and because z_t is an unobservable variable, but we can write it in reduced form:

---

[2] The impact of z_t on s_t is normalized to one

$$\begin{bmatrix} i_t \\ s_t \end{bmatrix} = \begin{bmatrix} \frac{1}{1-\alpha\beta} & \frac{\beta}{1-\alpha\beta} \\ \frac{\alpha}{1-\alpha\beta} & \frac{1}{1-\alpha\beta} \end{bmatrix} \begin{bmatrix} \theta \\ \phi \end{bmatrix} x_t + \begin{bmatrix} \frac{1}{1-\alpha\beta} & \frac{\beta}{1-\alpha\beta} \\ \frac{\alpha}{1-\alpha\beta} & \frac{1}{1-\alpha\beta} \end{bmatrix} \begin{bmatrix} \gamma z_t + \varepsilon_t \\ z_t + \eta_t \end{bmatrix}$$

Or

$$\begin{bmatrix} i_t \\ s_t \end{bmatrix} = \Phi x_t + \begin{bmatrix} v_t^i \\ v_t^s \end{bmatrix} \qquad (1)$$

where:

$$\begin{aligned} v_t^i &= \frac{1}{1-\alpha\beta}\left(\left(\gamma+\beta\right) z_t + \beta\eta_t + \varepsilon_t\right) \\ v_t^s &= \frac{1}{1-\alpha\beta}\left(\left(1+\alpha\gamma\right) z_t + \eta_t + \alpha\varepsilon_t\right) \\ \Phi &= \begin{bmatrix} \frac{1}{1-\alpha\beta} & \frac{\beta}{1-\alpha\beta} \\ \frac{\alpha}{1-\alpha\beta} & \frac{1}{1-\alpha\beta} \end{bmatrix} \begin{bmatrix} \theta \\ \phi \end{bmatrix} \end{aligned}$$

Normally in the VAR literature, it is common practice to recover the estimates of structural form parameters from reduced form residuals. Given the structure of correlations specified above, the covariance matrix of reduced form residuals is the following:

$$\Omega = \begin{bmatrix} \Omega_{1,1} & \Omega_{1,2} \\ \Omega_{2,1} & \Omega_{2,2} \end{bmatrix} = \begin{bmatrix} var\left(i_t\right) & cov\left(i_t, s_t\right) \\ cov\left(i_t, s_t\right) & var\left(s_t\right) \end{bmatrix} =$$

$$= \frac{1}{\left(1-\alpha\beta\right)^2} \begin{bmatrix} \left(\beta+\gamma\right)^2 \sigma_z^2 + \beta^2\sigma_\eta^2 + \sigma_\varepsilon^2 & \left(1+\alpha\gamma\right)\left(\beta+\gamma\right)\sigma_z^2 + \beta\sigma_\eta^2 + \alpha\sigma_\varepsilon^2 \\ \left(1+\alpha\gamma\right)\left(\beta+\gamma\right)\sigma_z^2 + \beta\sigma_\eta^2 + \alpha\sigma_\varepsilon^2 & \left(1+\alpha\gamma\right)^2 \sigma_z^2 + \sigma_\eta^2 + \alpha^2\sigma_\varepsilon^2 \end{bmatrix}$$

By estimating the model in reduced form, we obtain a consistent estimate for the covariance matrix of reduced form residuals. Unfortunately, the covariance matrix provides only three moments Ω_{11}, Ω_{12}, Ω_{22}, which are not enough to achieve identification. While the maximum number of parameters that can be identified is three, in matrix Ω we have six unknowns: α, β, γ, σ^2_z, σ^2_η and σ^2_ε. Hence, we do not have enough restrictions to recover the structural form parameters.

Still, heteroskedasticity can help in our task if we can identify different regimes for the covariance matrix of the reduced form residuals. The additional regimes provide new restrictions and may enable us to identify the parameters of the structural form. Unfortunately, for each new regime indexed by the subscript *i*, we add three new equations but also three new unknowns: $\sigma^2_{i,z}$, $\sigma^2_{i,\eta}$ and $\sigma^2_{i,\varepsilon}$. Nevertheless, by assuming that the monetary policy shock ε is homoskedastic (thus is constant across regimes), we add three equations and only two unknowns for each regime.

With three regimes we have nine equations and ten unknowns (α, β, γ, σ^2_z, $\sigma^2_{1,z}$, $\sigma^2_{1,\eta}$, $\sigma^2_{2,z}$, $\sigma^2_{2,\eta}$, $\sigma^2_{3,z}$, $\sigma^2_{3,\eta}$). This is enough to achieve partial identification, and in particular we can estimate the parameter β.

The assumption that σ^2_z is constant is not very restrictive because it does not imply that it is homoskedastic. In fact, the variance of the interest rate is also composed of $\sigma^2_{i,z}$ and $\sigma^2_{i,\eta}$ which change through time. The other essential assumption to achieve identification is that the parameters α, β and γ are constant across regimes. This is common practice in the VAR literature, also when heteroskedasticity is not considered.

For each regime, we have the following covariance matrix:

$$\Omega_i = \frac{1}{(1-\alpha\beta)^2}\begin{bmatrix} (\beta+\gamma)^2\sigma^2_{i,z} + \beta^2\sigma^2_{i,\eta} + \sigma^2_\varepsilon & (1+\alpha\gamma)(\beta+\gamma)\sigma^2_{i,z} + \beta\sigma^2_{i,\eta} + \alpha\sigma^2_\varepsilon \\ (1+\alpha\gamma)(\beta+\gamma)\sigma^2_{i,z} + \beta\sigma^2_{i,\eta} + \alpha\sigma^2_\varepsilon & (1+\alpha\gamma)^2\sigma^2_{i,z} + \sigma^2_{i,\eta} + \alpha^2\sigma^2_\varepsilon \end{bmatrix}$$

With three regimes one solution of the following quadratic equation is a consistent estimator for β:

$$a\beta^2 - b\beta + c = 0$$

Where[3]:

[3] $\Delta\Omega31{,}22$ is the (2,2) element of matrix $\Delta\Omega31$. $\Delta\Omega31 = \Omega3 - \Omega1$

$$
\begin{aligned}
a &= \Delta\Omega_{31,22}\Delta\Omega_{21,12} - \Delta\Omega_{21,22}\Delta\Omega_{31,12} \\
b &= \Delta\Omega_{31,22}\Delta\Omega_{21,11} - \Delta\Omega_{21,22}\Delta\Omega_{31,11} \\
c &= \Delta\Omega_{31,12}\Delta\Omega_{21,11} - \Delta\Omega_{21,12}\Delta\Omega_{31,11}
\end{aligned}
$$

With four regimes, we have over identifying restrictions that allow us to estimate β by GMM.

A nice feature of this model is that many assumptions are testable. In fact, if the model is correctly specified, we should find the same results for β under any three regimes, since the parameter β is supposed to be constant in the sample period. If this doesn't hold, this could imply: (1) The parameters are unstable across regimes (2) The assumption of homoskedasticity for the monetary policy shock is not correct or (3) There are nonlinearities that are not captured in the Rigobon and Sack's formulation.

To determine the regimes, we estimate the VAR (1) in reduced form and take the residuals. The heteroskedasticity of the shocks allows us to identify four regimes: regime 1 where both shocks have low volatility, regime 2 where the interest rate shock has low volatility and the stock market shock has high volatility, regime 3 where both shocks have high volatility, regime 4 where the interest rate shock has high volatility and the stock market shock has low volatility.

The study by Furlanetto (2008) that used this approach confirmed that regimes with high stock market volatility are more useful for identifying the parameters.

The observations are split into the four regimes according to the following criterion: one observation is considered to have high variance if the thirty-day rolling variance of the residual is more than one standard deviation over the average of the series (lim=1 in our notation)[4]. RS admit that this approach is arbitrary, but at least two arguments can justify this choice:

[4] It can happen that, using this criterion, very few observations enter the high volatility regimes. In these cases, the window is lowered to 0.75 of a standard deviation or to one-half of a standard deviation (lim=0.75 or lim=0.5).

(1) Rigobon (2003) shows that the estimates are consistent even if the regimes are badly specified. The estimates are not consistent only if the misspecification is so large that the system fails the following order condition:

$$\Omega_{11,i}\Omega_{12,j} - \Omega_{11,j}\Omega_{12,i} \neq 0$$

For regimes *i* and *j* with $i \neq j$

This condition has an intuitive explanation. It fails when two covariance matrices are proportional, i.e. relative variances are constant across regimes. In this case, some moment conditions are not independent and heteroskedasticity cannot be helpful, Rigobon (2003)

(2) The same criterion is largely used in the literature to identify periods of excessive volatility in asset markets ((Bordo & Jeanne, 2002)as quoted in Furlanetto (2008)

The last step is to compute the distributions of the estimated coefficients. The distributions are calculated by bootstrap. Residuals are supposed to be normal with mean zero and variance for each regime. We will simulate 1000 draws for each Ω_i. For each covariance matrix, we estimate β using different subsets of regimes. In the end, we obtain 1000 estimates making it possible to compute the distributions

3.2. Criticism of the model

A possible criticism to the specification as explained in (Furlanetto, 2008) is that it is excessively simple, hence this simple bivariate VAR can miss important information coming from other macroeconomic variables affecting at the same time the interest rate and the stock market index.

Nevertheless, this procedure is defended on the basis of these arguments: (1)The presence of the unobservable common shock z_t takes into account to a large extent all the possible shocks driving interest rates and stock prices. Identification through heteroskedasticity heavily relies on the common shocks and, in fact, when the common shock is excluded by (Furlanetto, 2008), the results worsen significantly. (2) The inclusion of monthly macroeconomic shocks in a model with daily data is questionable. An alternative would be to include daily shocks such as daily variations in the trade weighted exchange rate. This study doesn't intend to do this.

4. DATA ANALYSIS AND RESULTS

4.0. VAR estimation of the contemporaneous relationship

One of our primary aims is to test for the coefficients of the contemporaneous relationship that exists between the interest rate i_t as a monetary policy instrument and the NSE-20 return s_t. Prior to this, we identify the lag lengths to use for the variables fort the VAR framework below:

$$A\begin{bmatrix} i_t \\ s_s \end{bmatrix} = C(L)\begin{bmatrix} i_{t-1} \\ s_{t-1} \end{bmatrix} + B\begin{bmatrix} \varepsilon_t \\ \eta_t \end{bmatrix}$$

Limiting the lags of each variable to 3, we re-write the VAR estimation equation:

$$i_t = \alpha_1 i_{t-1} + \alpha_2 i_{t-2} + \alpha_3 i_{t-3} + \beta_0 s_t + \beta_1 s_{t-1} + \beta_2 s_{t-2} + \beta_3 s_{t-3} + \varepsilon_t$$

$$s_t = \beta_1 s_{t-1} + \beta_2 s_{t-2} + \beta_3 s_{t-3} + \alpha_0 i_t + \alpha_1 i_{t-1} + \alpha_2 i_{t-2} + \alpha_3 i_{t-3} + n_t$$

:

Table 1: VAR lag order selection criteria

Endogenous variables			NSE-20 return, Interest rate			
Lag	*LogL*	*LR*	*FPE*	*AIC*	*SC*	*HQ*
1	3708.80	NA	1.11e-09	-14.94	-14.91	-14.93
2	3837.00	254.34	6.76e-10	-15.44	15.37*	-15.41
3	3845.19	16.18*	6.64e-10*	15.46*	-15.35	15.42*

These are results of the lag order selection. *indicates the lag order selected by the criterion

The subsequent step involves testing for significance of the coefficients of the VAR system that includes different combinations of lag orders 1 and 2 as obtained in the results above. The resultant VAR equations are:

$$i_t = \beta_0 s_t + \beta_1 s_{t-1} + \beta_2 s_{t-2} + \varepsilon_t$$

$$s_t = \alpha_0 i_t + \alpha_1 i_{t-1} + \alpha_2 i_{t-2} + n_t$$

The equations above yield the following coefficients for the two equations:

Table 2: The response of interest rates to stock returns

Variable	Coefficient	Std. Error	t-Statistic	Prob.
NSE20RT	1.96	0.85	2.32	0.02
NSE20RT(-1)	2.06	0.85	2.42	0.02

Dependent Variable: INTBRT

Table 3: The response of stock returns to interest rates

Variable	Coefficient	Std. Error	t-Statistic	Prob.
INTBRT	0.01	0.00	2.32	0.02
NSE20RT(-1)	0.29	0.04	6.66	0.00

Dependent Variable: NSE20RT

This can be expressed in equation form as:

$$i_t = 1.97s_t + 2.06s_{t-1} + \varepsilon_t$$

and

$$s_t = 0.06i_t + 0.29s_{t-1} + \mathrm{n}_t$$

The first equation which is the reaction of the interest rate to the evolution of the stock market and the interest rates shows that interest rates only respond to stock returns where both variables are considered simultaneously. This relationship is positive as capture by the coefficients 1.97 and 2.06 which means that interest rates increase as stock prices increase. This could imply that the Central bank responds to increase in stock prices by increasing interest rates.

On the other hand, the second equation shows that daily stock prices (captured by stock returns) respond positively to an increase in current interest rates and the previous day's stock returns. This reaction to interest rates, though minimal (0.06), is "unorthodox" as it is expected that an increase in interest rates lowers the discounted value of future dividends resulting in lower asset prices. The positive and higher (0.29) response to previous day prices could be attributed to investors' confidence which is bolstered by historical returns resulting in higher demand for well-performing stocks.

Considering the existence of the contemporaneous relationship between the interest rates and stock reruns, the realization of both variables can be seen as the intersection between the two reaction functions. The results of the two equations seem to affirm each other since the interest rate is a positive function of the NSE-20 stock returns (and a lag) which is a positive function of the interest rate and the 1-period lag of the returns.

An alternative explanation of the foregoing paragraph can be offered considering that the econometric tests show the interest rate i_t not be affected by lagged (historical) rates within the VAR framework that also includes stock returns and their lags. The rational is that current stock prices are affected largely to historical interest rates and hence the returns are sufficient in capturing the evolution of interest rates and/or monetary policy.

Our VAR model set-up does not involve a constant. Where a constant is included, even the simple direct causality relationship between the interest rate and NSE-20 return has insignificant coefficients.

Table 4: VAR estimation including a constant

Variable	Coefficient	Std. Error	t-Statistic	Prob.
NSE20RT	0.42	0.34	1.25	0.21
C	0.10	0.00	49.31	0.00

The implication of the foregoing is that in conducting an endonegeity test of the variables $i_t$and s_t, we cannot include a constant as an exogenous variable.

4.1. Test for VAR stability

We then test for the stability of our VAR system considering our lag specification:

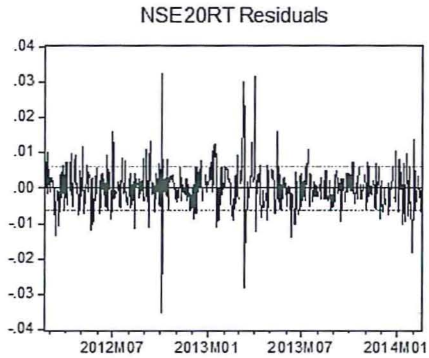
Table 5: Test for VAR stability

Roots of characteristic polynomial	
Endogenous variables: INTBRT NSE20RT Exogenous variables: C	
Root	**Modulus**
0.9747	0.9747
0.4550	0.4550
0.4117	0.4117
-0.1658	0.1658
No root lies outside the unit circle. VAR satisfies the stability condition.	

4.2. Residuals analysis

The next step is an analysis of our residuals where we study the nature of our residuals and subsequently consider the residuals correlation and covariance matrices.

Table 6: Residual graphs



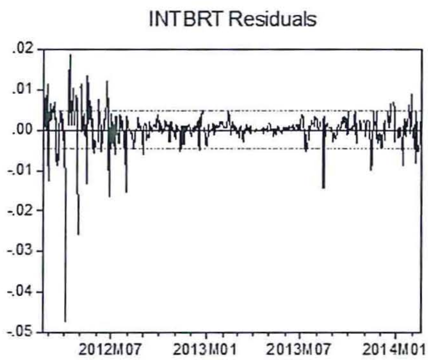


Table 7: The residual correlation matrix

	NSE20RT	INTBRT
NSE20RT	1.0000	0.0531
INTBRT	0.0531	1.0000

Table 8: The covariance matrix

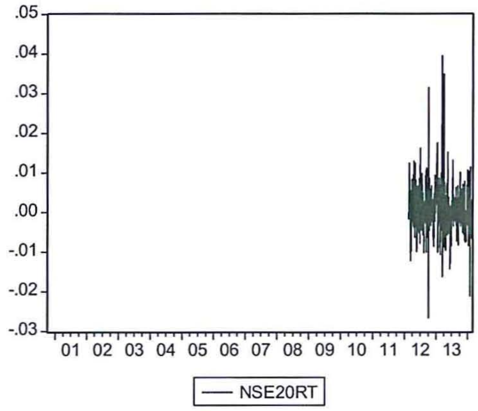
	NSE20RT	INTBRT
NSE20RT	3.58E-05	1.48E-06
INTBRT	1.48E-06	2.17E-05

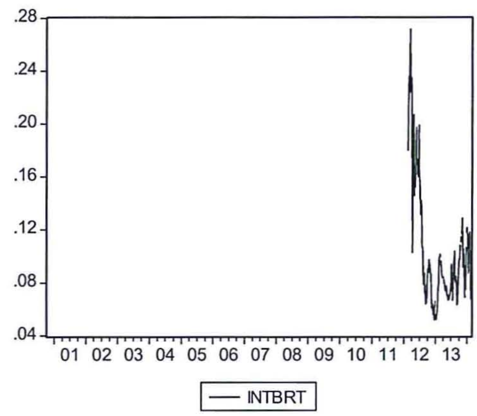
Hence:

$$\Omega = \begin{bmatrix} \Omega_{11} & \Omega_{12} \\ \Omega_{21} & \Omega_{22} \end{bmatrix} = \begin{bmatrix} var(i_t) & cov(i_{t,}s_t) \\ cov(i_{t,}s_t) & var(i_t) \end{bmatrix} = \begin{bmatrix} 3.58E-05 & 1.48E-06 \\ 1.48E-05 & 2.17E-05 \end{bmatrix}$$

Below are the endogeneity graphs:

Table 9: Endogeneity graphs





4.2.1. Residuals normality tests

The next step our econometric tests is to conduct VAR residual normality tests on our residuals. We could use orthogonalisation or carry out VAR heteroskedasticity test of residuals assuming cross-terms i.e. products of the residuals. Below are the results of the orthogonalisation test:

Table 10: VAR Normality test using orthogonolisation

Orthogonalization: Cholesky (Lutkepohl)			
Residuals joint test			
	Chi-square	Degrees of freedom	Prob.
Skewness	1019.12	2	0.0000
Kurtosis	18581.55	2	0.0000
Jarque-bera statistic	19600.67	4	0.0000

The null H0 is for normality hence we reject the null

The Jarque-Bera statistic is far much above the 5% critical value of 5.99 for a χ^2 distribution with 2 degrees of freedom. We thus reject the null hypothesis that the residuals are normally distributed. Alternatively, we make the same decision by inspecting the *p*-value, 0.0000, which is less than our chosen level of significance. Thus the residuals are heteroskedastic

The results above are affirmed by the results of the VAR heteroskedasticity test as evident below:

Table 11: VAR Heteroskdasticity test (with cress terms)

	VAR Heteroskdasticity test (with cress terms)		
	Chi-square	**Prob.**	**Df**
Joint	378.89	0.0000	42
res1*res1	149.38	0.0000	
res2*res2	191.32	0.0000	
res2*res1	54.19	0.0000	

Again, we reject the null of homoskedasticity

5. CONCLUSION

This paper has effectively determined the reaction of the short-term interest rate to the stock market, even when the stock market is endogenously reacting to the interest rate at the same time. The results in the previous section show a positive policy response with estimated coefficients β_0= 1.97 and β_1=2.06 that measure responsiveness to s_t and s_{t-1}respectively. The point estimate for the response coefficient $\beta_0$indicates that a 1% rise in the NSE-20 share index tends to increase the interest rate by 1.97%. Considering the effect I symmetrical, a 1% drop in the NSE-20 index reduces the interest rate by 1.97%.

Translating this response estimate into the probability of policy action, this means that an increase in stock prices may necessitate tightening measures by the CBK. Put differently, the CBK should increase interest rates when stock prices increase and reduce interest rates when stock prices reduce. Considering the coefficient of 1.97% is greater than 1, the response by the CBK could be more than proportionate to the changes in the stock market.

Whilst this empirical exercise is concerned majorly with measuring the policy reaction to the stock market, it doesn't help us determining whether such a reaction is optimal. There is also the need to consider whether the central bank's reaction to stock price movements depends on the frequency of the data since a rise in stock prices over the course of a day would prompt a different policy response than a same-sized rise that is sustained over a longer period

The results presented should be regarded as an initial step in addressing a very difficult question. One issue is that the CBK might want to react differently to equity price movements that are driven by different types of shocks. Our analysis attempts to measure the policy response to an exogenous movement in equity prices—one driven by a change in investors' willingness to bear risk. Hence, the results obtained are not justification to recommend the CBK to react positively to stock market movements using interest rates. Nevertheless, obtaining the magnitude of the response of short-term interest rates to a typical movement in stock prices is an important step in understanding the contemporaneous interactions between interest rates and equity prices. A useful topic for future research may be to measure the policy response to price movements on the NSE that are more effectively conditioned on the type of underlying shock.

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Appendices

Appendix 1: VAR lag order selection criteria

VAR Lag Order Selection Criteria
Endogenous variables: NSE20RT INTBRT
Exogenous variables:
Date: 01/15/15 Time: 19:19
Sample: 10/12/2000 2/19/2014
Included observations: 496

Lag	LogL	LR	FPE	AIC	SC	HQ
1	3708.796	NA	1.11e-09	-14.93869	-14.90477	-14.92538
2	3837.000	254.3396	6.76e-10	-15.43952	-15.37167*	-15.41288
3	3845.188	16.17847*	6.64e-10*	-15.45640*	-15.35463	-15.41645*

* indicates lag order selected by the criterion
LR: sequential modified LR test statistic (each test at 5% level)
FPE: Final prediction error
AIC: Akaike information criterion
SC: Schwarz information criterion
HQ: Hannan-Quinn information criterion

Appendix 2: The response of interest rates to stock returns

Dependent Variable: INTBRT
Method: Least Squares
Date: 01/15/15 Time: 15:52
Sample (adjusted): 2/20/2012 2/19/2014
Included observations: 498 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
NSE20RT	1.966912	0.849582	2.315153	0.0210
NSE20RT(-1)	2.058417	0.849364	2.423481	0.0157

R-squared	-4.807712	Mean dependent var	0.105320
Adjusted R-squared	-4.819421	S.D. dependent var	0.047167
S.E. of regression	0.113784	Akaike info criterion	-1.505019
Sum squared resid	6.421628	Schwarz criterion	-1.488109
Log likelihood	376.7498	Durbin-Watson stat	0.023009

Appendix 3: The response of stock returns to interest rates

Dependent Variable: NSE20RT
Method: Least Squares
Date: 01/15/15 Time: 15:54
Sample (adjusted): 2/20/2012 2/19/2014
Included observations: 498 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
INTBRT	0.005435	0.002348	2.315153	0.0210
NSE20RT(-1)	0.286663	0.043029	6.662109	0.0000

R-squared	0.085079	Mean dependent var	0.000815
Adjusted R-squared	0.083235	S.D. dependent var	0.006247
S.E. of regression	0.005981	Akaike info criterion	-7.396322
Sum squared resid	0.017745	Schwarz criterion	-7.379412
Log likelihood	1843.684	Durbin-Watson stat	2.038684

Appendix 4: VAR estimation including a constant

Dependent Variable: INTBRT
Method: Least Squares
Date: 01/15/15 Time: 19:00
Sample: 10/12/2000 2/19/2014
Included observations: 499

Variable	Coefficient	Std. Error	t-Statistic	Prob.
NSE20RT	0.422343	0.338237	1.248659	0.2124
C	0.104906	0.002127	49.31064	0.0000

R-squared	0.003127	Mean dependent var	0.105253
Adjusted R-squared	0.001122	S.D. dependent var	0.047144
S.E. of regression	0.047117	Akaike info criterion	-3.268353
Sum squared resid	1.103360	Schwarz criterion	-3.251468
Log likelihood	817.4540	F-statistic	1.559150
Durbin-Watson stat	0.029222	Prob(F-statistic)	0.212378

Appendix 5: VAR estimation output

Vector Autoregression Estimates
Date: 01/15/15 Time: 18:53
Sample (adjusted): 2/21/2012 2/19/2014
Included observations: 497 after adjustments
Standard errors in ( ) & t-statistics in [ ]

	INTBRT	NSE20RT
INTBRT(-1)	1.409187	0.017788
	(0.02823)	(0.03644)
	[49.9194]	[0.48814]
INTBRT(-2)	-0.423629	-0.013741
	(0.02822)	(0.03643)
	[-15.0117]	[-0.37722]
NSE20RT(-1)	0.010487	0.266545
	(0.03483)	(0.04496)
	[0.30106]	[5.92799]
NSE20RT(-2)	0.020727	0.072192
	(0.03484)	(0.04498)
	[0.59484]	[1.60500]
C	0.001274	0.000115
	(0.00051)	(0.00066)
	[2.49342]	[0.17390]
R-squared	0.990377	0.090176
Adj. R-squared	0.990299	0.082779
Sum sq. resids	0.010586	0.017640
S.E. equation	0.004639	0.005988
F-statistic	12659.29	12.19098
Log likelihood	1967.846	1840.959
Akaike AIC	-7.898778	-7.388167
Schwarz SC	-7.856438	-7.345827
Mean dependent	0.105170	0.000820
S.D. dependent	0.047096	0.006252
Determinant resid covariance (dof adj.)		7.69E-10
Determinant resid covariance		7.54E-10
Log likelihood		3809.492
Akaike information criterion		-15.28971
Schwarz criterion		-15.20503

Appendix 6: Test for VAR stability

Roots of Characteristic Polynomial
Endogenous variables: INTBRT NSE20RT
Exogenous variables: C
Lag specification: 1 2
Date: 01/15/15 Time: 19:02

Root	Modulus
0.974784	0.974784
0.455096	0.455096
0.411730	0.411730
-0.165878	0.165878

No root lies outside the unit circle.
VAR satisfies the stability condition.

Appendix 7: VAR Normality test using orthogonolisation

VAR Residual Normality Tests
Orthogonalization: Cholesky (Lutkepohl)
H0: residuals are multivariate normal
Date: 01/15/15 Time: 19:23
Sample: 10/12/2000 2/19/2014
Included observations: 497

Component	Skewness	Chi-sq	Df	Prob.
1	0.393736	12.84152	1	0.0003
2	-3.485438	1006.283	1	0.0000
Joint		1019.124	2	0.0000

Component	Kurtosis	Chi-sq	df	Prob.
1	10.28675	1099.544	1	0.0000
2	32.05515	17482.01	1	0.0000
Joint		18581.55	2	0.0000

Component	Jarque-Bera	Df	Prob.
1	1112.385	2	0.0000
2	18488.29	2	0.0000
Joint	19600.67	4	0.0000

Appendix 8: VAR residual heteroskedasticity tests with cross terms

VAR Residual Heteroskedasticity Tests: Includes Cross Terms
Date: 01/15/15 Time: 19:24
Sample: 10/12/2000 2/19/2014
Included observations: 497

Joint test:

Chi-sq	Df	Prob.
378.8869	42	0.0000

Individual components:

Dependent	R-squared	F(14,482)	Prob.	Chi-sq(14)	Prob.
res1*res1	0.300563	14.79470	0.0000	149.3798	0.0000
res2*res2	0.384955	21.54873	0.0000	191.3225	0.0000
res2*res1	0.109027	4.212984	0.0000	54.18656	0.0000