A Test of the Fisher Effect in Nigeria

Tule, M. K., U. M. Okpanachi, E. T. Adamgbe and S. E. Smith

Abstract

The "Fisher Effect" has stimulated enormous research interest, especially in monetary policy. Expectedly, empirical evidence has varied greatly – from absence of effect to strong effect. This has kept the debate alive, with the benefit of fresh policy-relevant insights and clues especially in developing countries where the literature on the subject is fast growing. This paper contributes to the debate by using the state space model to investigate the dynamic relationship between real interest rate and inflation in Nigeria. The paper reveals varying degrees of effect across interest rate and time horizons.

Keywords: Fisher Effect, State space model, co-integration

JEL Codes: E31, E43, C32

I. Introduction

The conclusion of Fisher (1930) concerning the relationship between changes in short-term interest rates and expected inflation has continued to elicit considerable discussion and research in both academic and policy circles globally. Several empirical studies have been carried out across industrialised and non-industrialised countries on the subject matter. Fisher had posited that nominal interest rate adjusted one-to-one to changes in expected inflation. If this were indeed the case, then, movements in rates should contain vital information about the direction and level of prices in the future. However, empirical evidence on the subject matter has varied from one country to another and across periods.

The relationship between inflation expectation and nominal interest rate is crucial for monetary policy. Continuous examination of this relationship is warranted by the inconclusive nature of available evidence and the likelihood that such a relationship, even if established, may not be permanent. Fisher effect studies have seemingly gained additional impetus and momentum as inflation targeting

Tule, M. K., U. M. Okpanachi, S. E. Smith and E. T. Adamgbe are staff of the Monetary Policy and Research Departments, Central Bank of Nigeria. The views expressed in this paper are those of the author and do not necessarily reflect the opinions of the Central Bank of Nigeria.

became popular. The reason is simple – it relies on the use of short-term rates, often overnight rate as an intermediate target. The vastness of the literature on industrialised countries in particular, is therefore, not surprising. Interest rate plays a pivotal role in the economy. The viability of Fisher's hypothesis holds overarching implications for monetary policy and, therefore, significant for central banks as well.

In the developing world, the literature on the Fisher's effect is growing. Some studies have pooled developing countries along with advanced countries in multi-country analysis, with most suggesting that the Fisher Effect is either absent or not very strong in these countries (Berument and Jelassi, 2002). Some others have provided contrary indications. Maghyereh and Zoubi (2006), for example, reported a strong Fisher Effect in Turkey, Brazil, Argentina, Mexico and Malaysia. As such, any generalisation about the Fisher Effect in a developing country could easily be misleading. Country-specific studies will continue to be relevant in providing contextual analysis and informed conclusions.

The Central Bank of Nigeria (CBN) like others in developing countries would find studies of this nature useful in enriching evidence needed to support the conduct of monetary policy generally, and particularly in evaluating policy instruments. There are currently only a few studies conducted using Nigerian data to verify this very important proposition.

In Nigeria, the Central Bank of Nigeria (CBN) is the sole monetary authority and its policy stance has continued to evolve. In 2006, the Bank introduced the Monetary Policy Rate (MPR) and a standing deposit/lending facility with a corridor around the MPR as part of its monetary policy implementation framework[1]. Prior to this time, the Bank used the Minimum Rediscount Rate (MRR) to influence interest rates and lending decisions of banks. The MRR was found to be ineffective as it neither

[1]Both the lending and deposit facilities are always available to banks and have helped them to manage their liquidity positions better than previously. They have also reduced the desperation that hitherto characterised activities at the interbank in times of liquidity scarcity thereby helping to reduce volatility in rates at the interbank.

anchored inflation expectations nor short-term interest rates. In fact, for a long time the MRR was unchanged at 14.0 per cent, serving simply as the Bank's rediscount rate.

The introduction of the MPR and the standing deposit/lending facility, following the refinement of the framework, proved to be useful as interbank rates started to show some response to the adjustment decisions of the Bank's Monetary Policy Committee (MPC) with regards to both policy rate and the corridor. Since 2006, the MPR and corridor have been changed on many occasions in response to prevailing macroeconomic and market liquidity conditions[2]. Both the collateralised open buy back (OBB) and uncollateralised interbank call (IBR) have mostly oscillated within the corridor. In addition, by manipulating the MPR the Bank has been able to gain some influence on inflation expectations.

Nigeria's inflation history is mixed with episodes of high and low inflation. The country's worst inflation experience was in the 1990s when inflation rose to above 60.0 per cent. The last ten (10) years have witnessed relatively moderate inflation of less than 20.0 per cent. As monetary policy became more proactive following recent refinements in strategy, inflation outcomes have tended to improve. In fact, year-on-year inflation has not exceeded 15 per cent in the last 5 years. In 2013, inflation was subdued within single digit owing mainly to prolonged tight monetary policy stance. Until the deregulation of the financial system in 1986, interest rates were not market determined and were mostly at a low level applicable to both domestic assets and liabilities of the banking system. The aftermath of the deregulation resulted in an increase in lending rates, which rose in excess of 20.0 per cent on non-prime assets during most of the period up to 2013. Savings and deposit rates have, however, remained relatively low, leaving wide spreads between lending and savings rates.

---

[2]At inception, the MPR was set at 10.0 per cent with a symmetric corridor of 200 basis points above for the lending facility and below for the deposit facility. There have been occasions since then when the Bank implemented the asymmetric variant of the corridor. Currently, the MPR is 12.0 with 200 basis points symmetric corridor.

The objective of this paper is to investigate the dynamic relationship between inflation and interest rates in Nigeria. The paper tested the Fisher Effect in Nigeria focusing on the basic hypothesis that inflation and nominal interest rates exhibit a proportional relationship.

This paper is unique in its contribution to the literature on Fisher's Effect in Nigeria on the premise that it provides empirical evidence to support policy decisions especially on the impending Inflation Targeting Framework (IT) of the Central Bank by informing the choice of policy instruments. The questions this paper aims to answer are: (i) Does the Fisher Effect Hold in Nigeria?, If yes; how strong is the effect? and (ii) Is there any inter-temporal variations in the Effect or is the Fisher's Effect time-invariant?

This paper is structured into 6 sections. Following this introduction, section 2 reviews the theoretical and empirical literature while section 3 presents the modelling technique and the empirical methodology. The data and modeling of the variables are presented in Section 4. Section 5 is a presentation and analysis of the results while section 6 concludes with some policy recommendations.

II. Literature Review

II.1 Theoretical Review

The idea that gave birth to the Fisher' Effect was initially expressed in Fisher (1896)[3]. His hypothesis about inflation and interest rates which became known as the Fisher's Effect was, however, formally and fully developed much latter in Fisher (1930)[4]. Based on the findings of the study in the U.S and U.K, Fisher came to the conclusion that long-run, nominal interest rate is given by the sum of expected inflation and expected real interest rate. Simply, the Fisher's equation otherwise referred to as the Fisher's parity may be symbolically stated as:

$$R = r^* + \pi^*$$

[3]Irving Fisher's work, "Appreciation and Interest" published in 1896 provided the first clue about what was later called the Fisher's Effect.

[4]"Theory of Interest"

where:
R is nominal rate of interest, r^* is expected real interest rate and π^* is expected inflation[5]. Based on the premise that expected real interest rate (r^*) is constant, nominal interest rate should vary point-for-point with inflation.

$$F'(r^*) = 0, \text{ while } F'(\pi^*) = 1; \text{ therefore, } R \text{ varies with } \pi^* \text{ point-for-point.}$$

If inflation rises by x per cent as a result of monetary expansion, the nominal interest rate also adjusts upwards by the same magnitude. The Fisher's proposition of one-to-one adjustment between inflation and nominal interest rate was inferred from his estimates of the relationship between interest rates and inflation in Britain over the period 1890 to 1924 and in the U.S., 1890 to 1927. Fisher used the distributed lag structure with arithmetically declining lags to model inflation expectation. Some studies have used either the same or a variant of the original Fisher's approach in modeling inflation expectation (Sargent 1969 and Gibson 1972)[6].

Following this exposition by Fisher, very many empirical investigations have been conducted on the same countries studied by Fisher and on several others. Analytical methods, results and conclusions have varied in many respects. If Fisher's Effects holds, then real interest rates must be independent of monetary policy working through expected inflation and long-run nominal interest rates. However, there have been some other propositions that appear to negate the Fishers' consequence. For example, whilst not denying the existence of a positive relationship between inflation and nominal interest rates, some scholars have argued that the proposition of one-to-one could not possibly hold since inflation reduces money balances (Mundel, 1963 and Tobin, 1965).

In a related sense, it is argued that the Fisher's relationship breaks down in the face of prolonged Quantitative Easing (QE) due to what is referred to as 'policy duration effect'.

---

[5]This relation is stated in various forms such as $r^* = R - \pi^*$
[6]Following the development of rational expectations by Muth (1961) and efficient markets by Fama (1975), the approach to handling the unobservable inflation expectations shifted a bit. Fama (1975) and Levi and Makin (1979-Not listed (NL) on the reference list) were among the earliest to incorporate the new thinking in the analysis of the Fisher's Effect.

(Okina and Shirasuka, 2004). Policy duration effect arises from expectations of the duration of monetary easing into the future. They further argued that prolonged quantitative easing leads to the formation of stable market expectations about short-term interest rates which cause long-term rate to fall, flattening the yield curve. Inflation expectations could however, remain unchanged because the market is rather concerned with how long the QE would last than the current surplus liquidity. As nominal interest rate falls leaving inflation expectations unchanged, the real economy benefits making monetary policy able to impact on long-run growth.

Soderlind (2001) finds that a very active monetary policy or stricter inflation targeting reduces the strength of the relationship between nominal rates and inflation. Mitchell-Innes (2006) confirms this for South Africa, noting that in the long-run, adjustment of interest rates to inflation is less than unity which he attributed to the success of inflation targeting in meeting inflation expectations within the target range.

II.2 Empirical Literature

II.2.1 Evidence from Advanced Countries

Fisher's hypothesis received tremendous attention in industrialised countries owing to the substantial studies that showed significant relationship between inflation and nominal interest rates. However, evidence on the stability of the one-to-one relationship between the two, remains quite conflicting. The estimated slope coefficients of nominal interest rates on various measures of expected inflation have been shown to be substantially lower than '1', the theorised value (Fama and Gibson, 1984; Huizinga and Mishkin 1986). These studies have nonetheless shown that real interest rates are negatively associated with expected inflation[7].

The observed less than proportional reaction of interest rates to changes in expected inflation as observed in most empirical studies has commonly been

[7] A few other studies, for example Darby (1975), have reported results suggesting that the adjustment of interest rate to expected inflation could be higher than 1.

referred to in the literature as the Fisher Effect Puzzle (Mishkin and Simon, 1995).

Test of the Fisher hypothesis in advanced economies although inconclusive, apparently reveals some time-varying effects and country-specific outcomes. The evidence portrays not very distinctive but an emerging differential along the time periods and tools of analysis. Studies such as Fama (1979), Nelson and Schwert (1977), Mishkin (1984, 1988) and Fama and Gibbsons (1984) have indicated a strong post-war Fisher effect in the U.S, UK and Canada up till 1979, but a reduced effect post-1979. However, a correlation analysis by Mishkin and Simon (1995) indicated a weak nominal interest rates and inflation nexus. Using the Johansen co-integration technique, Hawtrey (1997) failed to find the Fisher effect for Austria over the periods of 1969 to 1994 and 1969 to 1983. This finding corroborated Inder and Silvapulle (1993) that used ECM for the period, 1965 to 1990.

Mishkin and Simon (1995) segmented their study sample into three, 1962 to 1993, 1962 to 1979 and 1979 to 1993 and applied the Engle and Granger approach to show that the Fisher Effect exist in the long-run and it was absent in the short-run. However, Atkins and Sun (2003) used the discrete wavelet transformation technique to investigate Fisher Effect for Canada. The study which covered the period, 1959 to 2002, found support for the long-run Fisher Effect. The robustness of this finding was, however, contested by several studies. In Olekalns (1996), using Austrian data and applying ARCH and Maximum likelihood estimation techniques from 1969 to 1993 there was little evidence of a long-run Fisher Effect. Also, Choudhry (1997) applied the Engle and Granger estimation technique for the period 1955 to 1994 with little evidence of a long-run Fisher Effect in Belgium; Atkins and Serletis (2002) used the Pesaran et. al. (2001), estimation techniques for the period 1880 to 1983 and found little support for a long-run Fisher effect in Norway, Sweden, Italy, Canada, the United Kingdom, and the United States.

In a more recent study Ramadanović (2011) used monthly data of long-term rates to test for the Fisher hypothesis. The evidence did not support the presence of a long-run equilibrium relationship between inflation and nominal interest rates in the

United Kingdom, Switzerland and Germany.

Panopoulou (2005) examined the Fisher effect using both short-term and long-term interest rates in 14 OECD countries. Sufficient evidence was found to support the existence of a long-run Fisher effect. However, application of a discrete wavelet transformation (DWT) to the series as an alternative for the more commonly used differencing approach by Atkins and Sun (2003) found evidence of a Fisher effect for Canada and the United States, using data from 1959 to 2002. Atkins and Coe (2002) used the ARDL Technique to investigate for the Fisher effect in Canada. They used data from 1953 to 2000 and found evidence in support of the Fisher Effect. Other studies that provided evidence in support of the Fisher Effect in Canada include Dutt and Ghosh (1995), Crowder (1997) and Lardic and Mignon (2003); while those that found no support in the same country include Ghazali and Ramlee (2003) and Yuhn (1996).

II.2.2 Evidence from Emerging and Developing Countries

Mitchell-Innes (2006) examined the Fisher Effect under an inflation targeting regime for South Africa using the 3-month bankers' acceptance rate and the 10-year government bond rate as substitutes for short- and long-term interest rates. The data used in the study covered April 2000 to July 2005. The short-run Fisher Effect was not empirically established, while long-term interest rates and expected inflation were found to exhibit a long-run co-integrating relationship. Similarly for South Africa, Wesso (2000) used the Johansen estimation technique to examine whether a relationship exists for the period 1985 to1999 with little evidence of a long-run Fisher Effect. Cooray (2002) examined Sri Lankan data for the presence of Fisher Effect using the Johansen estimation technique. The data covered the period, 1952 to 1998 but finds no evidence of the Fisher Effect. In Turkey, Aksoy and Kutan (2002), using the GARCH estimation technique found no support in the analysis for the long-run Fisher Effect.

From Latin America comes some strong evidence of the Fisher Effect. Carneriro et. al., (2002) examined the Argentine economy for the Fisher Effect using the

Johansen estimation technique using data from 1980 to 1997. The authors confirm a long-run Fisher Effect. Earlier, Garcia (1993) and Phylaktis and Blake (1993) found evidence of a long-run Fisher Effect in Brazil and Argentina. Jorgensen and Terra (2003) also investigated the effect in Latin America using a four variable VAR estimation technique. They found no evidence of a long-run relationship between nominal interest rate and inflation for Brazil, Peru and Chile. Their results, however, supported a long-run Fisher Effect in Mexico and Argentina. Studies by Asemota and Bala (2013) and Obi et. al., (2009) on Nigeria using error correction and Kalman filtration support the existence of a partial Fisher Effect for the period between 1961 and 2009.

III. Methodology

III.1 Data Sources and Research Method

Monthly data for Nigeria between 1970 and 2013 were used to model the relationship between inflation and short-term interest rate. Inflation is the year-on-year change in consumer prices (Inf), while various interest rates were considered such as three-month Nigerian Government Treasury Bills rate (NTB91), three-month deposit rate (dr3m); inter-bank and lending rates. Interest rate series were compiled from various CBN publications while inflation numbers were obtained from the National Bureau of Statistics (NBS) inflation reports.

From the literature, we note a variety of methods for evaluating the relationship between inflation and interest rate or the Fisher Effect. Early attempts at verifying the Fisher Effect relied mostly on OLS regression of interest rate on inflation. The major challenge was how to measure the unobservable inflation expectation. In addition, OLS estimation requires that the variables are stationary in their levels. More often than not interest rate and inflation series lack this highly essential property. With integrated variables, OLS estimates are generally unreliable.

Mishkin (1992) outlined the reasoning and implications of the variables (interest rate and inflation) displaying stochastic trends. Using monthly US data, Mishkin found that interest rate and inflation exhibit common trend which signaled strong correlation between them. This approach has subsequently dominated Fisher Effect studies in both developed and developing countries[8].

Co-integration between inflation and interest rate imply long-run equilibrium between the two variables, which in a way indicates some Fisher Effect. However, a slightly different argument is emanating, which seems to suggest that co-integration between nominal interest rate and inflation should be more appropriately seen as only a necessary condition for Fisher effect. The sufficient condition is that nominal interest rate should embody an optimal inflation forecast (Miron, 1991)[9]. This dimension calls for the application of other estimation techniques that can more efficiently handle expectations as supplements to the usual co-integration analysis.

Against the foregoing background, this paper employs a state space model following Hamilton (1994) and others as well as a co-integration analysis, to examine Nigerian data for the Fisher's Effect. Unlike the fixed coefficients that co-integration yields, the state space model provides time-varying parameters which provide some insights about the inter-temporal stability or otherwise of parameters (Hamilton, 1994).

III.2. Model Specification

III.2.1 The State Space Model

The state space framework (SSF), given its time-varying properties, provides an informative approach to analysis of the inflation-nominal interest rate relationship. In particular, unlike forecast based methods applied in Million (2004), the SSF is preferred for its ability to estimate unobserved components such as inflation expectations. In addition, when inflation expectation time series generated for such forecast based expectations and other approaches are not available, the SSF becomes a useful tool in the study of the nominal interest rate-inflation

---

[8]See examples: Mishkin and Simon (1995), Crowder (1997), Dutt and Ghosh (1995), Lee et. al., (1998) Cameiro et. al., (2002), and Granville and Mallick (2004).

[9]For a detailed and more comprehensive presentation of this idea, see Johnson (2005).

relationship. Essentially, it uses the Kalman filter estimation to uncover the time varying effect of inflation dynamics on the nominal interest rate. The general specification of the state space model consists of a state (transition) and measurement or signal (observation) equation. The state equation governs the dynamics of the unobserved or state variables, while the measurement equation relates the observed variable to the unobserved variable. A state space model can be represented as follows:

$$y_t = c_t + \beta_t Z_t + \varepsilon_t \qquad \varepsilon_t \sim N(0, H_t) \qquad \text{(Signal equation)}$$

$$\beta_t = T_t \beta_{t-1} + a_t + R_t \mu_t \qquad \mu_t \sim N(0, Q_t) \qquad \text{(State equation)}$$

In the signal or measurement equation, y_t represents a vector of measured variables of n by 1 dimension; β_t gives the state vector of unobserved variables of m by 1 dimension; Z_t represents a matrix of parameters of n by m dimension and $\varepsilon_t \sim N(0, H_t)$. In the state equation, T_t is an m by m matrix, α_t is an m by 1 vector, R_t is an arbitrary *m* by *g* matrix such that redefining the error term produces an SQS' covariance matrix.

The Fisher relation (Fisher, 1930), postulates that the nominal rate of interest is the sum of the ex-ante real interest rate and expected inflation suggesting that a percentage change in the expected inflation will result in a change in the nominal interest rate. Algebraically, this relation is expressed as:

$$i_t = r_t^e + \pi_t^e \qquad (1)$$

In equation (1), i_t is the nominal interest rate, r_t^e is the ex-ante real rate, while π_t^e denotes the inflation expectation. In order to derive an expression for inflation expectation, we consider the inflation forecast error μ_t, as the difference between actual and expected inflation which we can express in the form:

$$\mu_t = \pi_t^e - \pi_t \qquad (2)$$

From equation 2, we can re-arrange to obtain an expression for inflation expectation as:

$$\pi_t^e = \pi_t + \mu_t \qquad (3)$$

Under the assumption of rational expectation, the forecast error is assumed to be stationary such that substituting for π_t^e in equation (1) produces equation (4).

$$i_t - \pi_t = r_t^e + \mu_t \quad (4)$$

Thus, from equation 4, the ex post real rate, $i_t - \pi_t$, is given as the addition of the ex-ante real rate and the inflation forecast error. In the literature, an examination of the Fisher effect involves fitting the nominal interest rate on the realised or actual inflation. We form this equation by simply rearranging and parameterising equation (4), thus:

$$i_t = r_t^e + \beta_t \pi_t + \mu_t \quad (5)$$

To evaluate the Fisher effect, if the coefficient β_t=1 there exists a full Fisher effect, but if β_t<1 it suggests a partial Fisher effect. However, equation (5) which is constant parameterisation can be put in a state space form in order to capture the changing role of monetary policy on the existence or otherwise of the Fisher effect, i.e. to evaluate the time varying dimension of the Fisher effect. Thus, the state space form of equation (5) is given by equation 6.

$$i_t - r_t^e = \alpha_t + \beta_t \pi_t + \mu_t \quad (6a)$$

$$\alpha_t = F_t \alpha_{t-1} + \upsilon_t \quad (6b)$$

$$\beta_t = H_t \beta_{t-1} + \eta_t \quad (6c)$$

Equation (6a) represents the measurement equation, while equation (6b) and (6c) are the state or transition equations for the time-varying intercept term and varying effect of inflation on the real interest rate. The measurement equation relates real interest rate and the unobserved state variable (β_t) with the regression coefficient at the beginning of the series, while the transition equation shows changing path of the state variable and measures the association between the real interest rate and inflation over time. The observation error μ_t and state error η_t are assumed to be white noise.

The first state series is a time-varying intercept (α), that is, the values of the level at the beginning of the series, whereas the second state series is a time-varying measure of inflation persistence, that is, is the slope parameter.

To model inflation expectation, we similarly apply a state space model in equation (7):

$$\pi_t = C_t + \beta_t \pi_{t-1} + \mu_t \quad (7a)$$

$$C_t = F_t C_{t-1} + \varepsilon_t \quad (7b)$$

$$\beta_t = Z_t \beta_{t-1} + \varsigma_t \quad (7c)$$

As in the case of equation (6), the observation error is μ_t and the state errors ε_t *and* ς are assumed to be white noise, while C_t is the drift parameter.

This enables us using the Kalman filter to examine the time varying path of the state (β_t) using observed data. In addition, it can help in establishing whether real interest rate and inflation have common factors. The Kalman filter is a recursive algorithm for carrying out computations in a state space model. Kalman Smoothing produces a more precise estimate of the state vector or slope coefficient. The unknown variance parameters (σ^2_μ and σ^2_η) are estimated by the maximum likelihood estimation via the Kalman filter prediction error decomposition initialised with the exact initial Kalman filter.

IV. Modeling of Variables

IV.1 Data Patterns and Statistics

Three of the earlier identified series (inflation, NTB rate and 3-month deposit rate) are shown graphically over the period, 1970 to 2013, on figures 1 and 2. Both charts show some co-movement – though insufficient to conclude on the exact nature of the relationship. Between 1970 and around the middle of the 1980s, interest rates appear quite stable, almost flat but started showing minimal movements thereafter. Inflation, on the other hand, rose and fell intermittently across the sample period.

Figure 1: NTB (91-day) rate and inflation (%)

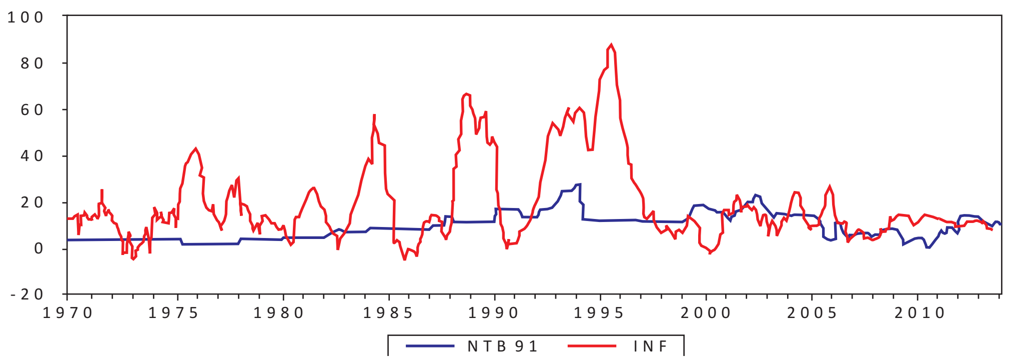


Figure 2: 3-month deposit rate and inflation (%)

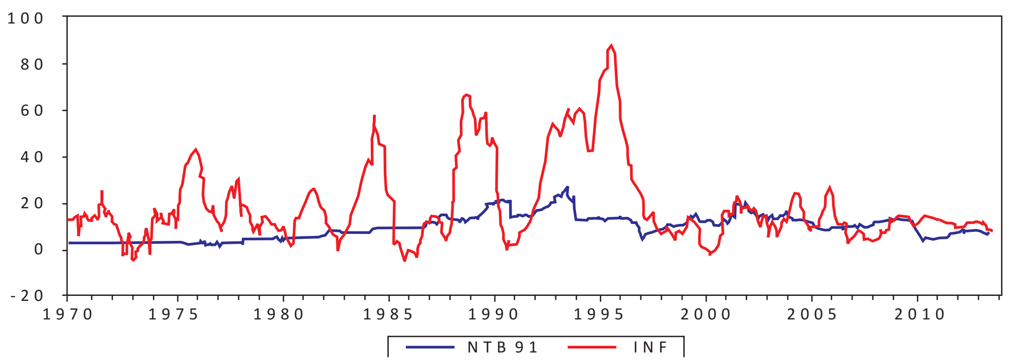
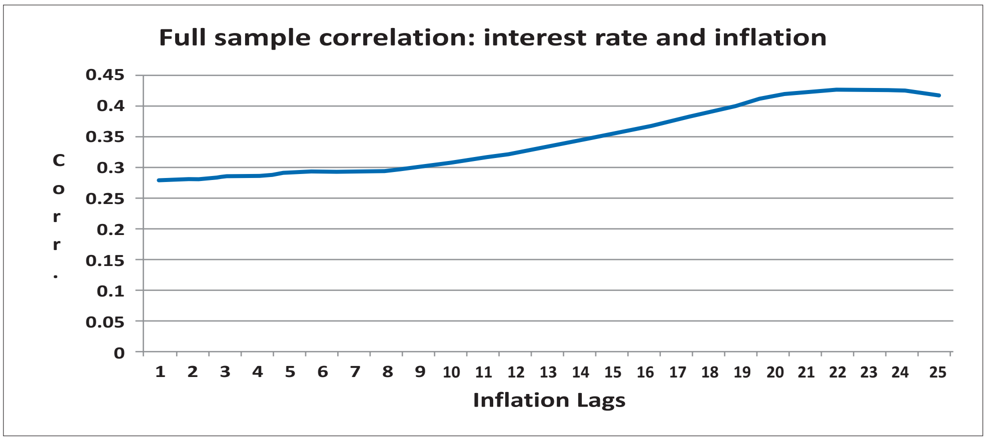


Figure 3 provides further insights about the nature and strength of the relationship between inflation and interest rate. By connecting correlation coefficients between interest rate and inflation at lags (1 – 25) we find a weak positive correlation rising through from about 0.28 to 0.47 around lag 22, after which it starts to diminish. This is not very suggestive of the strong relationship implied by the Fisher hypothesis.

Figure 3: Correlations between NTB (91-day) rate and inflation (%)



Sample statistics vary across periods, but more substantially for inflation (Table 1). For example, while inflation averaged 19.69, 23.43, 17.95 and 10.8 for full, 1974 to 1993, 1994 to 2013 and 2007 to 2013 periods, respectively, NTB rate averaged 9.8, 9.16, 11.62 and 8.02 over the same periods. Expectedly, standard deviations are higher for inflation and over the four sample periods, inflation standard deviations are 17.9, 18.3, 17.98 and 3.02 compared with NBT's 5.65, 6.16, 4.67 and 3.77.

Table 1: Sample Statistics: Full and Sub-Periods

	Full Sample (1970-2013)			1974-1993			1994-2013			2007-2013		
	NTB91	3MDR	Inf	NTB91	3MDR	Inf	NTB91	3MDR	Inf	NTB91	3MDR	Inf
Mean	9.80	9.83	19.69	9.16	9.65	23.43	11.62	11.39	17.95	8.02	9.18	10.80
Maximum	28.00	27.00	89.57	28.00	27.00	67.60	24.50	23.60	89.57	15.00	14.65	15.59
Minimum	1.04	2.00	-4.98	2.50	2.00	-4.98	1.04	4.13	-2.49	1.04	4.13	4.12
Std. Dev.	5.65	5.20	17.90	6.61	6.10	18.31	4.67	3.30	17.98	3.77	2.81	3.02

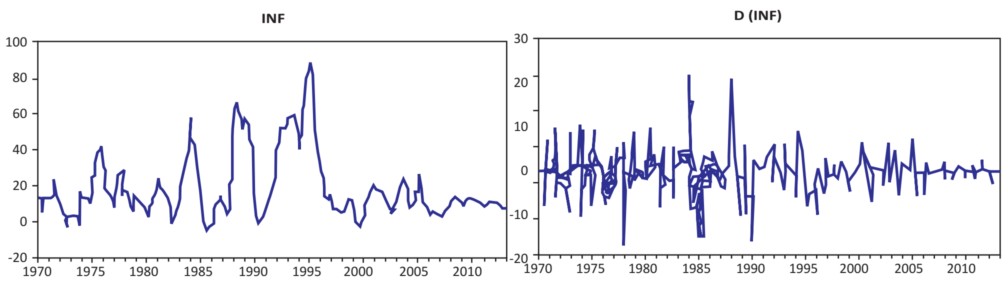
Jarque	39.82	22.84	299.91	57.92	26.03	25.81	1.35	3.15	472.54	2.34	4.10	6.15
Prob.	0.00	0.00	0.00	0.00	0.00	0.00	0.51	0.21	0.00	0.31	0.13	0.05
Obs.	525	526	525	240	240	240	237	237	237	81	81	81

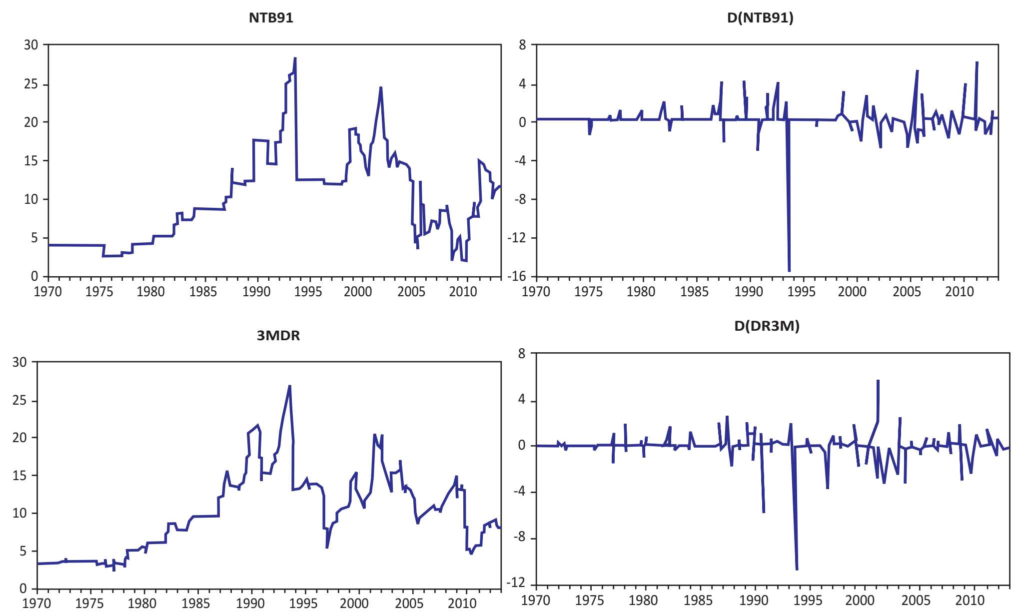
IV.2 Stationarity

Economic analysis using time series has continued to evolve with better understanding of some of covert properties of the series. In one such refinement, Sims (1980) showed that OLS regression of series that are integrated produces spurious results. Following this realisation it is standard practice to check series for stationary. The result of such an evaluation typically determines the choice of modeling technique to be applied. Figure 4 show the series in levels and first differences.

Figure 4 show inflation, NTB rates and deposit rate in levels and first differences side-by-side. The differenced series show better convergence compared to the levels that appear to drift. This is an early indication of the presence of unit root in the series at their levels. After subjecting the series to two standard unit root tests (ADF and Phillips-Peron), we found that they were all integrated of order 1 (Appendix 1). This finding means that OLS modeling of the data will be inappropriate.

Figure 4: Series in levels and first differences





V. Presentation and Analysis of Results

V.1 Co-integration

Following from the stationary results presented in the previous section, the paper proceeded to explore co-integration between inflation and interest rate – which can be a basis for some preliminary inferences about Fisher effect. However, using both the Engle and Granger and Phillips-Ouliaris techniques, the hypothesis of no co-integration between short-term interest rates (proxied by the 91-day NTB rate and 3-month deposit rate) and inflation was not rejected (see Appendices). Absence of co-integration means that there is no long-run equilibrium relationship between the variables and, possibly, no Fisher Effect present[10]. The finding of no co-integration in the full sample (1970-2013) does not rule out the possibility of Fisher effect occurring in sub-periods. To investigate this, the paper employs a suitable technique – The state space model.

[10] Absence of co-integration generally diminishes the possibility of long-run Fisher Effect (Mishkin, 1992; Johnson, 2005). The co-integration approach is limited in this wise. For studies using this approach, it is practically the end the road.

V.2 State Space Model

In order to analyse the existence and extent of the Fishers' Effect, the paper used various interest rates - 90-day Treasury bill rate (TBR), maximum lending rate (MLR), Prime lending rate (PLR), inter-bank call rate (IBCR) and 3-month deposit rate (3MDR). This should help determine which interest rate is subject to the Fisher Effect. Sequel to the estimations, however, the IBCR, PLR and 3MDR showed no evidence of the nominal interest rate-inflation nexus. For robustness and sensitivity evaluation, three measures of inflation were included in the estimation, namely, expected inflation based on its natural trend (generated using equation 7), the actual inflation and a backward-looking inflation, a one-period lag of the actual inflation. The estimates are presented in Tables 2-7.

Figure 5: Estimates of Ex ante TBR and Time-varying Fisher Coefficients

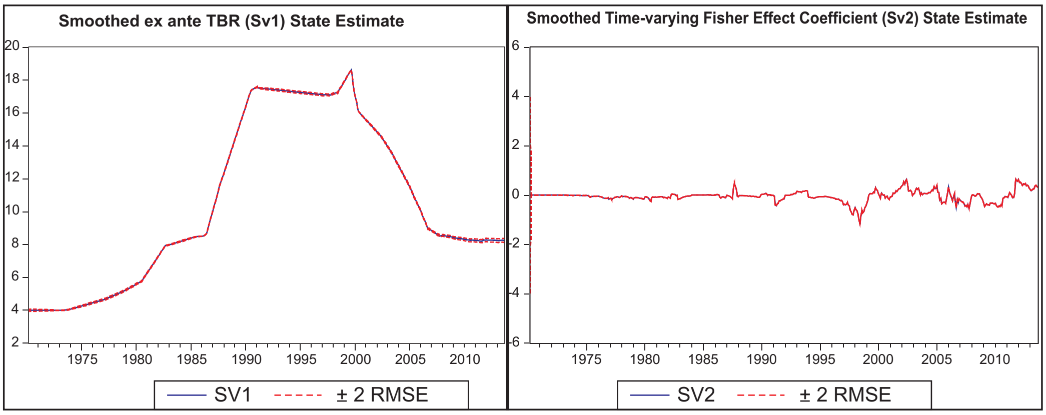


Figure 5 illustrates the ex-ante Treasury bill rate and the time-varying fisher coefficients. The literature review demonstrated that the nominal interest rate is the sum of expected inflation and the ex-ante real interest rate signifying that a percentage change in the expected inflation will result in a change in the nominal interest rate. A fairly obvious inverse co-movement exists between the level of the TBR and inflation rate which is suggestive of the coefficients as common factors. A higher inflation implies a reduced real interest rate, while a higher or lower coefficient on inflation reflected a concomitant change in the real interest rate as shown in Figure 6.

Figure 6: Real Interest-Inflation Relationship

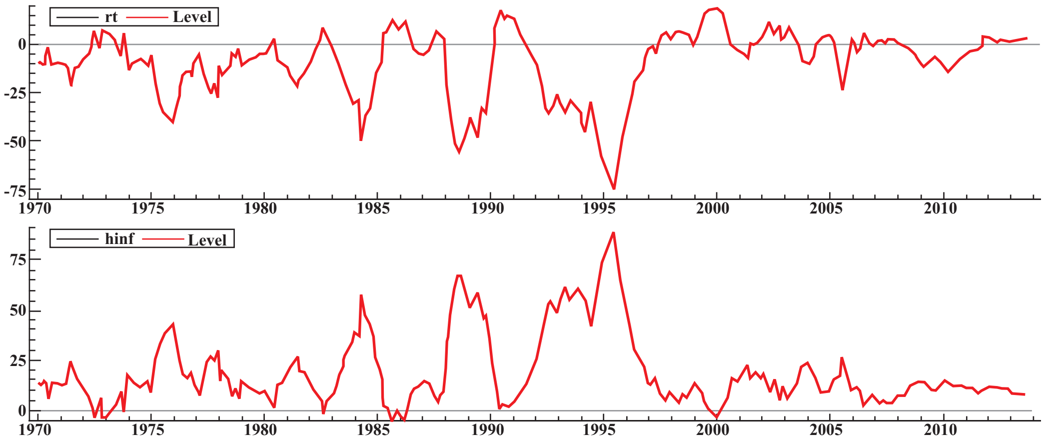


Table 2: Test of Fisher Effect-Treasury Bill Rate with Expected Inflation

Method: Maximum likelihood (Marquardt)				
Sample: 1970M03 2013M09				
Included observations: 523				
Convergence achieved after 1 iteration				
	Final State	Root MSE	z-Statistic	Prob.
Ex-ante TB rate (SV1)	8.24814	0.05900	139.80	0.00
Expected inflation (SV2)	0.32282	0.00982	32.88	0.00
Log likelihood	-82423.39	Akaike info criterion		315.206
Parameters	3	Schwarz criterion		315.231
Diffuse priors	2	Hannan-Quinn criter.		315.216

Table 3: Test of Fisher Effect - Treasury Bill Rate with Actual Inflation

Method: Maximum likelihood (Marquardt)				
Sample: 1970M03 2013M09				
Included observations: 523				
Convergence achieved after 1 iteration				
	Final State	Root MSE	z-Statistic	Prob.
Ex-ante TBR (SV1)	10.1610	0.0599	169.77	0.00
Actual inflation (SV2)	0.0947	0.0101	9.39	0.00
Log likelihood	-77080.28	Akaike info criterion		294.77
Parameters	3	Schwarz criterion		294.80
Diffuse priors	2	Hannan-Quinn criter.		294.78

Table 4: Test of Fisher Effect-Treasury Bill Rate with Backward-looking Inflation Expectations

Method: Maximum likelihood (Marquardt)				
Sample: 1970M03 2013M09				
Included observations: 523				
Convergence achieved after 1 iteration				
	Final State	Root MSE	z-Statistic	Prob.
Ex-ante TBR (SV1)	8.4598	0.0595	142.08	0.00
Backward looking inflation (SV2)	0.2981	0.0099	30.17	0.00
Log likelihood	-77657.65	Akaike info criterion		296.98
Parameters	3	Schwarz criterion		297.01
Diffuse priors	2	Hannan-Quinn criter.		296.99

Table 5: Test of Fisher Effect-MLR with Expected Inflation

Method: Maximum likelihood (Marquardt)				
Sample: 1970M03 2013M09				
Included observations: 523				
Convergence achieved after 1 iteration				
	Final State	Root MSE	z-Statistic	Prob.
Ex-ante MLR (SV1)	19.6720	0.0590	333.45	0.00
Expected inflation (SV2)	0.6583	0.0098	67.06	0.00
Log likelihood	-174153.4	Akaike info criterion		665.99
Parameters	3	Schwarz criterion		666.01
Diffuse priors	2	Hannan-Quinn criter.		666.00

Table 6: Test of Fisher Effect-MLR with Actual Inflation

Method: Maximum likelihood (BHHH)				
Sample: 1970M03 2013M09				
Included observations: 523				
Convergence achieved after 1 iteration				
	Final State	Root MSE	z-Statistic	Prob.
Ex-ante MLR (SV1)	20.3440	0.0598	339.96	0.00
Actual inflation (SV2)	0.5981	0.0101	59.29	0.00

Log likelihood	-204670	Akaike info criterion		782.69
Parameters	3	Schwarz criterion		782.71
Diffuse priors	2	Hannan-Quinn criter.		782.70

Table 7: Test of Fisher Effect-MLR with Backward-looking Inflation Expectation

Method: Maximum likelihood (Marquardt)				
Sample: 1970M03 2013M09				
Included observations: 523				
Convergence achieved after 1 iteration				
	Final State	Root MSE	z-Statistic	Prob.
Ex-ante TBR (SV1)	10.1610	0.0599	169.77	0.00
Actual inflation (SV2)	0.0947	0.0101	9.39	0.00
Log likelihood	-77080.28	Akaike info criterion		294.77
Parameters	3	Schwarz criterion		294.80
Diffuse priors	2	Hannan-Quinn criter.		294.78

The time-varying coefficients of the Fisher Effect are determined on a monthly basis and reveals interesting characteristics as observed in the smoothed state and time-varying plot above. First, for the Treasury bill rate, the Fisher Effect became evident with a coefficient of 0.62 to 0.65 in the last quarter of 2011 suggesting a partial but strong Fisher Effect. The Effect declined steadily to a state position of 0.32, 0.09 and 0.30 as in Table 2-4 in the ninth month of 2013 for each measure of inflation used (expected, actual and backward-looking inflation). Secondly, for the maximum lending rate the effect was observed much earlier in 2008 and within the same period. For the three measures of inflation used on MLR, we found an even and gradual increase in the 'Effect' until it reached its state levels of 0.66, 0.60 and 0.63 as in Table 5-7. Thirdly, Figure 5 showed that the relationship between the nominal interest rate and inflation is generally asymmetric with negative and positive effects across time. Fourthly, in a more repressed financial era, the Fisher Effect was found to be non-existent.

To a large extent, economic agents reallocated their portfolios in order to account for periods of very high inflation. This is why on the average; periods of high inflation produced lower Fisher Effect based on the two interest rate measures. Finally, the MLR dominates the TBR in its adjustment to changes in inflation. This is obvious since a lower coefficient on the inflation rate in the TBR is implied once the TBR changes. This change triggers a change in other interest rates which also includes the MLR and a possible 'Fisherian debt inflation'.

VI. Conclusion and Policy Recommendations

Using the full sample, the null hypothesis of no co-integration could not be rejected from the estimates (Engle-Granger and Phillips Ouliaris techniques) reported earlier even when other tests were used[11]. The absence of co-integration between inflation and NTB and 3-month deposit rates in the full sample is not surprising. First, during most of the period 1970 to 2013, both interest rates were negative in real terms. Until the deregulation of the economy in the mid-1980s, interest rates were administratively repressed. In fact, as Figures 1 and 2 show, both NTB and 3-month deposit rates were almost flat in the period up to 1986. They started rising only gradually, in an apparently benign response to inflation, from about 1987, but never really met up with the pace of inflation in the late 1980s and mid-1990s. Up to September 2011, the NTB rate was lower than inflation in most cases, implying negative real rates. Figure 3 further buttresses this fact with the very low correlation coefficients at lower lags.

Generally, the relationship between interest rate and inflation is expected to reflect the orientation of monetary policy during any particular period. During 1980s and 1990s, there were economic conditions, some policy-induced, that led to frequent disconnect between inflation and interest rates. First, the CBN regularly financed government debt, ignoring the impact on market dynamics. Low NTB rates facilitated availability of cheap money for government. Secondly, some

---

[11]To be double sure, alternative evaluation techniques were used: (1) Residual series obtained from an OLS estimate of ($R = \alpha + \beta\pi$) in level was found to be integrated and (2), upon assumption of co-integration, a co-Integrating regression was performed using the fully modified least squares (FMLS) and tested for co-integration using Hansen stability test, Engle and Granger and Phillips Ouliaris. Non rejected the null of no co-integration.

actions of the Bank were intermittently focused on stabilising the financial markets during the period under review. Moreover, in the 1990s, although inflation soared, the Central Bank's policy orientation did not directly involve raising interest rates. A similar situation played out in the mid-2000s and, in a different form in 2011 when the Central Bank embarked on quantitative easing to smoothen the impact of the global economic and financial crisis. Interest rates during most of the period 1970 to 2013 reflected more of costs imposed by the structural deficiencies in the economy than inflation.

Real returns on NTB rates were consistently positive between 2011 and 2013, unlike in the previous periods. In principle, the Fisher effect is to be expected during such times. But, we could not analyse the period separately for co-integration because of the short span. Fortunately, the state space model was able to achieve this. From the state space model, it was revealed that depending on which measure of inflation is used, varying degrees of the Fisher effect is observed.

Two quick policy issues are apparent from these results: first, the TBR and MLR produce a stronger link with all the different measures of inflation used in the paper, especially backward and forward-looking expectation; and secondly, both backward and forward-looking expectations produced relatively higher partial Fisher Effect. This obviously implies that agents form inflation expectations about their investment decisions which influence the behaviour of interest rates. Therefore, anchoring inflation expectations is important for the interest rate setting behaviour of the Bank.

It can also be inferred that targeting the interbank rate as a basis for the interest rate setting process might not yield positive outcomes in the changing structure of the other interest rates. It means that the TBR and MLR adjust faster, relative to IBCR as inflation changes, reducing its negative influence on the real interest rate. It is apparent for the IBCR that where the Fisher Effect does not exist, its adjustment to inflation changes is sluggish and could be a source of an upward pressure on credit and money growth. This paves the way for agents to react to a long-lasting propensity of a liquidity surfeit and expenditure, thus, elevating the price level. It is also intuitive to reason that government borrowing plays an important role in the determination of inflation. The fact that TBR and MLR showed a strong link and a partial FE, there is also a strong correlation between these rates.

References

Aksoy, T. A. and A. M. Kutan (2002). "A Public Information Arrival and the Fisher Effect in Emerging Markets", Istanbul Stock and Gold Exchanges, *Working Paper 02-1101*. Edwardsville: Department of Economics and Finance, Southern Illinois University. *American Economic Review* 62, 854–865.

Asemota, O. J. and D. A. Bala (2013). "Kalman Filter Approach to Fisher Effect: Evidence from Nigeria", *CBN Journal of Applied Statistics* Vol. 2 No.1.

Atkins, F. and P. J. Coe (2002). "An ARDL Bounds Test of the Long-run Fisher Effect in the United States and Canada", *Journal of Macroeconomics*. 24, 2: 255-266.

Atkins, F. J. and A. Serletis (2002). "A Bounds Test of the Gibson Paradox and the Fisher Effect: Evidence from Low-frequency International Data", *Discussion Paper* 2002-13. Calgary: Department of Economics, University of Calgary.

Atkins, F. J. and Z. Sun (2003). "Using Wavelets to Uncover the Fisher Effect", *Discussion Paper 2003-09*, Calgary: Department of Economics, University of Calgary.

Berument, H. and M. M. Jelassi (2002). "The Fisher Hypothesis: a Multi-country Analysis", Department of Economics, Bilkent University, Ankara, Turkey, *Applied Economics*, 2002, 34, 1645-1655.

Carneiro, F. G., J. A. Divino and C. H. Rocha (2002). Revisiting the Fisher Hypothesis for the Cases Argentina, Brazil and Mexico. *Applied Economics Letters*. 9, 95-98.

Choudhry, A. (1997). Co-integration Analysis of the Inverted Fisher Effect: Evidence from Belgium, France and Germany. *Applied Economics Letters*. 4, 257-260.

Cooray, A. (2002). "Testing the Fisher Effect for Sri Lanka with a Forecast Rate of Inflation as Proxy for Inflationary Expectation", *The Indian Economic Journal*, 50, 1:26-37.

Crowder, W. J. (1997). International Evidence on the Fisher Relation, *Working Paper*, Department of Economics, University of Texas at Arlington.

Crowder, W. J. (1997). "The long-run Fisher Relation in Canada", *Canadian Journal of Economics*. 30, 4:1124-1142.

Darby, M. R. (1975). "The Financial and Tax Effects of Monetary Policy on Interest Rates, "*Economic Inquiry", Western Economic Association International*, Vol.

13(2), pages 266-76, June.

Dimand, R. W. and R. G. Betancourt (2012). "Retrospectives: Irving Fisher's Appreciation and Interest (1896) and the Fisher Relation", *Journal of Economic Perspectives*, 26(4): 185-96.

Dutt, S. D. and Ghosh, D. (1995). The Fisher hypothesis: Examining the Canadian experience. *Applied Economics*. 27, 11:1025-1030. *Econometrica* 29, 315–335.

Engle, R. F. and C. W. J. Granger (1987). "Co-Integration and Error Correction: Representation, Estimation and Testing", *Econometrica*, 55, 251-276.

Fama, E. and M. Gibson (1982). "Inflation, Real Returns, and Capital Investment", *Journal of Monetary Economics*, 9, pp. 297-324.

Fama, E. F. (1975). "Short-term Interest Rates as Predictors of Inflation", *American Economic Review* 65, 269–282.

Fama, E. F. (1982). "Inflation, Output, and Money," *The Journal of Business*, University of Chicago Press, vol. 55(2), pages 201-31, April.

Fama, E. F. and M. R. Gibbsons (1984). "A Comparison of Inflation Forecasts", *Journal of Monetary Economics,* 13, 327-348.

Fisher, I. (1896). "Appreciation and Interest." *Publications of the American Economic Association*, First Series, 11(4): 1–110 [331– 442], and as *Appreciation and Interest*, New York: Macmillan, 1896; reprinted in *The Works of Irving Fisher* (Fisher, 1997), Vol. 1.

Fisher, I. (1896). "*Appreciation and Interest*", New York: Macmillan; reprinted in *The Works of Irving Fisher* (Fisher, 1997), Vol. 1.

Fisher, I. (1930). The Theory of Interest Rates. New York: Macmillan.

Garcia, M. G. P. (1993). "The Fisher Effect in a Signal Extraction Framework: The Recent Brazilian Experience", *Journal of Development Economics,* 41, 1:71-93.

Ghazali, N. A. and S. Ramlee (2003). "A Long Memory Test of the Long-run Fisher Effect in the G7 Countries", *Applied Financial Economics*. 13,10: 763- 769.

Gibson, W. E. (1970). "Price-Expectations Effects on Interest Rates", *Journal of Finance* 25, 19–34.

Gibson, W. E. (1972). "Interest Rates and Inflationary Expectations: New Evidence", *American Economic Review*, 62, Dec., pp. 854-865.

Gibson, W. E. and G. G. Kaufman (1971). Monetary Economics: Readings on Current Issues. London, McGraw-Hill Book Company.

Granville, B. and S. Mallick (2004). "Fisher hypothesis: UK Evidence Over a Century," *Applied Economics Letters*, 11:87–90.

Hamilton, J. (1994). *Time Series Analysis*, Princeton University Press, New Jersey, Ch. 13.

Hawtrey, K. M. (1997). "The Fisher Effect and Australian Interest Rates", *Applied Financial Economics*, Vol. 7 No. 4, pp. 337-346.

Huizinga, J. and F. S. Mishkin (1986). "Monetary Policy Regime Shifts and the Unusual Behaviour of Real Interest Rates", *NBER Working Papers* 1678, National Bureau of Economic Research, Inc.

Inder, B. and P. Silvapulle (1993). Does the Fisher Effect Apply in Australia? *Applied Economics*. 25, 6:839-843.

Johansen, S. (2005). "Interpretation of Co-integrating Coefficients in the Co-integrated Vector Autoregressive Model", *Oxford Bulletin of Economics and Statistics*, Department of Economics, University of Oxford, Vol. 67(1), pages 93-104, 02.

Johnson, P. A. (2005). "Is It Really the Fisher Effect?", *Vassar College Economics Working Paper* #58.

Jorgensen, J. J. and P. Terra (2003). "The Fisher Hypothesis in a VAR Framework: Evidence from Advanced and Emerging Markets", Conference Paper. Helsinki: *European Financial Management Association* Annual Meetings, 25-28 June.

Kandel, S., A. R. Ofer and O. Sarig (1996). "Real Interest Rates and Inflation: An Ex-Ante Empirical Analysis", *Journal of Finance, American Finance Association*, Vol. 51(1), pages 205-25, March Paper. Helsinki: European Financial Management Association. Annual Meetings, 25-28 June.

Lardic, S. and V. Mignon (2003). "Fractional Co-integration Between Nominal Interest Rates and Inflation: A Re-examination of the Fisher Relationship in the G7 countries", *Economic Bulletin*, 3, 14:1-10.

Maghyereh, A. and H. Al-Zoubi (2006). "Does Fisher Effect Apply in Developing Countries: Evidence From a Nonlinear Co-trending Test Applied to Argentina, Brazil, Malaysia, Mexico, Korea and Turkey", *Applied Econometrics and International Development*, Euro-American Association of Economic Development, Vol. 6(2).

Million, N. (2004). Central Bank's Interventions and the Fisher Hypothesis: A Threshold co-integration Investigation, *Economic Modeling* 21, 1051– 1064.

Miron, J. A. (1991). "Comment", in NBER Macroeconomics Annual 1991, Olivier Jean Blanchard and Stanley Fischer (eds.), MIT Press, Cambridge, pp 211-218.

Mishkin, F. S. (1984). "The Real Interest Rate: A Multi-country Empirical Study", *Canadian Journal of Economics* 17, 283-311.

Mishkin, F. S. (1988). "Understanding Real Interest Rate", *American Journal of Agricultural Economics*, Vol. 70, issue 5, pages 1064-1072

Mishkin, F. S. (1992). "Is the Fisher effect Real? A Re-Examination of the Relationship between Inflation and Interest Rates", *Journal of Monetary Economics* 30:195-215

Mishkin, F. S. and J. Simon (1995). "An Empirical Examination of the Fisher Effect in Australia", *The Economic Record*, Vol. No. 214 Sept., pp. 217-229.

Mitchell-Innes, H. A. (2006). "The Relationship between Interest Rates and Inflation in South Africa", M.Sc Thesis, Rhodes University.

Mundell, R. (1963). "Inflation and Real Interest", *Journal of Political Economy*, University of Chicago Press, Vol. 71, pages 280.

Muth, J. F. (1961). "Rational Expectations and the Theory of Price Movements", *Econometrica*, Vol. 29, No. 3, July, pp. 315-335

Nelson, C. and G. W. Schwert (1977). "Short-Term Interest Rates as Predictors of Inflation: On Testing the Hypothesis that the Real Rate of Interest is Constant", *American Economic Review* 67, 478–486

Obi, B., A. Nurudeen and O. G. Wafure (2009). "An Empirical Investigation of the Fisher Effect in Nigeria: A Co-Integration and Error Correction Approach", *International Review of Business Research Papers*, Vol. 5 No. 5 September

2009 Pp. 96-109.

Okina, K. and S. Shiratsuka (2004) "Policy Duration Effect Under Zero Interest Rates: An Application of Wavelet Analysis", *CESIFO Working Paper* No. 1138

Olekalns, N. (1996). Further Evidence on the Fisher Effect. *Applied Economics*. 28, 7:851-856.

Panopoulou, E. (2005). A Resolution of the Fisher Effect Puzzle: A Comparison of Estimators, National University of Ireland, Maynooth and University of Piraeus, Greece.

Pesaran, M. H., Y. Shin and R. J. Smith (2001). "Bounds Testing Approaches to the Analysis of Level Relationships", *Journal of Applied Econometrics*, Vol. 16, pp. 289–326, May.

Phillip P. C. B. and S. Ouliaris (1988). "Testing for Co-integration Using principal Components methods", *Journal of Economic Dynamics and Control*, 12, 205-230.

Phylaktis, K. and D. Blake (1993). "The Fisher Hypothesis: Evidence from Three High Inflation Economies", *Weltwirtschaftliches Archiv*. 129, 3:591-599.

Ramadanović, A. (2011). Testing the Long-run Fisher Effect, Erasmus University Rotterdam Erasmus School of Economics.

Sargent, T. J. (1969). Commodity Price Expectations and the Interest Rate, in: W. E. Gibson and G. G. Kaufman, (ed.) *Monetary Economics*: Readings on Current Issues, McGraww Hill Book Co. NY.

Soderlind, P. (2001). "What if the Fed Had Been an Inflation Nutter?", *Working Paper Series in Economics and Finance* 0443, Stockholm School of Economics.

Tobin, J. (1965). "The Burden Of The Public Debt: A Review Article", *Journal of Finance*, American Finance Association, Vol. 20(4), pages 679-682, December.

Tobin, J. (1965). Money and Economic Growth, *Econometrics* 33, 671-684

Wesso, G. R. (2000). "Long-term Yield Bonds and Future Inflation in South Africa: a Vector Error Correction Analysis", *Quarterly Bulletin*, Pretoria: South African Reserve Bank. June.

Yuhn, K. (1996). "Is the Fisher Effect Robust? Further Evidence", *Applied Economics Letters*, 3, 41–44.

Appendices

Appendix 1: Eagle/Granger Co-integration Result

Series: NTB91 INF

Dependent	tau-statistic	Prob.*	z-statistic	Prob.*
NTB91	-2.784752	0.2036	-15.19728	0.1745
INF	-3.221783	0.0813	-28.27496	0.0115

*MacKinnon (1996) p-values.

Series: DR3M INF

Dependent	tau-statistic	Prob.*	z-statistic	Prob.*
DR3M	-2.808208	0.1949	-15.34575	0.1697
INF	-3.328534	0.0628	-30.52411	0.0070

*MacKinnon (1996) p-values.

Appendix 2: Phillips/Ouliaris Co-integration Results

Series: NTB91 INF

Dependent	tau-statistic	Prob.*	z-statistic	Prob.*
NTB91	-2.700799	0.2367	-14.13558	0.2127
INF	-3.399511	0.0525	-23.13259	0.0351

*MacKinnon (1996) p-values.

Series: DR3M INF

Dependent	tau-statistic	Prob.*	z-statistic	Prob.*
DR3M	-2.771219	0.2087	-14.30950	0.2061
INF	-3.500592	0.0403	-24.48716	0.0263

*MacKinnon (1996) p-values.

Appendix 3: Test of Fisher Effect-Treasury Bill Rate with Expected Inflation

Method: Maximum likelihood (Marquardt)				
Sample: 1970M03 2013M09				
Included observations: 523				
Convergence achieved after 1 iteration				
	Final State	Root MSE	z-Statistic	Prob.
Ex-ante TB rate (SV1)	8.24814	0.05900	139.80	0.00
Expected inflation (SV2)	0.32282	0.00982	32.88	0.00
Log likelihood	-82423.39	Akaike info criterion		315.206
Parameters	3	Schwarz criterion		315.231
Diffuse priors	2	Hannan-Quinn criter.		315.216

Appendix 4: Test of Fisher Effect - Treasury Bill Rate with Actual Inflation

Method: Maximum likelihood (Marquardt)				
Sample: 1970M03 2013M09				
Included observations: 523				
Convergence achieved after 1 iteration				
	Final State	Root MSE	z-Statistic	Prob.
Ex-ante TBR (SV1)	10.1610	0.0599	169.77	0.00
Actual inflation (SV2)	0.0947	0.0101	9.39	0.00
Log likelihood	-77080.28	Akaike info criterion		294.77
Parameters	3	Schwarz criterion		294.80
Diffuse priors	2	Hannan-Quinn criter.		294.78

Appendix 5: Test of Fisher Effect-Treasury Bill Rate with Backward-looking Inflation Expectations

Method: Maximum likelihood (Marquardt)				
Sample: 1970M03 2013M09				
Included observations: 523				
Convergence achieved after 1 iteration				
	Final State	Root MSE	z-Statistic	Prob.
Ex-ante TBR (SV1)	8.4598	0.0595	142.08	0.00
Backward looking inflation (SV2)	0.2981	0.0099	30.17	0.00
Log likelihood	-77657.65	Akaike info criterion		296.98
Parameters	3	Schwarz criterion		297.01
Diffuse priors	2	Hannan-Quinn criter.		296.99

Appendix 6: Test of Fisher Effect-MLR with Expected Inflation

Method: Maximum likelihood (Marquardt)				
Sample: 1970M03 2013M09				
Included observations: 523				
Convergence achieved after 1 iteration				
	Final State	Root MSE	z-Statistic	Prob.
Ex-ante MLR (SV1)	19.6720	0.0590	333.45	0.00
Expected inflation (SV2)	0.6583	0.0098	67.06	0.00
Log likelihood	-174153.4	Akaike info criterion		665.99
Parameters	3	Schwarz criterion		666.01
Diffuse priors	2	Hannan-Quinn criter.		666.00

Appendix 7: Test of Fisher Effect-MLR with Actual Inflation

Method: Maximum likelihood (BHHH)				
Sample: 1970M03 2013M09				
Included observations: 523				
Convergence achieved after 1 iteration				
	Final State	Root MSE	z-Statistic	Prob.
Ex-ante MLR (SV1)	20.3440	0.0598	339.96	0.00
Actual inflation (SV2)	0.5981	0.0101	59.29	0.00
Log likelihood	-204670	Akaike info criterion		782.69
Parameters	3	Schwarz criterion		782.71
Diffuse priors	2	Hannan-Quinn criter.		782.70

Appendix 8: Test of Fisher Effect-MLR with Backward-looking Inflation Expectation

Method: Maximum likelihood (Marquardt)				
Sample: 1970M03 2013M09				
Included observations: 523				
Convergence achieved after 1 iteration				
	Final State	Root MSE	z-Statistic	Prob.
Ex-ante TBR (SV1)	10.1610	0.0599	169.77	0.00
Actual inflation (SV2)	0.0947	0.0101	9.39	0.00
Log likelihood	-77080.28	Akaike info criterion		294.77
Parameters	3	Schwarz criterion		294.80
Diffuse priors	2	Hannan-Quinn criter.		294.78