An Empirical Study on the Fisher Effect and the Dynamic Relation between Nominal Interest Rate and Inflation in South Africa in South Africa

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Abstract

Interest rate and inflation are two major central issues in the study of financial markets. Given the fact that maintaining price stability is one of the primary objectives of monetary policy in any economy, this necessitates the need to investigate the existence of Fisher effect and Price Puzzle in order to understand the nature, extent and dynamics of effective monetary policies in South Africa. Against this backdrop, this paper employs the ARDL bounds test approach, the OLS- Wald coefficient test and Granger causality test to analyze the existence of Fisher effect and the Price Puzzle in South Africa for the period 2001Q1 to 2014Q4. Empirical findings suggest that the nominal interest rates and expected inflation move together in the long run but not on one-to-one basis. This indicates that full Fisher hypothesis does not hold in South Africa. Furthermore, the study does not identify the existence of the Price Puzzle in the long run as the relationship between nominal interest rates and inflation is negative. The South African Reserve Bank should therefore continue with the inflation targeting policy where interest rates are used as nominal anchor.

Keywords: ARDL test, Granger causality test, Fisher effect, Price Puzzle, South Africa.
1. Introduction

Interest rate and inflation are two major central issues in the study of financial markets. The Fisher hypothesis postulates that there is a one-to-one relationship between nominal interest rate and expected inflation, assuming that the real interest rate is constant over the long-run. Fisher (1930) asserts that a permanent change in the rate of inflation will cause an equal change in the nominal interest rate so that the real interest rate is not affected by monetary shocks in the long run. This implies that the monetary policy measures cannot influence the real interest rate. The real interest rate is therefore basically determined by real factors of the economy (Jayahinghe and Udayaseelan, 2008; Edirisinghe et al, 2015).

Krugman and Obstfeld (2003) define the Fisher effect by saying that all thing being equal, a rise in a country’s expected inflation rate will eventually cause an equal rise in the interest rate that deposits of its currency offer: similarly, a fall in the expected inflation rate will eventually cause a fall in the interest rate (Awomuse and Alimi, 2012).

Fisher hypothesis has maintained a key position in economic literature as it is considered as one of the bases in monetary economics (Hewarathna, 2000; Fuei, 2007).

Conversely, Price Puzzle simply states the positive relationship between nominal interest rate and inflation. According to the conventional view of monetary policy transmission mechanism there should be a positive association between nominal interest rates and inflation. Generally, a tightening of monetary policy is expected to increase nominal interest rates and reduce the output and prices, implying a negative relationship between nominal interest rate and inflation.

Given the fact that maintaining price stability is one of the primary objectives of monetary policy in any economy, as price instability will tend to reduce investments and productivity growth and; in turn reduce economic growth, this necessitates the need to investigate the existence of Fisher effect and Price Puzzle in order to understand the nature, extent and dynamics of effective monetary policies in South Africa.

Against this backdrop, this study employs the autoregressive distributed lag bounds test approach, the OLS-Wald coefficient test and Granger causality test to analyze the existence of Fisher effect and the Price Puzzle in South Africa. Furthermore, it investigates the long run dynamic relationship between nominal interest rates and inflation and examines the causal relationship between nominal interest rates, inflation and expected inflation.

The paper is structured as follows: Section 2 presents a brief outline of literature review on Fisher’s hypothesis and the Price Puzzle. Section 3 illustrates the theoretical framework and specifies the model. Data issues are presented in section 5. Section 4 presents econometric models employed in the study. Empirical findings of this study are presented in Section 6. Finally, Section 7 consist the concluding remarks and policy recommendations.
2. Literature Review

2.1 Theoretical literature

2.1.1 The Fisher effect

The famous Fisher hypothesis seems to be the starting point; in the attempt to understand the link between interest rates and inflation. The hypothesis, proposed by Irvin Fisher (1930) states that in the long run, “nominal interest rates move one-for-one with expected inflation, leaving the real rate of interest unaffected” (Innes, 2006:1). That is, a 10% increase in the nominal rate of interest, for example, translates into a 10% increase in the rate of inflation – leaving the real rate of interest unchanged (Blanchard, 2009).

The Fisher hypothesis has maintained such a key position in economic literature. There are reasons for its prominence. Innes (2006) asserts that, firstly, the real rate of interest plays an important role in any country’s economic growth, savings and investments. It also affects trade and capital flows through its influence on the exchange rate. Secondly, empirical studies have shown that nominal interest rates can be used to determine future inflation expectations. Thirdly, the Fisher hypothesis is widely considered by central banks.

Payne and Ewing (1997) advances that should a “long-run Fisherian link be established between interest rates and expected inflation, this would suggest that the real interest rate is not affected by monetary policy, but instead determined by real economic factors alone”.

The standard macro models explain the relationship between interest rates and inflation through aggregate demand and supply frameworks. The demand side of the economy is determined by equilibrium conditions in the money and goods markets. According to Gul and Ekinci (2006), a rise in the rate of interest increases the opportunity cost of holding cash balances. This reduces the demand for money. The reduction in money demand creates excess supply of credit and stimulates aggregate demand. Consequently, prices must rise (inflation) so that individuals can be satisfied to hold the existing stock of money rather than spending it on commodities or interest-bearing assets.

Equally, a change in the interest rate is likely to affect equilibrium in the goods market and hence, prices. For example, a rise in interest rate reduces the borrowers’ disposable income (but increases disposable income for lenders). If marginal propensity to consume for borrowers is higher relative to that for lenders, this will lead to drop in consumption demand. Moreover, a change in the rate of interest rate affects the desire to consume out of income; for both borrowers and lenders. Higher interest rate makes consumption cheaper tomorrow than today. Rational economic agents will tend to defer consumption and save more (higher marginal propensity to save). Ultimately, consumption spending declines through this channel.

In terms of investment spending, a higher rate of interest reduces the net present value on the expected return on investment and increases the cost of credit which deters investment
spending. This channel further reduces aggregate demand and, in turn, prices. The interaction between interest rate and the demand side of the economy does not give a clear prediction of the effect of interest rate on the price level (Kandil, 2005).

On the supply side of the economy indicates that an increase in the rate of interest means higher production costs and, therefore, a rise in prices (inflation). However, Ball (1990) suggests that an increase in the interest rate has an ‘intertemporal substitution effect on labor supply’. That is, workers prefer to work more today to benefit from the high interest rate through savings. This increased labor supply increases output and, thus, depresses prices.

2.1.2 Prize Puzzle

Generally, a tight monetary policy is expected to reduce the price level, and not increase it. However, the response of prices to a monetary policy shock is sometimes contrary to economic theory. This is referred to as Price Puzzle.

As suggested by Sims (1992), when monetary policy shocks are identified with innovation in the interest rate, the responses of output and money supply are correct as a monetary tightening (an increase in interest rate) is associated with a fall in the money supply and output. However, the response of the price level is wrong if monetary tightening is associated with an increase in the price level rather than decrease.

Sims (1992) called for the use of non-borrowed and borrowed reserves in the VAR model along with a commodity price index. He suggested that price puzzle might be due the fact that interest rate innovations partially reflect inflationary pressures that lead to price increases. He further argued that inclusion of a commodity price index in the VAR appears to capture enough additional information about future inflation as to possibly solve the puzzle.

Sims, (1992), Grilli and Roubini, (1995) provided the evidence that this explanation of the price puzzle might also explain the exchange rate puzzle. Sims and Zha (1995) propose structural VAR approach with contemporaneous restrictions, which includes variables proxying for expected inflation.

Several other explanations for the price puzzle have been proposed in the literature. Hanson (2004), investigating different commodity price indices, shows that this approach does not solve the price puzzle in pre-1979 data: there is still a significant increase in prices up to 18 months after a contractionary monetary policy shock. For the post-1982 period, there is no significant increase in prices; however, point estimates of the price level response tend to stabilize at a level that is higher than before the contractionary monetary policy shock.

Barth and Ramey (2001) and Chowdhury et al. (2006) argue that the price puzzle is not really a puzzle, but reflects the increase in prices due to higher borrowing costs caused by the increase in the interest rate. Giordani (2004) suggests that the price puzzle is due to the VAR model not including a measure of potential output or the output gap. The price puzzle is hence a sign of model misspecification and is therefore distantly related to our explanation.
Castelnuovo et al. (2010) proposed that the positive response to a monetary policy shock is associated with a weak interest rate response to inflation. Krusec (2010) argue that imposing the long run restrictions in the cointegrated structural VAR framework can resolve the price puzzle. The advantage of long-run identification is that there is no need for additional variables besides prices, interest rate and output. Sims and Zha (2006) suggest that change in the systematic component of monetary policy have not allowed reduction in inflation or output variance without substantial costs. Inclusion of commodity prices resolves the price puzzle because they contain information that helps the Federal Reserve to forecast inflation (Hanson, 2004).

2.2 Empirical Literature

A significant numbers of empirical studies on the Fisher effect have been conducted for developed countries (Bajo-Rudio, Daiaz-Roldan and Esteve, 2005; Fuei, 2007; Ling, Liew and Wafa, 2008; Horn, 2008; and Toyoshima and Hamori, 2011). However, there are only few studies for developing countries (Hewarathna, 2000; Cooray, 2002; Ahmad, 2010; and Jayahinghe and Udayaseelan, 2008). There is therefore a need to conduct a study on the analysis of fisher effect in developing countries, particularly for South Africa.

(Castelnuovo and Surico, 2010; Ling, Liew and Wafa, 2008; Toyoshima and Hamori, 2011 and Fuei, 2007) have obtained presence of Fisher Effect and absence of Price Puzzle (Solomon and Ruiz, 2006; Uddin, Alam and Alam, 2008; Obi, Nurudeen and Wafure, 2009; Javid and Munir, 2011; Awomuse and Alimi, 2012; and Fatima and Sahibzada, 2012) have found the absence of Fisher Effect and presence of Price Puzzle. From literature reviewed, there seem to be no studies on the analysis of Fisher Effect and the dynamic relationship between inflation and interest rates in South Africa. Besides, the studies on the analysis of fisher effect were conducted for the period up to 2011 in South Africa. This study will also help to fill the gap from 2011 to 2014 in South Africa.

3. Theoretical Framework and Model Specification

3.1 Theoretical Framework

The famous Fisher hypothesis, proposed by Irvin Fisher (1930) states that in the long run, “nominal interest rates move one-for-one with expected inflation, leaving the real rate of interest unaffected” (Innes, 2006:1). That is, a 10% increase in the nominal rate of interest, for example, translates into a 10% increase in the rate of inflation – leaving the real rate of interest unchanged (Blanchard, 2009).

The Fisher equation is:

\[ i_t = r_t + \pi_t^e \]  \hspace{1cm} (1)
Where, \( i_t \) is the nominal interest rate, \( r_t \) is the ex-ante real interest rate and \( \pi_t^e \) is the expected inflation rate. Using the rational expectations model to estimate inflation expectations would mean that the difference between actual and inflation and expected inflation is captured by an error term \( (\epsilon_t) \).

\[
\pi_t - \pi_t^e = \epsilon_t \quad (2)
\]

This rational expectations model for inflation expectations can be incorporated into the Fisher equation as follows.

\[
i_t = r_t + \pi_t \quad (3)
\]

Rearranging equation 2:

\[
\pi_t = \pi_t^e + \epsilon_t \quad (4)
\]

Where, \( \epsilon_t \) is a white noise error term. If we assume that the real interest rate is also generated under a stationary process, where rate is the ex-ante real interest rate and \( v_t \) is the stationary component, we obtain:

\[
r_t = r_t^e + v_t \quad (5)
\]

Now by substituting equation (4) and (5) into equation (3):

\[
i_t = r_t^e + \pi_t^e + \mu_t \quad (6)
\]

3.2 Model Specification

The study follows Alimi and Ofonyelu (2013)’s model, which is a modified version of the traditional closed-economy Fisher hypothesis. The model incorporates the foreign interest rate and nominal effective exchange rate variable in the context of a small open developing economy.

The equation is thus modified as:

\[
i_t = \pi_t^e + fr_t + r_t^e + exch_t + \mu_t \quad (7)
\]

The model is therefore estimated as follows:

\[
INT_t = \delta EXPINFL_t + \varphi_1 USRATE_t + \varphi_2 r_t^e + \varphi_3 EXCH_t + \mu_t \quad (8)
\]

Where, \( \mu_t \) is the sum of the two stationary error terms (that is, \( \mu_t + v_t \)). \( EXPINFL_t \) is the expected rate of inflation, \( USRATE_t \) is the foreign interest rate, \( r_t^e \) is the long run real interest rate and \( EXCH_t \) is the nominal effective exchange rate. The full Fisher hypothesis is validated if a long-run unit proportional relationship exists between expected inflation \( (EXPINFL_t) \) and nominal interest rates \( (EXCH_t) \) and \( \varphi_1 =1 \). A strong Fisher effect occurs if \( \varphi_1 >1 \). However, if \( \varphi_1 <1 \), this would be consistent with a weak form Fisher hypothesis (Awomuse and Alimi, 2012).

4. Data Issues

This study uses quarterly data for the period 2001:1 to 2014:12.
4.1 Specification of Variables

Expected Inflation

The first challenge facing any empirical Fisherian study is to derive an inflation expectations proxy. Wooldridge (2003) suggested that the expected inflation this year should take the value of last year’s inflation. Therefore:

\[ \pi_t^e = \pi_{t-1} \]  

Foreign Interest rate

US dollar rate is used as a proxy of foreign interest.

Nominal interest rate

The data for nominal interest rates and US rates is available from www.tradingeconomics, which is the South African Reserve Bank (SARB) website.

Nominal Effective Exchange Rate

It is the nominal value of the South African rand relative to its twenty major trading currencies.

A priori assumption

According to monetary theory, there is a negative relationship between nominal interest rate and inflation (Castelnuovo and Surico, 2010). When the Central Bank adopts an expansionary monetary policy, it will reduce interest rates. Because, as an increase in money supply will result in an increase the demand for financial assets, and in turn, prices of the financial assets, resulting in a drop in interest rates. Finally, this will lead to increase in inflation (Edirisinghe, 2015). If, for some reasons, the relationship between nominal interest rate and inflation is positive; this is referred to as Prize Puzzle.

5. Econometric models

Different econometric tools were used to identify the existence of Fisher effect and Price puzzle, and different results were obtained. Amongst them are the Autoregressive Distributed Lag-bounds testing approach, Engle and Granger’s cointegration method, Johansen’s cointegration method, adoptive and rational expectation approaches, error correction model, impulse response functions and panel cointegration method. The present study will employ the Autoregressive Distributed Lag-bounds testing approach, the OLS-Wald test and Granger causality test.

5.1 Autoregressive Distributed Lag (ARDL) Bounds test Approach

The study uses the Autoregressive Distributed Lag (ARDL) cointegration bounds cointegration technique, developed by Pesaran and Shin (1999) and Pesaran et al. (2001), to determine the long run relationship between nominal interest rates and expected inflation in South Africa.

The ARDL cointegration approach has three advantages in comparison with other previous and traditional cointegration methods. Firstly, the ARDL does not need that all the variables
under study must be integrated of the same order and it can be applied when the under-lying variables are integrated of order one, order zero or fractionally integrated. Secondly, the ARDL test is relatively more efficient in the case of small and finite sample data sizes. Lastly, by applying the ARDL technique, we obtain unbiased estimates of the long-run model (Harris and Sollis, 2003).

The procedures to carry out the ARDL approach to cointegration technique include the determination of the long run relationships among the variables by using the Bounds F-Test; and the estimation of the coefficients of the long-run relationships by using the OLS method and error correction model.

5.2 Stationarity Test

The first step is testing each of the time-series to determine their order of integration, using stationarity test.

The theory behind autoregressive moving average (ARMA) estimation is based on stationary time series. A series is said to be stationary if the mean and auto-covariance of the series do not depend on time.

A common example of a non-stationary series is the random walk:

\[ y_t = y_{t-1} + \varepsilon_t \]  \hspace{1cm} (10)

where, \( \varepsilon_t \) is a stationary random disturbance term. The series \( y \) has a constant forecast value, conditional on \( t \), and the variance is increasing over time. The random walk is a difference stationary series since the first difference of \( y \) is stationary:

\[ y_t - y_{t-1} = (1 - L)y_t = \varepsilon_t \]  \hspace{1cm} (11)

A difference stationary series is said to be integrated and is denoted as \( I(d) \) where \( d \) is the order of integration. The order of integration is the number of unit roots contained in the series, or the number of differencing operations it takes to make the series stationary. For the random walk above, there is one unit root, so it is an \( I(1) \) series. Similarly, a stationary series is \( I(0) \).

Standard inference procedures do not apply to regressions which contain an integrated dependent variable or integrated regressors. Therefore, it is important to check whether a series is stationary or not before using it in a regression. The formal method to test the stationarity of a series is the unit root test.

There is a variety of tests used to test for the presence of unit root. Amongst them are the Augmented Dickey-Fuller (1979) and Phillips-Perron (1988), the GLS-detrended Dickey-Fuller (Elliot, Rothenberg, and Stock, 1996), Kwiatkowski,Phillips, Schmidt, and Shin (KPSS, 1992), Elliott, Rothenberg, and Stock Point Optimal (ERS, 1996), and Ng and Perron (NP, 2001) unit root tests. This study uses the Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) test.
A. The Augmented Dickey-Fuller (ADF) Test

The standard Dickey Fuller test is carried out by estimating the following equation:

$$\Delta Y_t = \alpha Y_{t-1} + X'_t \delta + e_t \quad \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots (12)$$

Where,

$$\alpha = p - 1$$

The null and alternative hypotheses may be written as,

$$H_0: \alpha = 0 \quad \text{(null hypothesis)} \quad \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots (13)$$

$$H_1: \alpha = 1 \quad \text{(alternative hypothesis)} \quad \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots (14)$$

The simple Dickey-Fuller unit root test described above is valid only if the series is an AR (1) process. If the series is correlated at higher order lags, the assumption of white noise disturbances \(e_t\) is violated. The Augmented Dickey-Fuller (ADF) test therefore constructs a parametric correction for higher-order correlation by assuming that the \(y\) series follows an AR\((p)\) process and adding \(p\) lagged difference terms of the dependent variable \(y\) to the right-hand side of the test regression. This is presented as follows:

$$\Delta y_t = \alpha y_{t-1} + X'_t \delta + \beta_1 \Delta y_{t-1} + \beta_2 \Delta y_{t-2} + \beta_p \Delta y_{t-p} + V_t \ldots \ldots \ldots \ldots (15)$$

There are two practical issues in performing an ADF test. Firstly, one should choose whether to include exogenous variables in the test regression. Therefore, one has the choice of including a constant, a constant and a linear time trend, or neither in the test regression. One approach would be to run the test with both a constant and a linear trend since the other two cases are just special cases of this more general specification. However, including irrelevant regressors in the regression will reduce the power of the test to reject the null of a unit root.

Secondly, one will have to specify the number of lagged difference terms (the lag length) to be added to the test regression (0 yields the standard DF test, whereas integers greater than 0 correspond to ADF tests). The usual (though not particularly useful) advice is to include a number of lags sufficient to remove serial correlation in the residuals.

B. The Phillips-Perron (PP) Test

Phillips and Perron (1988) developed a number of unit root tests that have become popular in the analysis of financial time series. The Phillips-Perron (PP) unit root tests differ from the ADF tests mainly in how they deal with serial correlation and heteroskedasticity in the errors. In particular, where the ADF tests use a parametric autoregression to approximate the ARMA structure of the errors in the test regression, the PP tests ignore any serial correlation in the test regression. It is therefore, an alternative (nonparametric) method of controlling for serial correlation when testing for a unit root.
When performing the PP test, one should also choose whether to include a constant, a constant and a linear time trend, or neither, in the test regression. The PP test regression is therefore:

$$\Delta Y_t = \beta_1 D_t + \pi Y_{t-1} + \mu_t \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots 
The PP tests correct for any serial correlation and heteroskedasticity in the errors $u_t$ of the test regression by directly modifying the test statistics:

$$t_\pi = 0 \quad \text{and} \quad t_\pi^\wedge.$$ 

5.2.1 Selection of lag-length criteria

The next step is determining the appropriate maximum lag length for the variables in the VAR. According to Brooks (2002: 335) financial theory has little to say on what an appropriate lag length used for a VAR model should be and how long changes in the variables should persist to work through the system. However, the optimal lag length selected should produce the number and form of co-integration relations that conform to all the a priori knowledge associated with economic theory (Seddighi et al. 2000: 309).

Three most popular information criteria (ICs) used to determine optimal lag length are the Akaike (1974) information criterion (AIC), Schwarz’s (1978) Bayesian information criterion (SBIC) and the Hannan-Quinn information criterion (HQIC). However, these information criteria sometimes produce conflicting vector autoregressive (VAR) order selections.

The VAR model is illustrated in the following manner:

$$y_t = \beta_0 + \beta_1 t^1 + \ldots + \beta_q t^q + \eta^q$$

Where $\{\eta_t\}$ sequence is a vector autoregression with k lag length and it can be presented as:

$$\eta_t = J_1 \eta_{t-1} + \ldots + J_k \eta_{t-k} + \epsilon_t$$

It is assumed that k is the optimal lag length and $\epsilon_t$ is random vector. Accordingly, the null hypothesis is to jointly test vector J:

$$H_0: J_1 = J_2 = \ldots = J_k = 0$$

5.2.2 Diagnostic Tests

The next step is making sure that the VAR is well-specified. This is done by conducting diagnostic tests. Diagnostic checks for serial correlation, normality and heteroskedasticity are then performed on the residuals from the VAR. These tests are most often used to detect model misspecification and as a guide for model improvement (Norat, 2005: 256) and aid in the validation of the parameter estimation outcomes achieved by the model (Karoro, 2007). The tests include serial correlation test, heteroskedasticity test and normality test.

A. Testing for Serial Correlation

Testing for serial correlation helps to identify any relationships that may exist between the current values of the regression residuals ($\mu_t$) and any of its lagged values (Brooks, 2002: 156). Such tests can be done via graphical exploration or by using formal statistical tests such as the Durbin-Watson test or the Lagrange Multiplier (LM) test. Although the first step in testing for autocorrelation would be to plot the residuals and look for any patterns, graphical methods may not be easy to interpret (Brooks, 2002: 156). In this study, the LM test is used to
investigate residual serial correlation. According to Harris (1995: 82), the lag order for the
LM test should be the same as lag order chosen for the VAR. The null hypothesis of the LM
test is that the residuals are not serially correlated, while the alternative is that the residuals are
serially correlated.

B. Testing for Heteroskedasticity

According to Brooks, (2002: 445), heteroskedasticity describes a scenario where the
variance of the errors in a model is not constant. Thus a problem arises when errors are
heteroscedastic but are assumed to be homoscedastic (constant variance). The result of such
an assumption would be that the standard error estimates might be wrong (Brooks, 2002:
445). In this study, the test for heteroscedasticity is done using an extension of White’s (1980)
test to systems of equations. The null hypothesis of the test is that the errors are
homoscedastic and independent of the regressors, and that there is no problem of
misspecification. In performing the test, each of the cross products of the residuals is
regressed on the cross products of the regressors, testing for the joint significance of the
regression. If the test statistic produced from this process is significant, the null hypothesis of
homoscedasticity (no heteroscedasticity) and no misspecification will be rejected.

C. Testing for Normality

In this study, the Jarque-Bera normality test is used to ascertain whether the regression
errors are normally distributed. Under the null hypothesis of normally distributed errors, the
test statistic has a Chi-Square distribution with two degrees of freedom (Brooks, 2002: 181).
Thus, if the Jarque-Bera statistic is not significant, that is, the p-value is greater than 0.05,
then the null of normality is not rejected at the 5 percent level of significance (Brooks, 2002:
181).

5.2.3 Granger (non-) Causality Test

According to the concept of Granger’s causality test (Granger, 1969; 1988), a time series
\( x_t \) Granger-causes another time series \( y_t \) if series \( y_t \) can be predicted with better accuracy by
using past values of \( x_t \) rather than by not doing so, other information is being identical.

We can test for the absence of Granger causality by estimating the following VAR model:
In the case of two time-series variables, \( X \) and \( Y \):

\[
Y_t = a_0 + a_1 Y_{t-1} + \ldots + a_p Y_{t-p} + b_1 X_{t-1} + \ldots + b_p X_{t-p} + \mu_1 \ldots (26)
\]

\[
X_t = c_0 + c_1 X_{t-1} + \ldots + c_p X_{t-p} + d_1 Y_{t-1} + \ldots + d_p Y_{t-p} + \mu_2 \ldots (27)
\]

Then, testing \( H_0 : b_1 = b_2 = \ldots . b_p \) against the alternative hypothesis:

\[ \text{\( H_A: \) Not } H_0 \text{’ is a test that } X \text{ does not Granger-cause } Y. \]

Similarly, testing \( H_0 : d_1 = d_2 = \ldots . d_p \) against the alternative hypothesis:

\[ \text{\( H_A: \) Not } H_0 \text{’ is a test that } Y \text{ does not Granger-cause } X. \]

In each case, a rejection of the null implies there is Granger causality (Giles, 2011).
6. Empirical results
6.1 Unit Root Testing
Firstly, all variables are tested for stationarity before the ARDL approach is applied. The use of non-stationary variables in the time series analysis leads to misleading inferences (Libanio, 2005). The unit root test is applied to check the order of integration and it is a crucial requirement for the existence of cointegration links (John et al., 2005). We use the traditional Augmented Dickey Fuller (ADF) and Phillips-Perron (PP) tests to check for the unit root in each variable and thereby determine the order of integration.

Table 1: Phillips-Perron Test

<table>
<thead>
<tr>
<th>Variables</th>
<th>Critical value</th>
<th>Calculated t-statistic</th>
<th>Probability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nominal interest rate (2)</td>
<td>-3.490662</td>
<td>-16.06897</td>
<td>0.0000</td>
</tr>
<tr>
<td>Expected inflation (1)</td>
<td>-3.490662</td>
<td>-10.42797</td>
<td>0.0000</td>
</tr>
<tr>
<td>Foreign interest rate (2)</td>
<td>-3.490662</td>
<td>-11.19163</td>
<td>0.0000</td>
</tr>
<tr>
<td>Nominal exchange rate (1)</td>
<td>-3.489228</td>
<td>-6.339524</td>
<td>0.0000</td>
</tr>
</tbody>
</table>

At 5% level of significance

Table 2: Augmented Dickey Fuller (ADF) Test

<table>
<thead>
<tr>
<th>Variables</th>
<th>Critical value</th>
<th>Calculated t-statistic</th>
<th>Probability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nominal interest rate (2)</td>
<td>-3.490662</td>
<td>-16.06897</td>
<td>0.0000</td>
</tr>
<tr>
<td>Expected inflation (2)</td>
<td>-3.490662</td>
<td>-10.42797</td>
<td>0.0000</td>
</tr>
<tr>
<td>Foreign interest rate (2)</td>
<td>-3.490662</td>
<td>-11.19163</td>
<td>0.0000</td>
</tr>
<tr>
<td>Nominal exchange rate (1)</td>
<td>-3.489228</td>
<td>-6.339524</td>
<td>0.0000</td>
</tr>
</tbody>
</table>

At 5% level of significance

Confirmatory analysis presented in Table 3 is drawn from the two unit root tests shown in Table 1 and Table 2. It shows that INT and foreign interest rate USRATE are stationary after second differencing while the variable EXCH is stationary after first differencing. However, for EXPINFL variable, the unit root decision is inconclusive. Following the modelling approach described earlier, we determine the appropriate lag length and conducted the cointegration test.

Table 3: Confirmatory Analysis

<table>
<thead>
<tr>
<th>Variables</th>
<th>ADF</th>
<th>PP</th>
<th>Decision</th>
</tr>
</thead>
<tbody>
<tr>
<td>EXPINFL</td>
<td>I(1)</td>
<td>I(2)</td>
<td>Inconclusive Decision (stationary after first and second differencing)</td>
</tr>
<tr>
<td>INT</td>
<td>I(2)</td>
<td>I(2)</td>
<td>Conclusive Decision (Stationary after second differencing)</td>
</tr>
<tr>
<td>EXCH</td>
<td>I(1)</td>
<td>I(1)</td>
<td>Conclusive Decision (Stationary after first differencing)</td>
</tr>
<tr>
<td>USRATE</td>
<td>I(2)</td>
<td>I(2)</td>
<td>Conclusive Decision (Stationary after second differencing)</td>
</tr>
</tbody>
</table>

Table 4 reports the optimal lag length of one (i.e m=1) out of a maximum of 4 lag lengths as selected by Final Prediction Error (FPE), Schwarz Information Criterion (SC) and Hannan-Quinn Information Criterion.

Table 4: Lag Length Selection Criteria

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6.2. Diagnostic tests

- Durbin Watson test

The Durbin Watson test results, indicated in the Breusch-Godfrey LM test show the absence of serial correlation as the DW statistic is around 2, that is 2.022089

- Breusch-Godfrey LM test

The Breusch-Godfrey LM test results show that the “F-statistic” and an “Obs*R-squared” statistic are insignificant, as the probability value is greater than zero strongly indicating no evidence of serial correlation.

### Table 5: Breusch-Godfrey Serial Correlation LM Test

<table>
<thead>
<tr>
<th></th>
<th>F-statistic</th>
<th>Prob. F(2,37)</th>
<th>Obs*R-squared</th>
<th>Prob. Chi-Square(2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>F</td>
<td>0.432578</td>
<td>0.6521</td>
<td>1.210963</td>
<td>0.5458</td>
</tr>
</tbody>
</table>

### Figure 1: AR Graph

Inverse Roots of AR Characteristic Polynomial

6.3 ARDL Model

### Table 6: Long Run Coefficients

<table>
<thead>
<tr>
<th>Variable</th>
<th>Coefficient</th>
<th>Std. Error</th>
<th>t-Statistic</th>
<th>Prob.</th>
</tr>
</thead>
</table>

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We report the estimation results of long run coefficients. All the estimated long-run coefficients are significant at 5%. The result of long run estimated coefficient shows that a one percentage increase in expected inflation rate will lead to about 0.5 percentage decrease in nominal interest rates while a one percentage rise in foreign interest rate will bring about an increase in nominal interest rate by 0.86 percent. Furthermore, a unit increase in nominal effective exchange rate will lead to about 1.92 unit fall in nominal interest rate. The negative relationship between nominal interest rates and expected inflation implies that there is no prize puzzle.

Next, we conducted the Wald coefficient tests to investigate whether full Fisher Hypothesis holds for South Africa or not, and if not, to verify if there is Fisher effect at all.

**Table 7: Wald coefficient test for full Fisher Hypothesis**

<table>
<thead>
<tr>
<th>Test Statistic</th>
<th>Value</th>
<th>df</th>
<th>Probability</th>
</tr>
</thead>
<tbody>
<tr>
<td>t-statistic</td>
<td>-3.902052</td>
<td>53</td>
<td>0.0003</td>
</tr>
<tr>
<td>F-statistic</td>
<td>15.22601</td>
<td>(1, 53)</td>
<td>0.0003</td>
</tr>
<tr>
<td>Chi-square</td>
<td>15.22601</td>
<td>1</td>
<td>0.0001</td>
</tr>
</tbody>
</table>

Null Hypothesis: C(1)=1

**Table 8: Wald coefficient test for strong Fisher Hypothesis**

<table>
<thead>
<tr>
<th>Normalized Restriction (= 0)</th>
<th>Value</th>
<th>Std. Err.</th>
</tr>
</thead>
<tbody>
<tr>
<td>-1 + C(1)</td>
<td>-0.548846</td>
<td>0.140656</td>
</tr>
</tbody>
</table>
The results of Wald coefficient test in table 7 reveal that the coefficient of expected inflation is not equal to one, as the \( t \)-statistic and chi-square are statistically significant (with \( p \)-value of 0.0000). This suggests that the nominal interest rates and expected inflation move together in the long run but not on one-to-one basis. This indicates that full Fisher hypothesis does not hold in the case of South Africa over the period under study.

The results of Wald coefficient test in table 8 reveal that the constant and the other variables are different from zero, as the \( t \)-statistic and chi-square are statistically significant (with \( p \)-value of 0.0000). This suggests that there is a strong Fisher effect in the case of South Africa over the period under study and that the other variables are significantly different from zero.

The Wald test results shown in Table 8 reveal that full (standard) Fisher’s hypothesis does not hold in the South African economy.

### Table 9: Pairwise Granger Causality test

<table>
<thead>
<tr>
<th>Null Hypothesis:</th>
<th>Obs</th>
<th>F-Statistic</th>
<th>Prob.</th>
<th>Granger causality</th>
</tr>
</thead>
<tbody>
<tr>
<td>EXP_INF does not Granger Cause NOM_INT</td>
<td>54</td>
<td>0.56742</td>
<td>0.5707</td>
<td>No causality</td>
</tr>
<tr>
<td>NOM_INT does not Granger Cause EXP_INF</td>
<td></td>
<td>0.67719</td>
<td>0.5127</td>
<td>No causality</td>
</tr>
<tr>
<td>FOR_INT does not Granger Cause NOM_INT</td>
<td>54</td>
<td>1.79313</td>
<td>0.1772</td>
<td>No Causality</td>
</tr>
<tr>
<td>NOM_INT does not Granger Cause FOR_INT</td>
<td></td>
<td>0.40544</td>
<td>0.6689</td>
<td>No causality</td>
</tr>
<tr>
<td>NOM_EXC does not Granger Cause NOM_INT</td>
<td>54</td>
<td>0.43217</td>
<td>0.6515</td>
<td>No causality</td>
</tr>
<tr>
<td>NOM_INT does not Granger Cause NOM_EXC</td>
<td></td>
<td>1.36718</td>
<td>0.2644</td>
<td>No causality</td>
</tr>
<tr>
<td>FOR_INT does not Granger Cause EXP_INF</td>
<td>54</td>
<td>1.16912</td>
<td>0.3192</td>
<td>No causality</td>
</tr>
<tr>
<td>EXP_INF does not Granger Cause NOM_INF</td>
<td></td>
<td>1.14082</td>
<td>0.3279</td>
<td>No causality</td>
</tr>
<tr>
<td>NOM_EXC does not Granger Cause EXP_INF</td>
<td>54</td>
<td>5.14318</td>
<td>0.0094</td>
<td>Causality</td>
</tr>
</tbody>
</table>
EXP_INF does not Granger Cause NOM_EXC | 1.46296 | 0.2415 | No causality
NOM_EXC does not Granger Cause FOR_INT | 54 | 1.28777 | 0.2851 | No causality
FOR_INT does not Granger Cause NOM_EXC | 2.1365 | 0.1289 | No causality

The results from Table 9 depicts that there is a unidirectional causality only runs from nominal exchange rates to expected inflation. However, the rest show no causality results. We can therefore conclude that inflation respond to movements in exchange rates.

7. Conclusion and Policy Recommendation

This paper employs the autoregressive distributed lag bounds test approach, the OLS-Wald coefficient test and Granger causality test to analyze the existence of Fisher effect and the Price Puzzle in South Africa for the period 2001Q1 to 2014Q4. Furthermore, it examines the causal relationship between the nominal interest rates, foreign interest rates, nominal exchange rates and expected inflation. The results of the unit root tests (ADF and PP) indicated the variables under study were I (1) and I (2). Consequently, the ARDL bounds testing approach was employed. The ARDL bounds testing model of cointegration results show that there is a long run relationship among the variables, which implies that all the variables move together in the long run.

The results of Wald coefficient test in table 7 reveal that the coefficient of expected inflation is not equal to one, as the t-statistic and chi-square are statistically significant (with p-value of 0.0000). This suggests that the nominal interest rates and expected inflation move together in the long run but not on one-to-one basis. This indicates that full Fisher hypothesis does not hold in the case of South Africa over the period under study.

The results of Wald coefficient test in table 8 reveal that the constant and the other variables are different from zero, as the t-statistic and chi-square are statistically significant (with p-value of 0.0000). This suggests that there is a strong Fisher effect in the case of South Africa over the period under study and that the other variables are significantly different from zero.

The partial Fisher effect implies that real interest rates do not remain constant over time. Constant real interest rates occur only if nominal interest rates and inflation change on a one to one basis. If, however, a change in nominal interest rates causes a smaller change in inflation, real interest rates will also increase. South Africa is experiencing producer inflation in recent years, implying that due to higher cost prices (higher wages, high energy prices, etc.) producers are forced to push these costs to consumers in the form of higher prices. Monetary policy is therefore unable to absorb all the shocks from inflation. The policy implication is that the government should encourage and support the real sector by coming up with permanent solution to high energy prices as it discourages producers and in turn hampers economic growth.
In case of higher wages, the government should reverse labour laws that cause poor productivity relative to wages.

References


Krusc Dejan (2010), The “price puzzle” in the monetary transmission VARs with long-run restrictions, Economic Letters, 106, 147-150.


