ISSN 2229-5518

Fractional Cointegration of Fisher Hypothesis in Regulated and Deregulated Periods in Nigeria

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Abstract
This study investigates the validity of Fisher hypothesis in regulated period (January 1961 to September1986) and the deregulated (October 1986 to December 2010) using monthly nominal interest rate and inflation. Tests for unit root and fractional root were conducted on these variables for the two periods. Fractional cointegration analysis was used to test the long run relationship between nominal interest rate and inflation. The results indicate fractional integration in the deregulated period for the variables. The variables were found to be fractionally cointegrated which implied that they are mean reverting and have long run relationship in the deregulated period. In the regulated period on the other hand, the variables were not fractionally cointegrated. The cointegration test did not support long run relationship between the variables in the deregulation period. This research work confirms the validity of Fisher hypothesis with deregulated period in Nigeria and there is no evidence of Fisher hypothesis in the regulated period. This is because in the regulated period interest rate is fixed and inflation is controlled, therefore not allowing the two economic variables to interplay. The study recommends that the Nigerian government should adopt policies that reduce inflation and interest rate to the minima points since Fisher hypothesis does exist in the current dispensation.

Keywords: Deregulated period, Fractional cointegration, Fractional root, Fisher Hypothesis, Long-run relationship, Long Memory, Regulated period.

1. INTRODUCTION

Nigeria's financial system has gone through noticeable changes in term of ownership structure. Several policies, with a number of institutions established to provide the necessary economic environment and regulatory framework. Prior to 1986 when the structural adjustment programme (SAP) was introduced, the lending rate practiced by banks in Nigeria were strictly regulated under the surveillance of the supervisory Central Bank of Nigeria. The deregulation period which brought about the Structural Adjustment Programme (SAP) era came with stringent banking rules ([1]).

Financial institutions are regulated in some countries (that is, interest rate control, compulsory public debt placement and control on external capital flows) fixing nominal interest rate and raising fiscal deficits to lower inflation. This was done in Nigeria which resulted in repressed (even negative) real interest rates as observed in [2]. As a reversal policy however, the government in September 1986 introduced some measure of deregulation into interest rate management due to wide variations and unnecessarily high interest rate under the complete regulation policy ([1]).

The relationship between interest rate and inflation has been frequently investigated in both theoretical and empirical economics. The one-to-one long-run relationship between interest rates and inflation known as the Fisher hypothesis, has been tested extensively in the last two decades. The study of this relationship initially tested by [3] known as Fisher hypothesis or the Fisher effect, examines the effect of nominal interest rate and inflation on the minimum required returns ([4]). According to [4], the Fisher effect or hypothesis states that a permanent change in the inflation rate will cause nominal interest rate to move in a one to one relation with inflation. Thus, the real interest rate will remain unchanged in response to a monetary shock if the Fisher effect holds. The real interest rate is determined entirely by the real factor in the economy, such as productivity of capital and investment time. This evidence of Fisher effect was found to be strong in some countries at certain period than others. For instance, United Kingdom, United States of America and Canada had strong evidence of Fisher effect in the post second world war period ([5]).

To uncover this long run relationship between nominal interest rate and inflation, most literature applied unit root developed by [6] and the Johansen cointegration test by [7]. The standard Johansen cointegration analysis assumes that all variables are integrated of order one I(1) and hence restricts the error correction term to be a stationary process I(0). This method was used by [8] to investigate the Fisher effect in Nigeria. The research discovered Partial Fisher effect in the long run between interest rate and inflation rate in Nigeria. Asemota and Bala [9] employed Kalman filter and cointegration approach to investigate Fisher effect in Nigeria using quarterly data. Their study did not find evidence of full Fisher effect. Noor and Shamim [10] used

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Johansen cointegration test to determine the nature of relationship between nominal interest rate and inflation. Variance decomposition was used to explain the error correction model and Granger causality to determine the direction of relationship. The results found the presence of Fisher effect in Pakistan for the period 1980-2010.

There is a more generalized model whose order of integration is continuum of real number known as fractional cointegration. The model does not only nest the unit-root behavior within it, but also display stationary and non-stationary, mean-reverting dynamics, long-memory and anti-persistent dependencies ([11]). The concept of long memory and fractional integrated models in time series was introduced by [12], [13] and [14]. Specifically, in Fisher effect, fractional integrated series may imply the existence of an equilibrium long term relationship between nominal interest rate and inflation. Consequently, the error correction term is fractionally cointegrated thus there exist fractional cointegration between nominal interest rate and inflation in line with Fisher hypothesis.

This study is to find out whether there is any relationship between nominal interest rate and expected inflation in Nigeria in the regulated and deregulated periods. It is also to determine evidence of Fisher hypothesis in both periods.

2 METHODOLOGY

This study employs Dickey-Fuller Generalised Least Square (DF-GLS) and Kwiatkowski, Phillips Schmidt and Shin (KPSS) to test for unit root and stationarity. Geweke and Porter Hudak (GPH), Robinson Log-periodogram (Roblpr) and the modified log-periodogram regression test for fractional differencing parameter of the long memory process.

The Fisher equation is of the form

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

where I_t is the nominal rate, r_t is the ex-ante real interest rate and π_t^e is the expected inflation rate. The Fisher equation can also be written in the form

$$I_t = \alpha + \beta\pi_t + \eta_t \qquad (2)$$

where α and β are all parameter to be estimated. π_t is the actual inflation rate, η_t is a long memory process, such as ARFIMA. The expected inflation rate coincide with actually recorded inflation rate (π_t) plus the random error (ε_t). Hence, the excepted inflation is estimated by the following equation.

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

where ε_t is the error component. Thus the composite error is equal to $\beta\varepsilon_t = Z_t$. In particular, an estimate of β is not significantly different from one in the cointegration regression equation (2), which indicate the presence of a full Fisher effect. The term $(I_t - \pi_t)$ is stationary if the estimate of β is significantly lower than one. That is, there will be a partial Fisher effect. Therefore the changes in the expected inflation rate would be transmitted in a proportion to ($\beta < 1$) the nominal interest rate.

By definition $\boldsymbol{r_t = I_t - \pi_t}$ where $\boldsymbol{r_t}$ is the real interest rate. In other word, $\boldsymbol{r_t}$ is given by the assumption of rational expectation. The real interest rate would only differ by a random stationary term, so that stationarity of the former (real interest rate) implies stationarity of the later $(\boldsymbol{I_t - \pi_t})$. However it could happen that in equation (2). The nominal interest rate and inflation rate would be cointegrated. If I_t and $\boldsymbol{\pi_t}$, are characterized by units root or are I(1) then Fisher hypothesis may be tested by examining whether these two variables form a stationary linear combination.

2.1 Unit Root Test.

All conventional unit root tests are based on ARIMA (p,d,q) model. In a traditional ARIMA model, d is restricted to be a non negative integer. When d=1, the process is non-stationary, if d = 0, the process is stationary. ([15]) observed that a standard unit-root test such as Dickey-Fuller test may have low power against fractional alternative. For that reason this study employ DF-GLS test developed by [16] and KPSS by [17] to test for unit root and stationarity. These approaches are described below.

2.2 Dickey-Fuller Generalized Least Squares Test

The Dickey-Fuller generalized least squares unit root test by [16] is a simple modification of the Augmented-Dickey Fuller test. Exploiting the result in [18] that uniformly powerful test do not exist for unit root tests, [16] modified the ADF test and showed that DF-GLS test has the limiting power function close to the point optimal test. In the conventional ADF test for non-stationarity, the alternative hypothesis is ρ<1 which shows that the test is not conducted against any value of ρ. Under these circumstances a power envelope was constructed covering the continuous set of each possible value of ϱ under the alternative. Elliot et al. [16] then proposed a family of tests whose power functions is tangent to the power envelope at one point and never lying below it. These tests were denoted by $P_T(0.5)$, *which shows* that they are optimal at the power of 50%. They went on to show that DF-GLS has the limiting power function close to $P_T(0.5)$.

In the DF-GLS test, the data are detrended (depending on whether the model is with drift only or has a linear trend) so that deterministic variables are taken out of the data prior to running the regression. A generalized least squares regression equation of detrended data, y_t^d using the estimate associated with $\hat{a}$ is given as

$$y_t^d = y_t - \hat{\alpha}_0 - \hat{\alpha}_1 t \qquad (4)$$

where y_t is the original series, $\hat{\alpha}_0$ and $\hat{\alpha}_1$ are the drift and trend parameters respectively obtained by regressing $\bar{y}$ on $\bar{x}$

$$\bar{y} = [y_1, (1 - aL)y_2, \ldots, (1 - aL)y_T]' \qquad (5)$$

$$\bar{x} = [x_1, (1 - aL)x_2, \ldots, (1 - aL)x_T]' \qquad (6)$$

with $\bar{x} = (1, T)'$, $\alpha = \left(1 + \frac{\bar{c}}{T}\right)$, $\bar{c}$ is 7 if the data generating process has a drift only and $\bar{c}$ is 13.5 if the data generating process has a drift with trend.

The DF-GLS test therefore involves estimating the equation

$$\Delta y_t^d = \beta_0 y_{t-1}^d + \beta_1 \Delta y_{t-1}^d + \ldots + \beta_p \Delta y_{t-p}^d + v_t \qquad (7)$$

As with the ADF test, the null hypothesis is H_0: $\beta_0 = 1$. This is considered with the t-ratio for $\hat{\beta}_0$ from equation (7). The DF-GLS t-ratio follows a Dickey-Fuller distribution in the case of constant only. The asymptotic distribution differs when you include both constant and trend. ([16]) simulate the critical values of the test statistics in this later case. By setting $T = \{50, 100, 200, \infty\}$, the null hypothesis is rejected if the test statistic falls below the critical value.

2.3 Kwiatkowski, Phillips Schmidt and Shin (KPSS) Test

The integrated properties of a series y_t may also be investigated by testing the null hypothesis

$H_0 = y_t = I(0)$ against the alternative hypothesis $H_A: y_t = I(1)$ (8)

That is the hypothesis that the data generating process is stationary [I(0)] against a unit root [I(1)]. Kwiatkowski et al. [17] have derived a test for the pair of hypothesis in the absence of linear trend term. They start from a data generating process.

$$y_t = x_t + z_t \qquad (9)$$

where x_t is a random walk

$$k_t = k_{t-1} + v_t, v_t \sim iid(0, \sigma^2 v) \qquad (10)$$

where z_t is a stationary process. In this framework the foregoing pair of hypothesis is equivalent to the pair.

$$H_o: \sigma_v^2 = 0 \;\; against \;\; H_a: \sigma_v^2 \neq 0 \qquad (11)$$

where H_o is the null hypothesis, and H_a is the alternative hypothesis. Kwiatkowski *et al.* [17] propose the following test statistics

$$KPSS = \frac{1}{T^2} \sum_{t=1}^{T} \frac{S_t^2}{\hat{\sigma}_\infty^2} \qquad (12)$$

where $S_t = \sum_{j=1}^{t} \hat{w}_j$, with $w_j = y_t - \bar{y}$ and $\hat{\sigma}_\infty^2$ is an estimator given as

$$\sigma_\infty^2 = \lim_{T\to\infty} T^{-1} Var\left(\sum_{t=1}^{T} Z_t\right) \qquad (13)$$

that is σ_∞^2 is an estimator of the long run variance of the process z_t, $w_j = 1 - \frac{v}{j_{q+1}}$ is a Bartlett window with truncated lag j_g. KPSS uses Kernel estimators to correct serial for correction, and Bartlett kernel is one of the best estimators. The null hypothesis is rejected if the test statistics is greater that the asymptotic critical values.

2.4 Fractional Cointegration Test.

The existence of fractional cointegration implies that the econometric data may be randomly drifting away from equilibrium for long episodes, but may finally return to equilibrium. Fractional cointegration enables us to distinguish between the case where the equilibrium errors are non-mean reverting and where they are actually mean-reverting but exhibiting a significant persistence in the short-run. If the equilibrium error is found to be integrated of order b with b>0 (which might not be necessarily I(0)), the series is fractionally cointegrated.

2.5 ARFIMA Model

Conventional unit-root tests are based on ARIMA (p,d,q) model and d the differencing parameter is restricted to be an integer. The ARFIMA model was however, introduced by [12] and [14]. The differencing parameter d is a real number. An ARFIMA (p, d', q) process is a stationary process that satisfies:

$$\phi_p(L)(1-L)^d y_t = c + \theta_q(L)\varepsilon_t, \quad t=1,2,\ldots,T \qquad (14)$$

where d is the parameter of fractional differentiation, c is a constant and ϕ_p and θ_q are autoregressive and moving average polynomials of order p and q, respectively. The autocorrelations, ρ_k, for an ARFIMA process for large k and $d < \frac{1}{2}$ are given by the following approximation (see ([12])).

$$\rho_k \approx \frac{\Gamma(1-d)}{\Gamma(d)} k^{2d-1} \quad (15)$$

which is a monotonic function. The autocorrelation function of ARFIMA decreases slowly to zero while its spectral density is infinite (see [14]),

2.6 Geweke and Porter-Hudak (GPH) Estimation of ARFIMA Processes

The test developed by [19] is a spectral regression-based method for estimating fractional difference (d) in the equilibrium error. The test was carried out using Monte Carlo simulation experiment performed by [19]. The test also provides a general way of testing for fractional difference which is not dependant on nuisance parameters of the ARMA process.

$$f_x(\lambda) = \sigma^2/2\pi\{4sin^2(\lambda/2\}^2 f_u(\lambda) \quad (16)$$

Assume a sample of X_t of size T is available. Take logarithms from both sides of equation (16), and evaluate it at harmonic frequencies $\lambda_j = \frac{2\pi j}{T}$, j= 0,1,2,…T-1. After adding $I(\lambda_j)$ the periodogram at ordinate j, to both sides of the log form of equation (16), becomes:

$$In\{I\lambda_i\} = In\{\sigma^2 f_u(0)/2\pi\} - dIn\{4sin^2(\lambda/2\} + In\{I(\lambda_j)/f_x(\lambda_j)\} \quad (17)$$

The last term on the right-hand side of equation (17) becomes negligible when low-frequency ordinates λ_j are near to 0. The following simple regression is hence suggested.

$$In[I(\lambda_j)] = \beta_0 + \beta_1 In[4sin^2(\lambda_j/2)] + \eta_j \quad (18)$$

where intercept $\beta_0 = In\{\sigma^2 f_u(0)/2\pi\}$, parameter $\beta_1 = -d$, error term $\eta_j = In\{I(\lambda_j)/f_x(\lambda_j)\}$ and j = 1,2,…,n. The number of observations, that is, the number of ordinates to be used in the estimation of the regression is n = g(T), where g(T) satisfy the following conditions: $\lim_{T\to\infty} g(T) = \infty$ and $\lim_{T\to\infty} g(T)/T = 0$. The function $g(T) = T^{\mu}$, with $0 < \mu < 1$, is the number of periodogram ordinates used to estimate d and satisfies both conditions and the estimator of d is consistent. The test of hypothesis for the parameter can be done based on the asymptotic distribution of $\hat{d}$, derived by [19].

$$\hat{d} \to N(d, \pi^2/6\sum(x_i - \bar{x}^2)) \quad (19)$$

where x_i is the regressor ($\ln[4sin^2(\lambda_j/2)]$). If $\lim_{T\to\infty}[g(T)]$ and $\lim_{T\to\infty} g(T)/T = 0$ then $p\lim s^2 = \pi^2/6$ where s^2 is the sample variance of the residuals from the regression equation (19).

The value of the power factor, μ, is the main determinant of ordinates included in the regression. Traditionally the number of periodogram ordinates is chosen from the interval [$T^{0.45}$, $T^{0.55}$]. However, ([20]) recently showed that the optimal m is of order O($T^{0.8}$).

2.7 Robinson Log-Periodogram Regression Estimator

An alternative log-peridogram regression estimation proposed by [21] provides asymptotic efficiency to Geweke and Porter-Hudak estimation. It also allows multivariate semi-parametric estimation of the long memory (fractional integration) parameters, d(g), of a set of time series, y(g), g=1,...,G, where G may be one if a series exhibits long memory. The series may neither be stationary nor have unit root but may be integrated process of order d, where d is a real number. When applied to a set of time series, the parameter d(g) for each series is estimated from a single log-periodogram regression which allows the intercept and slope to differ for each series. A choice must be made of the number of harmonic ordinates to be included in the spectral regression. Robinson's estimator is not restricted to using a small fraction of the ordinates of the empirical periodogram of the series. It also allows the removal of one or more initial ordinates, and the averaging of the periodogram over adjacent frequencies. Given the assumption that X_t represent a G-dimension vector with g^{th} element $X_{gt}, g = 1, \dots G.$ If X_t has a spectral density matrix

$$\int_{-\pi}^{\pi} e^{ij\lambda} f(\lambda)\, d\lambda, \quad (20)$$

where (g,h) is an element in $f_{gh}(\lambda)$. The g^{th} diagonal element $f_{gg}(\lambda)$, is the power of the spectral density of X_{gt} for $0 < C_g < \infty$ and $-\frac{1}{2} < d_g < \frac{1}{2}$.

Hence Robinson log-periodogram is given as

$$I_G(\lambda) = (2\pi n)^{-1} \left|\sum_{t=1}^{n} X_{gt} e^{itX}\right|^2, g = 1, \dots, G \quad (21)$$

2.8 Modified Log - Periodogram Regression Test (modlpr)

This is a modified form of the test by [19] which estimates the long memory process parameter d. The modified log-periodogram regression test was proposed by [22] and is designed to take care of the weakness in GPH estimation. The GPH estimation is inconsistent against $d > 1$ of the alternative hypothesis.

Let X_t be fractionally integrated process, it implies X_t satisfies a general model in equation (21) in the case where the $t > 0$ in the error term, $f_u(\lambda)$ is the spectral density.

ISSN 2229-5518

μ_t is stationa6ry with zero mean. In the case where the $t > 0$ in the error term

$$\mu_t = C(l)\varepsilon_t = \sum_{j=0}^{\infty} C_j \varepsilon_{t-j}, \quad \sum_{j=0}^{\infty} j\left|C_j\right| < \infty \quad C(1) \neq 0 \quad (22)$$

with $\varepsilon_t = iid(0, \sigma^2)$ with $\mathrm{E}|\varepsilon_t|^p < \infty$ and $p > 4$. Equation (22) implies that spectrum of μ_t is continuously differentiable for all frequencies.

The fractional process is

$$X_t = (1-d)^{-d}\,\mu_t = \sum_{k=0}^{t} \frac{(d)_k}{k!}\mu_{t-k},$$

$$with\ \mu_t = 0\ \ for\ all\ t \leq 0 \quad (23)$$

$$where \quad (d)_k = \frac{\Gamma(d+k)}{\Gamma(d)}$$

This is Pochammer's symbol for the forward factorial function. The modified estimator is expressed as

$$w_u(\lambda) = w_x(\lambda) D_n(e^{-i\lambda};\, d) + \frac{1}{\sqrt{2\pi n}}\left(\tilde{X}_{\lambda 0}(d) - e^{in\lambda}\tilde{X}_{\lambda n}(d)\right) (24)$$

$$where\ \tilde{X}_{\lambda n}(d) = D_n(e^{-i\lambda}L;\, d) = \sum_{p=0}^{n-1} \tilde{d}_{\lambda p} e^{-ip\lambda}, LP$$

$$X_n = \sum_{p=0}^{n-1} \tilde{d}_{\lambda p} e^{-ip\lambda} X_{n-p},$$

$$w_x(\lambda) = \frac{1}{\sqrt{2\pi n}} \sum_{t=1}^{n} X_t e^{i+t} \quad (25)$$

The discrete Fourier transform of X_t is $W_x(\lambda)$ which is associated with periodogram co-ordinates $w_u(\lambda)$. The Geweke and Porter-Hudak test establish consistency and asymptotic normality for $d < 0$. Robinson [21] proved consistency and asymptotic normality for $0 < d \leq 1/2$ in the case of non-stationary ARMA while [23] showed that d>1 is consistency with d exihibiting asymptotic bias towards unity. The null hypothesis of consistency is tested against both $d < 1\ and\ d > 1$.

2.9 Properties of Different Values of d.

(i) For $-0.5 < d < 0$, all the autocorrelations are negative and tend hyperbolically to zero in such case, the process is considered anti-persistent or with intermediate memory.

(ii) If $0 < d < 0.5$, then all the auto-correlation are positive and also decline hyperbolically. Therefore they are persistent and have a long memory process.

(iii) If $0.5 < d < 1$, the process is covariance non-stationary but mean reverting since an innovation will have no permanent effect on its value. This is in contrast to an I(1) which will be both covariance non-stationary and non-mean reverting in which case the effect of an innovation will persist forever.

3 RESULTS AND DISCUSSIONS

This section comprises of analysis of data for regulation period (1961M1 – 1986M9) and deregulation period (1986M10 – 2010M12). Consideration was given to period when interest rate was regulated by government and period when government remove some restrictions to interest and introduce the Structural Adjustment Programme from 1986 - 2010[1].The section contain plots, unit root tests, fractional difference estimations and model fittings. The variables employed in this study are nominal interest rate (nint) and inflation (inf). Fractional difference series of nominal rate (fint) and inflation (finf) and computed.

Table 1: DF-GLS test for inf in Regulation Period.

Level			First difference		
Lag order	t-stat	p-value	Lag order	t-stat	p-value
5	-4.5257	0.00005	5	-4.6950	0.0000
4	-4.0210	0.00014	4	-4.6981	0.0000
3	-3.0532	0.00253	3	-5.6437	0.0025
2	-3.0532	0.00252	2	-15.5349	0.0000
1	-3.0532	0.00251	1	-15.5249	0.0025
0	-3.0532	0.00250	0	-15.5249	0.0025

The critical values of the t-statistic are -3.4686, -2.9128 and -2.6099 at 1%, 5%, and 10% level of significance respectively, for both level and first difference.

The test was carried out including the trend and intercept. The results show that the inflation series is stationarity at both level and first difference at 5% level of significance.

Table 2: DF-GLS Test for (nint) in Regulation Period.

Level			First difference		
Lag order	t-stat	p-value	Lag order	t-stat	p-value
5	-2.1295	0.0341	5	-9.3311	0.0000
4	-1.3796	0.0000	4	-18.7312	0.0000
3	-1.3189	0.1883	3	-18.7312	0.0000
2	-1.3189	0.1883	2	-18.7312	0.0000
1	-1.3189	0.1883	1	-18.6927	0.0000

[1] For the purpose of this study, we are limiting the period of government relaxation of rule on interest rates (deregulation period) to 2010

ISSN 2229-5518

0	-1.4680	0.0000	0	-18.6927	0.0000

The critical values of the t-statistic are -3.4683, -2.9134 and -2.6110 at 1%, 5%, and 10% level of significance respectively, for both level and first difference.

The test is carried out including both trend and intercept. The results show that the series is stationary only at first difference of the series at 5% level of significance.

Table 3: DF-GLS Test for Inflation in Deregulation period.

Lag order	Level t-stat	p-value	Lag order	First difference t-stat	p-value
5	-3.1606	0.0017	5	-7.2758	0.0000
4	-3.1606	0.0017	4	-7.2758	0.0000
3	-3.1606	0.0017	3	-7.2758	0.0000
2	-2.5292	0.0000	2	-7.2758	0.0000
1	-2.1530	0.0321	1	-9.0975	0.0000
0	-1.6249	0.1052	0	-13.3222	0.0000

The critical values of the t-statistic are -3.4708, -2.9084 and -2.6012 at 1%, 5%, and 10% level of significance respectively, for both level and first difference.

The test was carried out including both trend and intercept. The results show that inflation is stationary in level at 5% from lags 3 to 5 and stationary for all lags in first difference at 5% level of significance.

Table 4: DF-GLS test for Nominal Interest Rate Deregulation Period.

Lag order	Level t-stat	p-value	Lag order	First difference t-stat	p-value
5	-2.4627	0.0000	5	-16.1295	0.0000
4	-2.2152	0.0275	4	-16.1295	0.0000
3	-2.2152	0.0000	3	-16.1295	0.0000
2	-2.2152	0.0275	2	-16.1295	0.0000
1	-2.4627	0.0143	1	-16.1295	0.0000
0	-3.7575	0.0002	0	-26.5841	0.0000

The critical values of the t-statistic are -3.4708, -2.9084 and -2.6012 at 1%, 5%, and 10% level of significance respectively, for both level and first difference.

In Table 4 the test was carried out including both trend and intercept. The results show that the interest rate series is stationary in level at 5% only at lag 0 and stationary for all lags in first difference at 5% level of significance.

Table 5: KPSS Test for Inflation and Nominal Interest Rate in Regulation and Deregulation periods.

	Regulated period				Deregulated period			
	Level		1st diff		Level		1st diff	
Var	t-stat	Crit region	t-stat	Crit region	t-stat	Cril region	t-stat	Crit region
Inf	0.053	0.216	0.021	0.216	0.148	0.216	0.036	0.216
Int rate	0.063	0.110	0.100	0.110	0.258	0.110	0.064	0.110

At 5% level of significance, the DF-GLS test reject that the null hypothesis of unit root for nominal interest rate and inflation rate. The KPSS tests uniformly reject trend stationarity for all series tested at the 5% level of significance. The combination of these evidences imply that both nominal interest rate and inflation rate are not stationary I(1) processes at level in the deregulated period but stationary in the regulated period.

These conventional unit root tests have frequently been employed to establish the non stationarity of time-series processes. Critiques of this strategy have been carried out by [24], [25] and [26]. Perron and Vogelsang [25] demonstrated in a simulation study that shifts in the intercept and/or slope of the trend function of a stationary time series biases these standard unit-root tests toward non rejection of the null hypothesis. This is the reason why an alternative measure of estimating order of integration has been employed in this study.

3.1 Fractional Integration Tests

Conventional unit-root tests, generally fail to consider the possibility that the order of integration of these series may be fractional $I(d)$, rather than integer (0, 1, 2, ...). The mean-reverting properties of nominal interest rate and inflation series may not be detectable by standard integer order of differencing (unit-root tests), due to some of the short comings earlier mentioned (low power against fractional alternatives).

Fractional integration tests are employed to overcome this challenge. This study makes use of three nonparametric

ISSN 2229-5518

tests for the order of fractional integration[2]. These are spectral based regression estimator [19], the log-periodogram regression estimator of [21] and the estimator of [22]. The Phillips' estimator is a recently proposed extension of [19] which addresses some of the weaknesses of the test in [19].

Table 6: Geweke and Porter-Hudak (GPH) Estimation of Deregulation Period

Power	Level		First difference	
	Interest rate	Inflation	Interest rate	Inflation
0.50	0.3335	1.0551	-0.3290	0.0694
0.55	0.6296	1.0486	-0.2915	0.0555
0.60	0.8690	1.3170	-0.1416	0.3227
0.65	0.9028	1.2447	-0.1361	0.2420
0.70	0.8026	1.3816	-0.2186	0.4506
0.75	0.8750	1.3506	-0.0913	0.3536
0.80	0.7498	1.2902	-0.2171	0.2704

From Table 6 GPH estimation reject the null hypothesis of stationarity in level of both series, but does not reject stationarity at first difference of both series, hence both series are fractional integrated at first difference.

Table 7: Geweke and Porter-Hudak (GPH) Estimation of Regulation Period.

Power	Level		First difference	
	Interest rate	Inflation	Interest rate	Inflation
0.50	0.6935	0.4416	-0.2416	-0.0433
0.55	1.1928	0.3906	0.1882	0.0876
0.60	1.2471	0.3386	0.2870	0.0240
0.65	1.1757	0.3840	0.2131	0.0343
0.70	1.1467	0.4639	0.1975	0.0146
0.75	1.0089	0.7047	0.0344	0.0308
0.80	0.9622	0.8974	0.0237	0.0035

The result of Table 7 show fractional integration of inflation at level hence inflation in regulation period is persistent and has a long memory process while interest rate of the same period is non-stationary but mean reverting.

[2] another methods of fractional integration estimation is the Lo modified rescaled range(R/S) test.

Table 8: Robinson Log- Periodogram Regression (Roblpr) Estimation of Deregulation Period.

Power	Level		First difference	
	Interest rate	Inflation	Interest rate	Inflation
0.70	0.7644	1.4284	-0.1999	0.4011
0.75	0.8380	1.3616	-0.1189	0.3292
0.80	0.7099	1.2256	-0.2189	0.2951
0.85	0.6280	1.1889	-0.2494	0.3132
0.90	0.5169	1.0252	-0.3236	0.2369

Result in Table 8 shows fractional integration of interest rate at level, while inflation at level is non-stationary but is fractionally integrated at first difference.

Table 9: Robinson Log-Periodogram Regression (Roblpr) Estimation of Regulation Period.

Power	Level		First difference	
	Interest rate	Inflation	Interest rate	Infla
0.70	0.4769	1.1065	0.0314	0.17
0.75	0.7200	0.9784	0.0301	0.02
0.80	0.8730	0.9156	0.0010	0.01
0.85	0.7393	0.9386	-0.0054	0.05
0.90	0.8065	0.8299	-0.0295	0.02

The two variables in Table 9 are fractionally integrated.

Table 10: Modified Log-Periodogram Regression (Moblpr) Estimation of Regulation Period.

Power	Level		First difference	
	Interest rate	Inflation	Interest rate	Inflation
0.50	-0.1942	0.6042	-0.0555	0.0186
0.55	-0.0914	0.8955	-0.0705	0.3241
0.60	-0.1023	1.1236	0.1061	0.4270
0.65	0.0666	1.0473	0.0363	0.2680
0.70	0.2443	1.0727	0.0873	0.2272
0.75	0.5031	0.9115	0.0574	0.0610
0.80	0.7536	0.8893	0.0166	0.0093

Table 11: Modified Log-Periodogram Regression (Moblpr) Estimation of Deregulation Period.

	Level	First difference

Power	Interest rate	Inflation	Interest rate	Inflation
0.50	0.5326	0.9150	-0.3798	0.0696
0.55	0.6277	0.9626	-0.3355	0.0566
0.60	0.8632	1.0772	0.1777	0.3285
0.65	0.8971	1.1154	-0.1665	0.2407
0.70	0.7994	1.1921	-0.2422	0.4367
0.75	0.8713	1.2284	-0.1100	0.3413
0.80	0.7492	1.1958	-0.2330	0.2590

Table 10 and Table 11 results agree with that of Geweke and Poter-Hudak and the log periodogram regression estimation.

3.2 Fractional Cointegration Test

The long memory parameter d estimated in Table 6 and 8 are used to generate fractionally difference series for inflation and interest rate for the deregulation period. The new set of data is now used to perform cointegration. The cointegration test is carried out using Johansen test for cointegration see Table 10.

Table 12: Cointegration test (GPH) of Deregulation Period

Number of equation = 2, Lag interval = 1 to 4.

The result in Table 10 does not show a long run relationship between the two variables at 95% confidence interval.

Table 13: Ordinary Least Squares (OLS) Test for regulation Period.

Var	Coeff	Error	t-stat	p-value
Const	9.2135	0.1246	73.94	0.00001
Inf	0.3819	0.0074	5.186	0.0516

Least square regression is given as

$$I_t = 9.21350 + 0.381939 \times i_t \qquad (26)$$

Results from Table 11 show a partial Fisher effect between nominal interest rate and inflation in regulated period. The least square regression is given as

Table 14: Ordinary Least squares (OLS) Test for Deregulated Period.

Variable	Coefficient	Standard error
Constant	21.4202	0.436624
Inflation	0.0274743	0.140552

The least square regression is given as

$$I_t = 21.4202 + 0.0275 \times i_t \qquad (27)$$

Equation (27) implies partial relationship between interest rate hand inflation in deregulation period.

4 CONCLUSION

In this study, we provide further empirical evidence on the validity of the Fisher hypothesis, which proposes a positive relationship between nominal interest rates and inflation by applying the fractional cointegration techniques to a data of regulation and deregulation periods. The results show that, nominal interest rate and inflation are fractionally cointegrated in the deregulation period using the Geweke and Poter-Hudak, the Robinson log-periodogram test and the modified log-periodogram regression estimation. The residuals of regulation period are not are fractionally integrated.

Therefore, the results show that there is a stable long run relationship between nominal interest rate and inflation suggesting the validity of Fisher hypothesis in deregulation era. The results also imply that equilibrium errors display long memory or deviation from the long run relationship

Eigen-value	Trace-stat	5% Critical value	P-value
0.053025	23.31639	15.49471	0.0027
0.027521	7.897682	3.841460	0.0050

shared by nominal interest rates and inflation takes a long time to dissipate and return to their equilibrium relationship, but the same can't be said for the regulation period.

This study is in agreement with the findings of [11] who examined the Fisher hypothesis using fractional integration. This thus confirm the validity of Fisher's hypothesis in the current dispensation of deregulation in Nigeria and found clear evidence that the research methodology used in several recent contribution to the Fisher equation literature using standard cointegration techniques is inappropriate. In conclusion, our results justify the increasing use of fractional cointegration analysis to validate the findings of Fisher hypothesis.

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