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Fractional Cointegration Analysis of Fisher Hypothesis in Nigeria

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ABSTRACT — ***In this paper, we examined fractional cointegration analysis of fisher hypothesis in Nigeria. It analyzed the existence of fractional cointegration relationship in nominal interest rate, real interest rate and inflation, which is consistent with the Fisher hypothesis. A conventional cointegration tests was applied between nominal interest rate, real interest and inflation, showing partial effect of Fisher. The value of the fractional intergrated parameter d was estimated. The fractional difference and the fractional cointegration analysis was carried out. It indicates that, there were two long run equilibrium relationships in the variables, showing full Fisher effect. This showed that the long-run relationship between nominal interest rates and inflation did not exist for Nigeria in the sample when conventional cointegration test was employed. However, fractional cointegration between the two variables was found, implying the validity of the Fisher hypothesis.***

Keywords— Cointegration, Fractional cointegration, Fisher hypothesis, Inflation, Nominal Interest Rates.

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1. INTRODUCTION

The Fisher hypothesis suggests that there is a positive relationship between interest rates and expected inflation. The one-to-one long-run relationship between interest rates and inflation, known as the Fisher hypothesis, has been tested extensively in the last decades. In a large part, this was a result of the emergence of the literature on unit roots and cointegration techniques designed to uncover long-run relations in the data [17].The long run properties of the Fisher variables are of intrinsic interest because these variables play a crucial role in determining investment, savings, and indeed virtually all intertemporal decisions.

An important strain of modern empirical macroeconomics is the question of whether or not important economic variables are bound together by an equilibrium relationship. The methodology of detecting equilibrium relationships in macroeconomics was fundamentally changed with the seminal work [5]. Researchers began to apply mainly cointegration techniques developed by [5] to test for long-run relationship between time series variables. This explains the conflicting results concerning the validity of the Fisher Hypothesis. This leads to the concept of fractional cointegration introduced by [5].

1.1 Fractional Cointegration Process

The notion of fractional integration has proven to be quite important in modeling macroeconomic data and their relationships. In particular researchers have used fractional models to study interest rates and inflation [1].

Several studies employ cointegration techniques to test the Fisher hypothesis. A cointegration test was carried out by [3] using [11] procedure for three-month Treasury bill rates and quarterly inflation for the period from 1952 to 1991, using US data. They find that nominal interest rates respond fully to movements in inflation, a finding consistent with the Fisher hypothesis. The long-run relationship between interest rates and inflation with cointegration analysis was examine by [6] and [16] but employ bivariate cointegration test instead which did not support the Fisher hypothesis, while [6] report that nominal interest rates move one-to-one with inflation.

According to [2] that examines the validity of Fisher hypothesis in Turkey, it was found that conventional cointegration tests do not provide strong evidence on the long run relationship. The results from fractional cointegration tests based on GPH and Robinson methods show that inflation and nominal interest rate series are fractionally cointegrated.

Conventional cointegration techniques employed by the recent studies on Fisher hypothesis may only be used to test the existence of a long-run Fisher relationship if nominal rates and inflation are both *I(*1) and, if two series are cointegrated, then the equilibrium error term is stationary, *I(0)*. A number of recent studies, however, have shown that the error term in the cointegration regression might be fractionally integrated (i.e., *I*(*d*)), rather than stationary. This result implies that deviations from the long-run relationship shared by nominal interest rates and inflation take a long time to dissipate before reaching their equilibrium level. Two published papers that use fractional cointegration technique to analyze the relationship between nominal interest rates and inflation are those of [14] and [8]. They examine the Fisher hypothesis for G7 countries and find that such a relationship exists for the majority of the countries, thus confirming its validity.

In contrast, [15] reported the presence of this relationship for the long-run, but he could not detect the presence of the Fisher effect in the short-run for the USA. If error term, is a long-memory stationary process, then two series are said to be fractionally cointegrated. In this study, we use fractional cointegration method to test the Fisher hypothesis.

2. METHODOLOGY

The Fisher hypothesis state that the nominal interest rates, i_t, is equal to the real interest rate; r_t, plus expected inflation, π_t^e:

$$i_t = r_t + \pi_t^e \tag{1}$$

previous studies on the Fisher's hypothesis often considered estimating the following regression:

$$i_t = \alpha + \beta \pi_t + \eta_t \tag{2}$$

where α is the leading matrix and β is the cointegration vector and are parameters to be estimated; π_t is realized inflation rate; η_t is a long-term memory process, such as an ARFIMA.

ARFIMA models were first introduced in [14]. An ARFIMA (p, d', q) process is a stationary process that satisfies:

$$\phi_p(L)(1-L)^d x_t = c + \theta_q(L)\varepsilon_t, \quad t=1,2,\ldots,T \tag{3}$$

where *d* is the parameter of fractional differentiation, c is a constant and ϕ and θ are autoregressive and moving average polynomials of order p and q, respectively.

All conventional unit-root tests are based on an ARIMA(p,d,q) model. In a traditional ARIMA model, d is restricted to be either zero or one. When d = 1,2, … the process is nonstationary in the mean. When d = 0, the process is stationary in the mean and the autocorrelation function of the process decays at a quick exponential rate. A more general modeling of the ARIMA process that allows non-integer d values has been proposed and is known as ARFIMA (Autoregressive Fractionally Integrated Moving Average) process. The theoretical model, which serves as a basic framework of the analysis, of the ARFIMA is the OLS equation of the fisher hypothesis of (2).

$$(1-L)^d \phi(L) x_t = c + \theta(L)\varepsilon_t, \tag{4}$$

$$(1-L)^d = 1 - dL - \frac{d(1-d)}{2!}L^2 - \frac{d(1-d)(2-d)}{3!}L^3 \tag{5}$$

The following fractional cointegration tests are based on the null hypothesis;

H_0 : π_t and i_t are not cointegrated, i.e. η_t is I(1), for all α, β∈ℜ, against the alternative:

H_1: π_t and i_t are cointegrated, i.e. η_t is I(d), with 0< d < 1

Those test are applied on the estimated residuals η_t of the long-term relationship in equation (4).

2.1 Fractional Cointegration tests based on the estimation of ARFIMA processes (Geweke and Porter-Hudak Method)

According to [7], abbreviated GPH, proposed a method for estimating d. its starting point is the spectral density function of x_t.

$$f_x(\lambda) = (\sigma^2/2\pi)\left\{4\sin^2(\lambda/2)\right\}^{-d} f_u(\lambda) \tag{6}$$

Assume a sample of x_t of size T is available. Take logarithms from both sides of equation (6), 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 (6), one has:

$$In\left\{I(\lambda_j)\right\} = In\left\{\sigma^2 f_u(0)/2\pi\right\} - dIn\left\{4\sin^2(\lambda/2)\right\} + In\left\{I(\lambda_j)/f_x(\lambda_j)\right\} + In\left\{f_u(\lambda_j)/f_u(0)\right\} \quad (7)$$

The last term on the right-hand side of equation (7) becomes negligible when low-frequency ordinates λ_j are near to 0. The following simple regression is hence suggested.

$$In\left[I(\lambda_j)\right] = \beta_0 + \beta_1 In\left[4\sin^2(\lambda_j/2)\right] + \eta_j \quad (8)$$

Where intercept $\beta_0 = In\left\{\sigma^2 f_u(0)/2\pi\right\}$, parameter $\beta_1 = -d$, error term $\eta_j = In\left\{I(\lambda_j)/f_x(\lambda_j)\right\}$ 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) should 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 hypothesis tests for the parameter can be done based on the asymptotic distribution of $\hat{d}$, derived by [7].

$$\hat{d} \to N\left(d, \pi^2/6\sum_{i=1}^{n}(x_i - \bar{x})^2\right) \quad (9)$$

Where x_i is the regressor $In\left[4\sin^2(\lambda_j/2)\right]$. This follows since if $\lim_{T\to\infty}\left[g(T)\right]$ and $\lim\left[g(T)/T\right] = 0$, then $p\lim s^2 = \pi^2/6$ where s^2 is the sample variance of the residuals from the regression equation (8). 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, [10] recently showed that the optimal m is of order O ($T^{0.8}$).

2.2 Unit Root test

However, for all the models that have been specified earlier, there is need to test for long memory and more importantly the covariance stationary of each of the series involved in order to obtain valid and accurate results. These tests and all others that will be implemented are introduced and explained as follows.

2.3 Augmented Dickey-Fuller (ADF) Test

The test was first introduced by [4] to test for presence of unit root(s). ADF takes into account possibility of autocorrelated innovations instead of pure random walk with or without drift; the test is based on the model of the form:

$$\Delta X_t = \phi X_{t-1} + \sum_{i=1}^{p-1}\alpha_i \Delta X_{t-i} + \varepsilon_t \quad (10)$$

where ΔX_t is the differenced series, X_{t-1} is the immediate previous observation, ϕ is the coefficient of the immediate previous observation, ΔX_{t-i} is the differenced lagged term, p is the number of lags, α_i is a parameter to be determined and ε_t, is called the white noise. The pair hypothesis in this model is

H_0 : $\phi = 0$ Vs H_A : $\phi < 0$.

and is tested based on t-statistics of the coefficient ρ from the estimation of (11).

$$t_{\infty} = \frac{\hat{\phi}}{se(\hat{\phi})}, \quad (11)$$

where $\hat{\phi}$ is the estimate of ϕ and $se(\hat{\phi})$ is the coefficient of the standard error

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2.4 Kwiatkowski, Phillips, Schmidt, and Shin (KPSS) Test

The integration properties of a series y_t may also be investigated by testing: $H_o : y_t \sim I(0)$ Vs $H_A : y_t \sim I(1)$ That is, the null hypothesis that the data generating process is stationary is tested against a unit root [13]. If there is no linear trend term, they start from a data generating process.

$$y_t = x_t + z_t \quad (12)$$

where x_t is a random walk, $x_t = x_{t-1} + v_t, v_t \sim iid(0, \sigma_v^2)$ and z_t is a stationary process. In this framework the foregoing pair of hypothesis is equivalent to the pair:

$H_0 : \sigma_v^2 = 0$ Vs $H_A : \sigma_v^2 \neq 0$

The test statistic is as follows;

$$KPSS = \frac{1}{T^2}\sum_{t=1}^{T}\frac{S_t^2}{\hat{\sigma}_\infty^2} \quad \text{where} \qquad (13)$$

$S_t = \sum_{j=1}^{t}\hat{w}_j$ with $w_j = y_t - \bar{y}$ and $\hat{\sigma}_\infty^2$ is an estimator of $\sigma_\infty^2 = \lim_{T\to\infty} T^{-1} Var\left(\sum_{t=1}^{T} z_t\right)$

That is σ_∞^2 is an estimator of the long-run variance of the process Z_t

$w_j = 1 - \frac{j}{l_q + 1}$ is a Bartlett window with truncated lay l_q.

Reject null hypothesis if the test statistic is greater than the asymptotic critical values.

3. RESULTS AND DISCUSSION

Monthly data on consumer price index are taken from Statistical Bulletin of the Research Department of the Central Bank of Nigeria. This consumer price index is used to measure inflation rate by taking the logarithmic first difference of the CPI. For the interest rate, monthly data from IMF's (International Financial Statistics) was used. Discount rate (end of period) was used as a proxy for interest rate. Our data set consists of monthly observations of the two macroeconomic variables in the Nigeria economy for the period of 1970–2003.

The first step in the analysis of time series is to plot the observations against time usually called the time plot and observe the behaviour of the series. The time plots of the variables in levels and the time plot of the variables in first differences were carried out. To test for unit root, we apply the Augmented Dickey-Fuller (ADF) test and KPSS to the levels and first differences of the three variables. The ADF test consists of testing the null hypothesis of unit root against the alternative of no unit root.

The ADF test the null hypothesis of unit root against the alternative hypothesis of no unit root. For the levels, the test statistics are greater than the critical values or p-values are greater than significant values, gives the non-rejection of the null hypothesis. Otherwise, for the first differences the test statistics is less than the critical values or p-values are less than significant values, gives the rejection of the null hypothesis.

The results of the three variables are not stationary in levels but stationary in first differencing, therefore they are integrated of order one. The KPSS statistic tests the null hypothesis of stationarity against the alternative of unit root. The tests confirm that the three series are integrated of order one, tables 1and 2.

Table1: Results of ADF Unit Root Tests

	Level				***First difference***			
Variable	***Zero const***		***Const & trend***		***Zero const***		***Const***	
	T S	***P-value***	***T S***	***P-value***	***T S***	***P-value***	***T S***	***P-value***
Nominal	-0.397671	0.5409	-2.95317	0.147	19.6013	1.418e-041	7.11314	9.183e-012
Inflation	-15.2975	8.041e-033	-16.709	6.878e-052	22.7143	9.252e-042	22.6582	6.389e-058
Real	-16.1891	1.184e-034	-16.6222	1.968e-051	20.0842	9.232e-42	22.6655	6.389e-058

At level all the series are not stationary but they are stationary in difference.
Lag 0rders: Nominal is zero, Inflation is 2, and Real interest rate is 2.

Table 2: Results of KPSS Unit Root Test

	Level		***Difference***	
Variables	***Zero const***	***Const & trend***	***Zero const***	***Const.***
Nominal	8.4079	0.6249	0.0589	0.0271
Inflation	0.3066	0.0432	0.0050	0.0050
Real	0.3050	0.0487	0.0051	0.0050
Critical Value at 5%	0.463	0.146	0.463	0.146

At level all the series are not stationary but they are stationary in difference.
This result gives some preliminary inference on the full Fisher effect hypothesis. Hence the results indicate that all variables are stationary in their first differences, which indicate that all variables are integrated of order one, I(1), then the cointegration test can be performed.

3.1 Cointegration Test

The next stage in cointegration is the determining the information criteria to obtain the most parsimonious model for the data. Table 3 shows the lag length of the cointegration relation.

Table 3.: Result of lag order

		Lag Order			
Lag		***AIC***	***FPE***	***HQC***	***SIC***
4	Const&Trend	4	4	3	2
6	Const&Trend	4	4	3	2
8	Const&Trend	4	4	3	2
10	Const&Trend	4	4	3	2

The optimal lag length by minimizing one of the information criteria is four.
Using the Johansen test for cointegration see table 4 below.

Table 4: Result of cointegration test
Number of equations = 3
Lag order = 4

Rank	**Eigenvalue**	**Trace test**	**p-value**	**Lmax test**	**p-value**
0	0.62105	602.38	[0.0001]	392.02	[0.0001]
1	0.40121	210.35	[0.1211]	207.19	[0.1211]
2	0.0078078	3.1667	[0.1752]	3.1667	[0.1752]

There is one long-run equilibrium relationship in the variables. Because the null hypothesis is not rejected for the first rank, when the p-value is less than the significant value. In carrying out the cointegration rank test an unrestricted constant which allows for the presence of a nonzero intercept in the cointegrating relations as well as a trend in the levels of the endogenous variables are used. It was also observed that there is at least one zero eigenvalue, which shows that the process is integrated.

3.2 Fractional Cointegration Analysis

The method of estimation of the parameters in equation below is ordinary least square. The least square equation is given by

$$i_t = \alpha + \beta\pi_t + \eta_t$$

where $\boldsymbol{i_t}$ = nominal interest rate, π_t = is realized inflation rate, η_t = long-term memory process, such as an ARFIMA, α and β are parameters.

Table 5: OLS estimates

Variable	*Coefficient*	*Std. Error*	*t-statistic*	*p-value*	
Const	0.0507096	0.0236028	2.1485	0.03227	**
Inf	0.99639	0.00189945	524.5675	<0.00001	***
Real	0.996388	0.00190118	524.0882	<0.00001	***

The least squares equation is

$$i_t = 0.05071 + 0.99639\pi_t$$

The *p*-values of fisher hypothesis is statistically significant, their values are less than the significant values 0.05 and 0.01 for 5% and 1% significant levels respectively. The *p*-values and *t*-values of constant terms, α is statistically insignificant since their values are less than the significant level values 0.05 and 0.01. This shows a long-run relationship between interest rates and inflation which is consistent with the fisher hypothesis. Since β is expected to be one as there is a one-to-one relationship between interest rates and the expected inflation. Here β is 0.99639 which is approximately equal to one. This is a full effect of fisher hypothesis, but when it is positive and less than one it shows a partial effect of fisher hypothesis. This shows that there is a one-to-one relationship between interest rates and the expected inflation.

3.3 Estimation of ARFIMA by Geweke and Porter-Hudak method

The application of these procedures on residual series allows us to test the null hypothesis of a unit root (d = 1) against the alternative of fractional integration (d < 1). The fractional integration parameter d' is estimated by using the regression of equation (9).

Table 6: GPH estimation of d'

Variable	d'	sd.as	Sd.reg
Nint	0.4245	0.1812	0.1556
Inf	0.08873	0.1812	0.1932
Real	0.4265	0.1812	0.1744

Here sd.as is the standard deviation while sd.reg is the standard error deviation.

3.4 Fractional Cointegration Tests

The value of the estimated long memory parameter is used to fractionally difference the data. The newly obtained set of data is now used to perform cointegration, since all the fractional integrated part have been removed. The cointegration test is perform.
Using the Johansen test for cointegration see table 7 below.

Table 7: Result of cointegration test (GPH)
Number of equations = 3
Lag order = 4

Rank	**Eigenvalue**	**Trace test**	**p-value**	**Lmax test**	**p-value**
0	0.083614	69.344	[0.0001]	34.752	[0.0002]
1	0.052816	34.592	[0.0022]	21.596	[0.0022]
2	0.032125	12.995	[0.1253]	12.995	[0.1253]

There are two long-run equilibrium relationships in the variables. Because the null hypothesis is not rejected for all the ranks, when the p-value is less than the significant value. In carrying out the cointegration rank test an unrestricted constant which allows for the presence of a nonzero intercept in the cointegration relations as well as a trend in the levels of the endogenous variables are used. It was also observed that there is at least one zero eigenvalue, which shows that the process is integrated.
The value of the estimated long memory parameter is used to fractionally difference the data. The newly obtained set of data is now $\phi(L)x_t = c + \theta(L)\varepsilon_t$, which is an ARMA(p,q) series, and is taken and modeled as an ARMA(p,q) process since all the fractional integrated part have been removed. For the nominal interest rate, the model that minimizes the information criteria is ARMA(2,1), because it has the lowest AIC. The model for both inflation rate and the real interest rate is ARMA(1,1), because it has the lowest AIC.

To assess the adequacy of the Fisher hypothesis analysis the following tests were applied to the residuals: Autocorrelation and partial autocorrelation of residual, Portmanteau test for autocorrelation, ARCH-LM and White's test for heteroskedasticity [8], and test for normality of residual. In testing the autocorrelation and partial autocorrelation, if the residuals are uncorrelated, then the result is adequate. The result shows that there is no serial correlation observed in the residuals of the three variables, since the three series are within the 95% confidence interval. Portmanteau test for autocorrelation of residual shows that the *p*-values for the test applied on the residual vectors are less than significant value 0.05. This shows that there are no serial correlations in the residuals. ARCH-LM test shows that the *p*-values for the test applied on the residual vectors are greater than significant values 0.05. This shows that there are no conditional heteroskedasticity in the residuals.Jarque-Bera test for normality shows that the p-value for the variables are 0.0314, 0.0296 and 0.00324 which is less than significant values 0.05 in the three series. This means that the residuals are normally distributed. The skewness and kurtosis of the three variables shows that the distribution is symmetry and hence normal.

Fractional cointegration analysis involves two steps. First, the Fisher equation (2) is estimated with ordinary least squares; then the residual series is used to estimate the differencing parameter (*d*) by the use of Geweke and Porter-Hudak's. To compare the results from fractional cointegration with those from conventional cointegration, the Johansen cointegration test is performed to identify any possibility of long run relationship between interest rates and inflation. The results are also reported in Table 4. Cointegration between interest rates and inflation shows that there is partial Fisher hypothesis. But when the fractional cointegration tests was carried out on the fractional series using the GPH method, the result shows that there is full Fisher effect on the residuals, showing the validity of the Fisher hypothesis in Nigeria. Since the residuals are fractionally integrated, the fractional difference parameter appears to be significantly different from zero. The results indicate that evidence of a stable long run Fisher effect is found when a more generalized procedure such as ARFIMA is used. The conventional unit root tests that limit the differencing parameter to 0 and 1, however, provide results that invalidate the Fisher effect, suggesting that the long run equilibrium relationship between interest rates and inflation does not exist. Therefore, our results confirm that, the conventional cointegration tests are more restrictive than their fractional counterparts. This implies that the stationary finding of real interest rates provides convincing foundation for various capital asset pricing models [12] and also monetary policy can be used as an effective tool to influence long-term interest rates in Nigeria [9]

4. CONCLUSION

The study employs an Autoregressive Fractionally Integrated Moving Average (ARFIMA) process to test the validity of the Fisher hypothesis, which proposes a positive relationship between nominal interest rates and inflation by applying the fractional cointegration technique in the Nigeria economy. The results suggest that nominal interest rates and inflation are partially cointegrated when the Johansen Cointegration test is employed. The results further indicate that the residuals are stationary. In contrast, stationarity of the error term is supported when fractional integration is used. The Geweke and Porter-Hudak (GPH) test results indicate that the residuals are fractionally integrated. Therefore, the results show that there is a stable long-run relationship between nominal interest rates and inflation suggesting the validity of the Fisher hypothesis.

In general, long-run relationship in between nominal interest rates and inflation rates has been identified by fractional cointegration test.

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