On Fractionally Integrated Logistic Smooth Transitions in Time Series

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Long memory and nonlinearity are two key features of some macroeconomic time series which are characterized by persistent shocks that seem to rise faster during recession than it falls during expansion. A variant of nonlinear time series model together with long memory are used to examine these features in inflation series for three economies. The results which compares favourably with that of van Dijk et al. (2002) elicit some interesting attributes of inflation in the developed and developing economies.

Keywords: Fractional integration, Long memory, Smooth transition autoregression, Inflation rates, Time series.

JEL Classification: C22, C51, C87.

1. Introduction

The era of nonlinear modelling has come to complement linear modelling in financial or econometric time series. This is due to the fact that many real world problems do not satisfy the assumptions of linearity and/or stationarity. The classical theory of stationarity and linearity may not apply to some economic, finance and macroeconomic series because they consider series at its level, $I(0)$; first order integrated series, $I(1)$ as well as higher order integrated series (Box and Jenkins, 1976). Hassler and Wolters (1995) considered a case of long memory, $I(0 < d < 0.5)$ for inflation data from five industrialized countries and found that the series are all within the long memory range.

The nonlinearity property of economic series can also be justified by the existence of asymmetry in inflation's dynamics (Mourelle *et* al., 2011). In order to consider these possible nonlinearities, it is necessary to have econometric models that are able to generate different dynamics according to the business cycle phase. (see Granger and Teräsvirta (1993); Teräsvirta (1994)). van Dijk *et* al. (2002) present the modelling cycle for specification of smooth transition autoregressive (STAR) model which include estimation of differencing parameter, testing for nonlinearity, parameter estimation and model adequacy tests, in the case where the transition function is the logistic function and applied this on US monthly unemployment rate. Smallwood (2005) and Boutahar *et* al. (2008) extend these results to the fractionally integrated STAR (FISTAR) model with an exponential transition function. The model was applied to measure the purchasing power

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by considering the real exchange rate data for twenty countries. This model is still new and has to be tried beyond its applicability to exchange rates.

This paper therefore seeks to examine the dynamics and application of fractionally integrated logistic STAR (FILSTAR) model on inflation rates with a view to obtaining better parameter estimates and reliable forecasts. The remaining sections of the paper are then organized as follows: Section 2 gives the general review of the FISTAR model and the linearity tests. Section 3 discusses the estimation of the model; Section 4 presents the results of the analysis and Section 5 gives the conclusion.

2. The FISTAR Model Specification

A Fractionally Integrated (FI) time series process $\{X_t\}, t=1,...,T$ is considered as

$$(1-B)^d X_t = y_t \tag{1}$$

Where B is the backward shift operator, d is the non-integer fractional differencing parameter and y_t is a covariance-stationary process. For fractionally integrated process in (1), the integration parameter d assumes values within the stationary and invertible range $-0.5 < d < 0.5$ (Sowell, 1992a; Mayoral, 2007).For $0 < d < 0.5$, X_t is a stationary long memory process in the sense that autocorrelations are not absolutely summable but rather at a much slower hyperbolic rate. It exhibits nonstationary process if $0.5 \le d < 1$.

Applying the Maclaurin's series expansion around $B=0$, the fractional difference operator is expanded as,

$$(1-B)^d = 1 - dB - \frac{d(1-d)B^2}{2!} - ... = \sum_{j=0}^{\infty} \frac{\Gamma(-d+j)}{\Gamma(-d)\Gamma(j+1)} B^j \tag{2}$$

where the Euler gamma function,

$$\Gamma(z) = \int_0^{\infty} s^{z-1} e^{-s} ds = (z-1)! \qquad z > 0 \tag{3}$$

Based on (2) and (1), the fractionally integrated STAR (FISTAR) model of order p is expressed as,

$$\begin{aligned} &\sum_{j=0}^{\infty} \frac{\Gamma(-d+j)}{\Gamma(-d)\Gamma(j+1)} B^j X_t = y_t \\ &y_t = \phi_1' \tilde{y}_t^{(p)} \left(1 - F(s_t;\gamma,c)\right) + \phi_2' \tilde{y}_t^{(p)} F(s_t;\gamma,c) + \varepsilon_t \end{aligned} \tag{4}$$

where $t = 1,2,...,T$, $\tilde{y}_t^{(p)} = (1, y_{t-1},..., y_{t-p})'$, $\phi_i = (\phi_{i0}, \phi_{i1},...,\phi_{ip})'$ and i=*1,2*. The ε_t is assumed to be a difference sequence distributed with $E(\varepsilon_t | \Omega_{t-1}) = 0$ and $E(\varepsilon_t^2 | \Omega_{t-1}) = \sigma^2$ with

$\Omega_{t-1} = y_{t-1}, y_{t-2}, ..., y_{1-(p-1)}, y_{1-p}$ representing the past history of the time series. Following Teräsvirta (1994), the transition variable s_t is assumed to be a lagged endogenous variable, that is, $s_t = y_{t-l}$ for certain integer $0 < l \leq p$. At point l, nonlinearity is sharper. For the case where 1 or 2 autoregressive parameters determine the linear part of the STAR model, the inequality $l > p$ holds. In the general FISTAR model in (4) above, the transition function $F(s_t;\gamma,c)$ is assumed to be either of logistic or exponential form (Teräsvirta, 1994) as given below:

$$F(s_t;\gamma,c) = \frac{1}{1+\exp(-\gamma(s_t - c))}, \quad \gamma > 0 \tag{5}$$

$$F(s_t;\gamma,c) = 1 - \exp\left(-\gamma(s_t - c)^2\right), \quad \gamma > 0 \tag{6}$$

In that case, using either (5) or (6) in the FISTAR model in (4) leads to fractionally integrated logistic STAR (FILSTAR) and fractionally integrated exponential STAR (FIESTAR) models respectively. The γ is the slope parameter and c, the intercept in the transition function. In the FILSTAR and FIESTAR models mentioned above, it is clear that the models reduces to linear autoregressive fractionally integrated (ARFI) of order p when the transition function, $F(s_t;\gamma,c) = 0$ or 1, that is shifting between two extreme linear regimes after staying in nonlinear region for some time. The fractional parameter *d*, the autoregressive parameters, ϕ_i and nonlinear parameters, γ and c make the FISTAR model potentially useful for capturing both long memory and nonlinear smooth transition features of the time series, X_t (Boutahar *et al*., 2008).

STAR modelling approach of Teräsvirta (1994) has been modified to capture our specification procedure for FISTAR, as it is proposed by van Dijk et al. (2002):

1. Specify a linear ARFI (*p*) model by selecting the autoregressive order *p* by means of Akaike and Schwarz information criteria (Akaike, 1974 and Schwarz, 1978).
2. Test the null hypothesis of linearity against the alternative of a FISTAR model.
3. Specify the model STAR model by choosing between the two competing transition functions.
4. Estimate the parameters in the specified FISTAR model.
5. Evaluate the estimated model using misspecification tests (no residual autocorrelation, serial correlation, normality test, ARCH test and others).

Teräsvirta (1994) follows the approach of Luukkonen, Saikkonen and Teräsvirta (1988) in replacing the transition function $F(s_t;\gamma,c)$ with a suitable Taylor series approximation about $\gamma = 0$ and test linearity by means of a Lagrange multiplier (LM) statistic. Luukkonen *et al*. (1988) then consider testing the null hypothesis $H_0 : \gamma = 0$ of linearity against the alternative of logistic STAR (LSTAR) nonlinearity by using the LSTAR function. The third order Taylor's series approximation of the logistic model is then given as auxiliary regression model,

$$y_t = \phi' \tilde{y}_t^{(p)} + \beta_1' \tilde{y}_t^{(p)} s_t + \beta_2' \tilde{y}_t^{(p)} s_t^2 + \beta_3' \tilde{y}_t^{(p)} s_t^3 + \tilde{\varepsilon}_t \tag{7}$$

where $\beta_i = (\beta_{i1},...,\beta_{ip})'$, $i = 1,2,3$ are functions of the parameters ϕ_1, ϕ_2, γ and c. The null hypothesis then becomes $H_0 : \beta_1 = \beta_2 = \beta_3 = 0$, which implies the selection of linear model. The approach of Teräsvirta (1994) is to specify the model based on the nested hypotheses:

$$H_{O1} : \beta_3 = 0$$

$$H_{O2} : \beta_2 = 0 | \beta_3 = 0 \; H_{O3} : \beta_1 = 0 | \beta_2 = \beta_3 = 0 \; (8)$$

which is supported by Escribano and Jordá (2001). This sequence of hypotheses implies that rejection of H_{O1} suggests acceptance of LSTAR model. Also, rejection of H_{O2} is an acceptance of exponential STAR (ESTAR) model. Lastly, rejection of H_{O3} implies the selection of LSTAR model.

Analytically, the test procedures follow:

1. Regressing y_t on $\{1, y_{t-j}; j = 1,2,..., p\}$ to form $\hat{\varepsilon}_t$, $(t = 1,2,...,T)$ and computing the residual sum of squares $SSR_0 = \sum_{t=1}^{T} \hat{\varepsilon}_t^2$;
2. regressing $\hat{\varepsilon}_t$ on $\{1, y_{t-i}, y_{t-i}s_t^k,; i = 1,2,..., p; k = 1,2,3\}$ to form the residuals $\tilde{\varepsilon}_t \; (t = 1,2,...,T)$ and $SSR_1 = \sum_{t=1}^{T} \tilde{\varepsilon}_t^2$ and
3. computing the test statistic $F = \dfrac{(SSR_0 - SSR_1)/3(p+1)}{SSR_0/(T - 4(p+1))}$ and $F \approx F_{3(p+1),\; T-4(p+1)}$

3. Estimation of FISTAR Parameters

The estimation of FISTAR model starts by estimating the fractional difference parameter in the series. This is achieved using Hurst (1951) by computing the Hurst coefficient. He used the non-parametric approach by employing a rescaled statistic (R/S) defined as:

$$R/S = 1/S_T(q)\left(\sup_{1\le m\le T}\sum_{j=1}^{m}\left(X_j - \overline{X}\right) - \inf_{1\le m\le T}\sum_{j=1}^{m}\left(X_j - \overline{X}\right)\right) \quad (9)$$

where S_T is the MLE estimate of standard deviation from time series, X_j. Then, $S_T(q) = S_T + 2\sum_{j=1}^{q} w_j(q)\hat{\gamma}_j$ and $w_j(q) = 1 - j/(q+1)$ such that $q < T$ (Lo, 1991).The Hurst coefficient, H is then estimated by,

$$\hat{H} = \frac{1}{\log(T)}\log(R/S). \quad (10)$$

The fractional differencing parameter, d is then obtained as,

$$\hat{d} = \hat{H} - 0.5. \quad (11)$$

The approximate values of y_t can be obtained in the time domain as in Sowell (1992a, b). The time domain approach follows the Binomial Theorem representation of $(1-B)^d$. This implies that y_t is approximated by using $\hat{d}$ estimated by the Hurst estimation approach and a truncated fractionally differenced series is given as,

$$\tilde{y}_t = \sum_{j=t}^{\infty} \frac{\Gamma\left(-\hat{d}+j\right)}{\Gamma\left(-\hat{d}\right)\Gamma\left(j+1\right)} X_{t-j} \tag{12}$$

$$= \sum_{k=0}^{\infty} \frac{\Gamma\left(-\hat{d}+t+k\right)}{\Gamma\left(-\hat{d}\right)\Gamma\left(t+k+1\right)} X_k \tag{13}$$

From (12), it is clear to set $X_{t-j}=0$ for $t-j$ outside of the sample, *T.*

The second transformation approach uses the frequency domain approach of Geweke and Porter-Hudak (1983). Here, the Fourier transform of the observed series, X_t is pre-multiplied by the Fourier transform of the fractional differencing operator based on $\hat{d}$, and then compute the inverse Fourier transform. The final series obtain follows an autoregressive moving average (ARMA (*p*,*q*)) process.

According to van Dijk et. al. (2002), after the estimation of the fractional difference parameter, all the remaining parameters in the STAR model are estimated together. Beran (1995) suggests approximate maximum likelihood (AML) estimator for invertible and possible nonstationary autoregressive fractionally integrated moving average (ARFIMA) model which allows for regime switching autoregressive dynamics. This estimator then minimizes the sum of squared residual of the STAR model as,

$$S\left(\phi_1,\phi_2,\gamma,c\right) = \sum_{i=1}^{T} \varepsilon_t^2\left(\phi_1,\phi_2,\gamma,c\right). \tag{14}$$

We now consider the choice of appropriate starting value parameters and the estimation of the smoothness parameter in the transition function. The estimation procedure can be simplified by concentrating the sum of squares function since the parameters γ and c in the transition function imply STAR model of parameters ϕ_1 and ϕ_2 and this makes the FISTAR model linear in the remaining parameters (Leybourne *et* al. (1998),van Dijk et al. (2002)). Then, estimates of $\phi=\left(\phi_1',\phi_2'\right)'$ can be obtained by ordinary least squares (OLS) as

$$\hat{\phi}\left(\gamma,c\right) = \frac{\sum_{t=1}^{T}\tilde{y}_t^{(p)}\left(\gamma,c\right)y_t}{\sum_{t=1}^{T}\tilde{y}_t^{(p)}\left(\gamma,c\right)\tilde{y}_t^{(p)}\left(\gamma,c\right)'} \tag{15}$$

where $\tilde{y}_t^{(p)}\left(\gamma,c\right)=\left[\tilde{y}_t'^{(p)}\left(1-F(s_t;\gamma,c\right),\tilde{y}_t'^{(p)}F(s_t;\gamma,c)\right]'$ and the notation $\hat{\phi}\left(\gamma,c\right)$ is used to indicate that the estimate of ϕ is conditional upon γ and c. Thus, the sum of squares function $Q_N(\varphi)$ can be concentrated with respect to ϕ_1 and ϕ_2 as,

$$Q_N(\gamma,c)=\sum_{t=1}^{T}\left[y_t-\hat{\phi}(\gamma,c)'\tilde{y}_t^{(p)}(\gamma,c)\right]^2 \quad (16)$$

and $Q_N(\gamma,c)$ will be minimized with respect to parameters γ and c only. The estimate of γ is very difficult to obtain when it is large because its large value makes the STAR model to be similar to threshold autoregressive (TAR) model as the transition function, $F(s_t;\gamma,c)$ comes close to a step function and this function is then standardized. To obtain an accurate estimate, there should be many observations, s_t in the neighbourhood of c and this implies small deviation. Sensible starting value for the nonlinear optimization of the STAR model can easily be obtained by considering a two dimensional grid search over γ and c. Then for any set of the two values $\left(A_j^c, A_k^\gamma\right)$, the parameter vectors (ϕ_1,ϕ_2) are then estimated through ordinary least squares (OLS). The outcome of this is a set of estimates, $\left(\hat{\phi}_1^0,\hat{\phi}_2^0,\hat{\gamma}^0,\hat{c}^0\right)$. Practically, most estimation software for STAR modelling are designed to follow the specification,

$$y_t=\phi_1'\tilde{y}_t^{(p)}+\left(\phi_2-\phi_1\right)'\tilde{y}_t^{(p)}F\left(s_t;\gamma,c\right)+\varepsilon_t \quad (17)$$

where the nonlinear part is on one side of the model.

4. Data Analysis and Results

The monthly macroeconomic time series data on inflation are sourced variously from Federal Reserve Bank of St. Louis (US Inflation data), National Bureau of Statistics (Nigerian Inflation data) and Office of National Statistics (UK Inflation data). These series range from January 1991 to December 2009 (T = 228). These data are large enough to adjust for the lag operations performed during model specification and estimation. Preliminary analyses have been performed using EViews 5 software from Quantitative Micro Software, LLC. Smooth Transition Regression (STR) analysis is performed using the R-STAR contributed package available through R Development Core Team (2009) for the analysis of nonlinear time series (Balcilar, 2008).

Table 1: Descriptive Statistics on Time Series

Statistics	Nigeria Inflation Series	US Inflation Series	UK Inflation Series
Minimum	0.90	-2.10	0.50
Maximum	78.50	5.65	8.50
Mean	22.020	2.650	2.351
Std. Dev.	19.856	1.179	1.574
Skewness	1.362	-0.867	2.252
Kurtosis	3.573	5.855	8.063
Jarque-Bera	73.596	105.957	436.189
Probability	0.0000	0.0000	0.0000

Table 1 shows the significance of the Jarque-Bera test of normality at 5% level for inflation series in Nigeria (NIIR), US (USIR) and the UK (UKIR) which implies that inflation rates are not normally distributed. Nigerian inflation rates rose as high as 78.50 between 1995 and 1996.The minimum inflation rate was experienced in 2000. US and UK displayed fair level of stable inflation between 1991and 2008. The time plots clearly display asymmetric behaviours and high persistence of inflation over the years and this is in accordance to van Dijk *et* al. (2002).

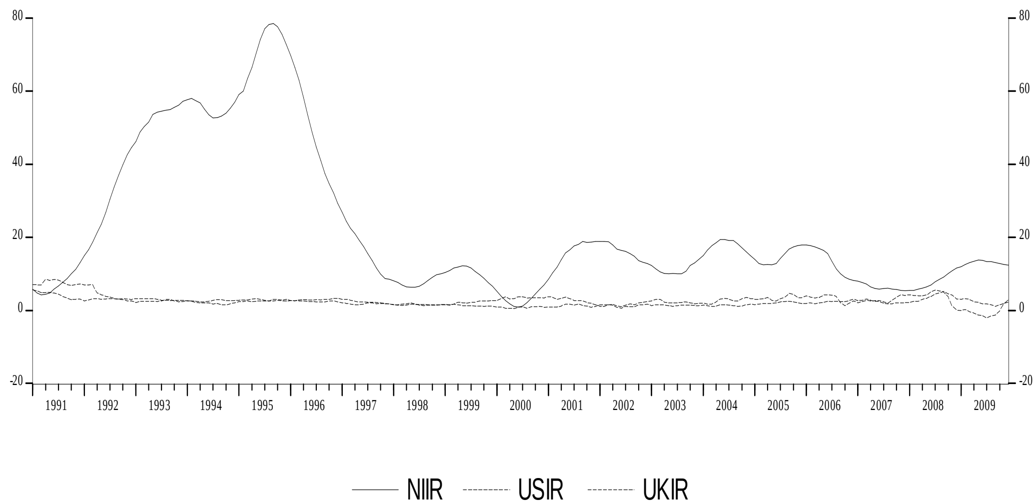

Fig. 1: Time Plots of Inflation Rates

Probing further into the dynamics of stationarity based on augmented Dickey Fuller (ADF) unit root tests which has the null hypothesis of unit root. The results of the ADF test indicate rejection of this null hypothesis at 1, 5 and 10% for Nigeria and US inflation series. UK inflation is stationary at 5 and 10% level. The ADF test is confirmed using the KPSS test of long memory as reported jointly with ADF test in Table 1. This test has been applied in Lee and Schmidt (1996) to test for stationarity in long memory range. It has the null hypothesis of series stationarity against long memory. Subjection of our inflation series to KPSS shows rejection of null hypothesis. Therefore, long memory is confirmed in the inflation series.

Table 2: Stationarity Tests on Inflation Time Series

<table>
<tr><td></td><td colspan="3">Nigerian Inflation Series(NIIR)</td><td colspan="3">US Inflation Series (USIR)</td><td colspan="3">UK Inflation Series (UKIR)</td></tr>
<tr><td>Test</td><td colspan="2">ADF</td><td>KPSS</td><td colspan="2">ADF</td><td>KPSS</td><td colspan="2">ADF</td><td>KPSS</td></tr>
<tr><td>Statistic</td><td colspan="2">-3.522</td><td>0.752</td><td colspan="2">-4.589</td><td>0.737</td><td colspan="2">-3.055</td><td>1.212</td></tr>
<tr><td>1%</td><td>-3.459</td><td rowspan="3">(0.0083)</td><td>0.739</td><td>-3.459</td><td rowspan="3">(0.0002)</td><td>0.739</td><td>-3.459</td><td rowspan="3">(0.0083)</td><td>0.739</td></tr>
<tr><td>5%</td><td>-2.874</td><td>0.463</td><td>-2.874</td><td>0.463</td><td>-2.874</td><td>0.463</td></tr>
<tr><td>10%</td><td>-2.574</td><td>0.347</td><td>-2.574</td><td>0.347</td><td>-2.574</td><td>0.347</td></tr>
</table>

Since fractional differencing is possible in the inflation series based on stationarity tests, Table 3then shows the estimates of the fractional difference parameter computed after Hurst (1951). The fractional difference estimates are actually in long memory range. The estimates of 0.3289 reported for Nigeria is another indication of increase in the inflation rate as compared with US and UK inflation rates.

Table 3: Estimation of Fractional Difference Parameters

	Non-Parametric Approach		
	Nigerian Inflation Series (NIIR)	US Inflation Series (USIR)	UK Inflation Series (UKIR)
$\hat{d}$ *R/S*	0.3289 (90.0325)	0.1542 (34.8870)	0.2819 (69.7733)

The series are then fractionally differenced based on the estimates in Table 3 to have “pure” stationary series. The transformed series, as subjected to stationarity tests in Table 4 give acceptance of null hypothesis of stationarity of KPSS test as against the alternative hypothesis. Fractional differencing actually removed long memory effects in the series.

Table 4: Stationarity Tests on Fractionally Differenced Time Series

	Nigerian Inflation Series (NIIR)			US Inflation Series (USIR)			UK Inflation Series (UKIR)		
Test	ADF		KPSS	ADF		KPSS	ADF		KPSS
Statistic	*-3.122*		*0.416*	*-3.186*		*0.1639*	-6.046		0.2543
1%	-3.459		0.739	-3.459		0.739	-3.459		0.739
5%	-2.874	(0.0264)	0.463	-2.874	(0.0222)	0.463	-2.874	(0.0000)	0.463
10%	-2.574		0.347	-2.574		0.347	-2.574		0.347

Modelling cycle of FISTAR model continues by fitting linear AR models to the inflation series. Optimal models were obtained based on minimum values of AIC and SIC. So, AR (2), AR (4) and AR (2) models are optimal models for Nigeria, US and UK inflation series respectively. Table 5 shows the result of the first stage in nonlinear STAR testing. Nonlinearity is found to be sharper at different lags, $l = 4$, $l = 3$ and $l = 1$ for Nigerian, US and UK inflation series. These are determined as least significant points for $0 < l \leq p$ or $l > p$. Note that this is determined based on $l > p$, that is certain point outside the model lags. Nonlinear smooth transitions are tested in these sharper points. The test results as given in Table 6 shows at least the significance of one of the β_i based on the auxiliary regression in (7) which is an indication that the three inflation series exhibit nonlinear smooth transition autoregressive behaviour.

Table 5: Determination of the Transition Variable, $s_t = y_{t-l}$

	Nigeria Inflation Series					US Inflation Series				UK Inflation Series			
Dela	1	2	3	4	5	1	2	3	4	1	2	3	4
Prob	0.013	0.010	0.007	***0.005***	0.007	0.000	0.000	***0.000***	0.000	***0.224***	0.318	0.327	0.418

Based on the nested hypothesis in (8), LSTAR models are specified for the three inflation rates unlike ESTAR model specified for exchange rates in (Boutahar, 2008). The specification of LSTAR model for inflation series support the fact that inflation series are assymetric.

Table 6: STAR Nonlinearity Test and Model Specification

	Nigeria Inflation Series			US Inflation Series			UK Inflation Series		
β_i	1	2	3	1	2	3	1	2	3
Prob..	0.37617	***0.00094216***	0.43241	***0.031438***	***8.34E-07***	***0.00019***	0.60882	0.69793	***0.03607***
Model	LSTAR			LSTAR			LSTAR		

Estimation results are presented in Tables 7-9. Note subset of the insignificant nonlinear parameters cannot be taken in the RSTAR contributed package for R software. So, the STAR and FISTAR models presented are optimal.

Table 7: Estimated LSTAR Model for Nigerian Inflation Rates

	Model	AR		ARFI		LSTAR		FILSTAR	
	Estimator	Estimates	Prob.	Estimates	Prob.	Estimates	Prob.	Estimates	Prob.
Linear part	$\hat{\phi}_{10}$	21.65910	0.00000	1.64978	0.0000	0.23993	0.0001	0.03211	0.4513
	$\hat{\phi}_{11}$	1.93548	0.00000	-0.48204	0.0001	1.98177	0.0000	1.58115	0.0000
	$\hat{\phi}_{12}$	-0.94128	0.00005	-0.18114	0.0030	-1.00173	0.0000	-0.32336	0.0538
	$\hat{\phi}_{13}$							-0.26088	0.0035
Nonlinear part	$\hat{\phi}_{20}$					2.79471	0.0398	1.65748	0.2963
	$\hat{\phi}_{21}$					-0.03051	0.0309	-0.64939	0.0815
	$\hat{\phi}_{22}$							0.17342	0.7273
	$\hat{\phi}_{23}$							0.95191	0.0324
	$\hat{\phi}_{24}$							-0.67563	0.0014
	$\hat{\gamma}$					2.92593	0.1887	10.98377	0.3251
	$\hat{c}$					43.88512	0.0000	15.10189	0.0000
	$\hat{l}$					4		4	
Diagnostic tests	*AIC*	332.0028		310.4322		300.2108		299.1587	
	SIC	342.2908		321.5621		324.0610		336.6868	
	R^2	0.9994		0.9959		0.9995		0.9963	
	ARCH-LM	0.5657	0.0452	1.8344	0.0177	2.08314	0.0150	3.43958	0.0650

In this Table, the point estimates of slope parameters $\hat{\gamma} = 2.92592$ for LSTAR and $\hat{\gamma} = 10.98377$ for FISTAR models indicate that the transition between the two regimes of STAR model is slow and fast. Fractional integration, in fact led to improved fit as indicated in the estimates of R^2.This implies that ARFI and FISTAR models are preferred to AR and STAR models respectively but the introduction of FI does not lead to improve fit in the FISTAR model (van Dijk et al., 2002).

Table8: Estimated LSTAR Model for US Inflation Rates

	Model	AR		ARFI		LSTAR		FILSTAR	
	Estimator	Estimates	Prob.	Estimates	Prob.	Estimates	Prob.	Estimates	Prob.
Linear part	$\hat{\phi}_{10}$	2.72725	0.0000	1.24780	0.0000	0.16843	0.1370	0.01088	0.6068
	$\hat{\phi}_{11}$	1.43073	0.0000	-0.54730	0.0000	1.28605	0.0000	1.16477	0.0000
	$\hat{\phi}_{12}$	-0.73275	0.0000	0.17335	0.0113	-0.52379	0.0000	-0.49817	0.0000
	$\hat{\phi}_{13}$	0.36304	0.0024			0.17673	0.0239	0.24095	0.0084
	$\hat{\phi}_{14}$	-0.14600	0.0397						
Nonlinear part	$\hat{\phi}_{20}$					5.36344	0.0818	-1.67135	0.3084
	$\hat{\phi}_{21}$					1.13672	0.0443	0.86859	0.3403
	$\hat{\phi}_{22}$					-2.24124	0.0123		
	$\hat{\gamma}$					7.67672	0.5270	6.05677	0.4182
	$\hat{c}$					4.90000	0.0000	1.64402	0.0000
	$\hat{l}$					3		3	
Diagnostic tests	*AIC*	206.8093		200.4433		179.6015		186.8999	
	SIC	223.9560		213.4328		210.3063		214.2287	
	R^2	0.8953		0.8223		0.9067		0.8383	
	ARCH-LM	1.9750	0.0118	1.5736	0.0196	2.1640	0.0142	4.3252	0.0377

Table 8 also shows the estimated slope parameters of $\hat{\gamma} = 7.67672$ for LSTAR and $\hat{\gamma} = 6.05677$ for FISTAR models indicating that the transition between the two regimes of STAR model is slow. The values of the slope parameters are closed to each other because of small value of the difference parameter, $\hat{d} = 0.1542$. Also, FI led to improved fit but STAR model is preferred to FISTAR model.

From Table 9, value of the slope parameter dropped from $\hat{\gamma} = 33.7800$ to $\hat{\gamma} = 6.05677$ indicating fast to slow smooth transitioning from one regime to the other.FI also improved the model fit from AR and STAR to ARFI and FISTAR models respectively.

Conclusion

This paper has considered a model proposed in Van Dijk*et* al. (2002) to model macro econometric time series that is asymmetric. The model is found to be able to describe both long memory and nonlinearity through fractional integration and smooth transition modelling. Inflation dynamics display high persistence which is an evidence of long memory. Stationary time series models can be improved by fractionally integrating the series. Also, time series model can be improved upon by considering and modelling nonlinearity in the series. We would have expected FILSTAR model to be the better one out of the four models for each of the inflation series but this is not the case for the three series. This indicates the serious competition arising between fractional integration and nonlinearity of series.

Table9: Estimated LSTAR Model for UK Inflation Rates

	Model	AR		ARFI		LSTAR		FILSTAR	
	Estimator	Estimates	Prob.	Estimates	Prob.	Estimates	Prob.	Estimates	Prob.
Linear part	$\hat{\phi}_{10}$	3.285163	0.0065			0.133100	0.0164	0.01088	0.6068
	$\hat{\phi}_{11}$	1.12114	0.0000	0.84805	0.0000	1.06600	0.0000	1.16477	0.0000
	$\hat{\phi}_{12}$	-0.13552	0.0443			-0.13540	0.0354	-0.49817	0.0000
	$\hat{\phi}_{13}$							0.24095	0.0084
Nonlinear part	$\hat{\phi}_{20}$					1.59100	0.5418	-1.67135	0.3084
	$\hat{\phi}_{21}$					-0.184300	0.5709	0.86859	0.3403
	$\hat{\gamma}$					33.7800	1.0000	6.05677	0.4182
	$\hat{c}$					6.02500	1.0000	1.64402	0.0000
	$\hat{l}$					1		1	
Diagnostic tests	*AIC*	137.9201		197.5456		129.4520		186.8999	
	SIC	148.2081		201.0211		153.3958		214.2287	
	R^2	0.9566		0.8335		0.9574		0.8383	
	ARCH-LM	0.0003	0.0985	0.0059	0.0939	0.05279	0.0818	1.70649	0.0193

Future research work should consider forecasts performance of these models. Fractional integration can also be combined with some other nonlinear time series models in order to confirm the inability FI-nonlinear model to give best fit. With this, the dominant feature between long memory and nonlinearity may be assessed.

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Best Linear Unbiased Estimate using Buys-Ballot Procedure when Trend-Cycle Component is Linear

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The Best linear unbiased estimate (BLUE) of Buys-Ballot estimates when trend-cycle component is linear are discussed in this paper. The estimates are those proposed by Iwueze and Nwogu (2004). Discussed are the Chain Based Estimation (CBE) method and the Fixed Based Estimation (FBE) method. The variates for the CBE method were found to have constant mean and variance but are correlated with only one significant autocorrelation coefficient at lag one. The variates for the FBE method were found to have constant mean, non-constant variance but with constant autocorrelation coefficient at all lags . Because the CBE variates exhibit stationarity, Best Linear unbiased estimators of the slope and intercept were derived. Numerical examples were used to illustrate the methods.

Keywords: Best linear unbiased Estimator, Buys-Ballot derived variables, stationarity, minimum variance, Moving Average Process of order one.

JEL Classification: C22, C32.

Introduction

Iwueze and Nwogu (2004) developed two methods of estimating the parameters of a linear trend-cycle component from the periodic averages of the Buys-Ballot Table (Table 1). The procedure was initially developed for short period series in which the trend-cycle component (M_t) is jointly estimated and can be represented by a linear equation:

$$M_t = a + bt,\ t = 1, 2, ..., n \qquad (1.1)$$

where a is the intercept, b is the slope and t is the time point.

The two alternative methods are: (i) the Chain Base Estimation (CBE) method which computes the slope from the relative periodic average changes and (ii) the Fixed Base Estimation (FBE) method which computes the slope using the first period as the base period for the periodic average changes.

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For short series in which the trend and cyclical components are jointly estimated, the two contending models for time series decomposition are the additive and multiplicative models (Chatfield (2004), Kendall and Ord (1990)).

Additive model: $$X_t = M_t + S_t + e_t \qquad (1.2)$$

Multiplicative model: $$X_t = M_t \; S_t \; e_t \qquad (1.3)$$

where M_t is the trend-cycle component; S_t is the seasonal component with the property that $S_{(i-1)s+j} = S_j$, $i = 1, 2, ..., m$, and e_t is the irregular or random component. Results obtained by Iwueze and Nwogu (2004) for the additive and multiplicative models are summarized in Table 2.

It is clear from Table 2 that the trend-cycle estimates are the same for both the additive and multiplicative models. We can also note from Table 2 that estimates of the intercept (a) and the seasonal indices $\left(S_j, i = 1, 2, ..., m\right)$ depend on the estimate of the slope (b). This paper will therefore concentrate on the Best Linear Unbiased Estimator (BLUE) of the slope (b) parameter. For the additive model (1.2), it is assumed that the irregular/error component e_t is the Gaussian $N\left(0,\sigma_1^2\right)$ white noise, while for the multiplicative model (1.3), e_t is the Gaussian $N\left(0,\sigma_1^2\right)$ white noise. For the additive model (1.2), the assumption is that the sum of the seasonal component over a complete period is zero $\left(\sum_{j=0}^{s} S_j = 0\right)$, while for the multiplicative model (1.3), the sum of the seasonal component over a complete period is $\left(\sum_{j=0}^{s} S_j = s\right)$.

Table 1: Buys-Ballot Table

p	Season								
	1	2	…	j	…	s	$T_{i.}$	$\overline{X}_{i.}$	$\hat{\sigma}_{i.}$
1	X_1	X_2	…	X_j	…	X_s	$T_{1.}$	$\overline{X}_{1.}$	$\hat{\sigma}_{1.}$
2	X_{s+1}	X_{s+2}	…	X_{s+j}	…	X_{2s}	$T_{2.}$	$\overline{X}_{2.}$	$\hat{\sigma}_{2.}$
3	X_{2s+1}	X_{2s+2}	…	X_{2s+j}	…	X_{3s}	$T_{3.}$	$\overline{X}_{3.}$	$\hat{\sigma}_{3.}$
…	…	…	…	…	…	…	…	…	…
i	$X_{(i-1)s+1}$	$X_{(i-1)s+2}$	…	$X_{(i-1)s+j}$	…	$X_{(i-1)s+s}$	$T_{i.}$	$\overline{X}_{i.}$	$\hat{\sigma}_{i.}$
…	…	…	…	…	…	…	…	…	…
m	$X_{(m-1)s+1}$	$X_{(m-1)s+2}$	…	$X_{(m-1)s+j}$	…	X_{ms}	$T_{m.}$	$\overline{X}_{m.}$	$\hat{\sigma}_{m.}$
$T_{.j}$	$T_{.1}$	$T_{.2}$	…	$T_{.j}$	…	$T_{.s}$	$T_{..}$		
$\overline{X}_{.j}$	$\overline{X}_{.1}$	$\overline{X}_{.2}$	…	$\overline{X}_{.j}$	…	$\overline{X}_{.s}$		$\overline{X}_{..}$	
$\hat{\sigma}_{.j}$	$\hat{\sigma}_{.1}$	$\hat{\sigma}_{.2}$	…	$\hat{\sigma}_{.j}$	…	$\hat{\sigma}_{.s}$			$\hat{\sigma}_{..}$

$$T_{i.} = \sum_{j=1}^{s} X_{(i-1)s+j} \;,\; i = 1, 2, ..., m \qquad \bar{X}_{i.} = \frac{T_{i.}}{s} = \frac{1}{s}\sum_{j=1}^{s} X_{(i-1)s+j} \;,\; i = 1, 2, ..., m;$$

$$T_{.j} = \sum_{i=1}^{m} X_{(i-1)s+j} \;,\; j = 1, 2, ..., s \qquad \bar{X}_{.j} = \frac{T_{.j}}{m} = \frac{1}{m}\sum_{i=1}^{m} X_{(i-1)s+j} \;,\; j = 1, 2, ..., s;$$

$$T_{..} = \sum_{i=1}^{m} T_{i.} = \sum_{j=1}^{s} T_{.j} = \sum_{i=1}^{m}\sum_{j=1}^{s} X_{(i-1)s+j}; \qquad \bar{X}_{..} = \frac{T_{..}}{ms} = \frac{T_{..}}{ms},\; n = ms$$

$$\hat{\sigma}_{i.} = \sqrt{\frac{1}{s-1}\sum_{j=1}^{s}\left(X_{(i-1)s+j} - \bar{X}_{i.}\right)^2} \;,\; i = 1, 2, ..., m; \qquad \hat{\sigma}_{.j} = \sqrt{\frac{1}{m-1}\sum_{i=1}^{m}\left(X_{(i-1)s+j} - \bar{X}_{.j}\right)^2} \;,\; j = 1, 2, ..., s$$

$$\hat{\sigma} = \sqrt{\frac{1}{n-1}\sum_{i=1}^{m}\sum_{j=1}^{s}\left(X_{(i-1)s+j} - \bar{X}_{..}\right)^2}$$

Table 2: Buys-Ballot estimates for linear trend.

	Additive model (1.2)	**Multiplicative model (1.3)**
$T_{i.}$	$as + \frac{bs}{2}\left[(2i-1)s+1\right]$	$as + \frac{bs}{2}\left[(2i-1)s+1\right]$
$\bar{X}_{i.}$	$a + \frac{b}{2}\left[(2i-1)s+1\right]$	$a + \frac{b}{2}\left[(2i-1)s+1\right]$
$T_{.j}$	$ma + \frac{mb}{2}\left[2j+n-s\right] + mS_j$	$\left[ma + \frac{mb}{2}(2j+n-s)\right]S_j$
$\bar{X}_{.j}$	$a + \frac{b}{2}\left[2j+n-s\right] + S_j$	$\left[a + \frac{b}{2}(2j+n-s)\right]S_j$
$T_{..}$	$na + \frac{nb}{2}\left[n+1\right]$	$na + \frac{nb}{2}\left[n+1\right]$
$\bar{X}_{..}$	$a + \frac{b}{2}\left[n+1\right]$	$a + \frac{b}{2}\left[n+1\right]$
$\hat{b}(CBE)$	$\frac{\bar{X}_{m.} - \bar{X}_{1.}}{n-s}$	$\frac{\bar{X}_{m.} - \bar{X}_{1.}}{n-s}$
$\hat{b}(FBE)$	$\frac{1}{n-s}\sum_{i=2}^{m}\left(\frac{\bar{X}_{i.} - \bar{X}_{1.}}{i-1}\right)$	$\frac{1}{n-s}\sum_{i=2}^{m}\left(\frac{\bar{X}_{i.} - \bar{X}_{1.}}{i-1}\right)$
$\hat{a}$	$\bar{X}_{..} - \frac{\hat{b}}{2}\left[n+1\right]$	$\bar{X}_{..} - \frac{\hat{b}}{2}\left[n+1\right]$
S_j	$X_{.j} - \left[\bar{X}_{..} + \frac{\hat{b}}{2}(2j-s-1)\right]$	$X_{.j} \Big/ \left[\bar{X}_{..} + \frac{\hat{b}}{2}(2j-s-1)\right]$

The multiplicative model (1.3) can be linearized to become the additive model (1.4)

$$X_t^* = M_t^* + S_t^* + e_t^*,\; t = 1, 2, ..., n \qquad (1.4)$$

where $X_t^* = \log_e X_t$, $M_t^* = \log_e M_t$, $S_t^* = \log_e S_t$, $e_t^* = \log_e e_t$. The behaviour of $M_t^* = \log_e M_t$ when M_t is represented by a linear equation (1.1) have been studied by Iwueze and Akpanta

(2007) and it was shown that for $-0.01 \le b/a \le 0.06$, M_t^* could still be represented by a straight line $M_t^* = \alpha + \beta t$, with $\alpha = \log_e a$ and $\beta = b/a$. The behaviour of $S_t^* = \log_e S_t$ to achieve $\left(\sum_{j=0}^{s} S_j = s\right)$ have been studied by Iwueze et al (2008). The behaviour of $e_t^* = \log_e e_t$ for $e_t^* \sim N(0, \sigma^2)$ when $e_t \sim N(1, \sigma^2)$ have been studied by Iwueze (2007) and it was shown that the logarithmic transform of the left-truncated $N(1, \sigma^2)$ distribution is approximately normal when $\sigma < 0.1$. It follows that we can study the additive model (1.1) and apply the results obtain to the multiplicative model after linearization.

The main objective of this paper is to obtain the BLUE of the slope parameter for the additive model. Section 2 presents the covariance structure of CBE derived variables, while Section 3 presents the covariance structure of the FBE derived variables. Section 4 contains the determination of the BLUE for the CBE estimate of the slope parameter. Section 5 presents the simple average of the CBE derived variables, Section 6 contains the numerical examples while Section 7 contains the concluding remarks.

2. Covariance Analysis of the CBE Derived Variables: Additive Model

Under the CBE method, the estimate of the slope $(\hat{b})$ was calculated as the average of $\hat{b}_i^{(c)}$, $i = 1, 2, ..., m-1$ given by Iwueze and Nwogu (2004) as:

$$\hat{b}_i^{(c)} = \frac{\overline{X}_{(i+1).} - \overline{X}_{i.}}{s}, \; i = 1, 2, ..., m-1 \qquad (2.1)$$

For the additive model the assumption is that the irregular components are independent and identically normally distributed with mean zero and common variance $\sigma_1^2 = \sigma^2 [\; e_t \sim N(0, \sigma^2)]$. Under this assumption, $\bar{e}_{i.} \sim N\left(0, \frac{\sigma^2}{s}\right)$, $\bar{e}_{.j} \sim N\left(0, \frac{\sigma^2}{m}\right)$, $\bar{e}_{..} \sim N\left(0, \frac{\sigma^2}{n}\right)$.

Using (1.2), the periodic averages are given by

$$\overline{X}_{i.} = a + \frac{b}{2}[(2i-1)s+1] + \bar{e}_{i.}, \; i = 1, 2, ..., m \qquad (2.2)$$

Hence, our variable of interest is now given by

$$\hat{b}_i^{(c)} = \frac{1}{s}\left(\overline{X}_{(i+1).} - \overline{X}_{i.}\right) = b + \frac{1}{s}\left(\bar{e}_{(i+1).} - \bar{e}_{i.}\right), \; i = 1, 2, ..., m-1 \qquad (2.3)$$

Therefore, the expected value and variance of $\hat{b}_i^{(c)}$ are

$$E\left(\hat{b}_i^{(c)}\right) = E(b) + \frac{1}{s}E\left(\bar{e}_{(i+1).} - \bar{e}_{i.}\right) = b \tag{2.4}$$

$$\text{`}\operatorname{var}\left(\hat{b}_i^{(c)}\right) = \sigma^2_{\hat{b}_i^{(c)}} = E\left[\left(\hat{b}_i^{(c)} - b\right)^2\right] = \frac{1}{s^2}E\left[\left(\bar{e}_{(i+1).} - \bar{e}_{i.}\right)^2\right]$$

$$= \frac{2\sigma^2}{s^3} \tag{2.5}$$

The covariance between $\hat{b}_i^{(c)}$ and $\hat{b}_j^{(c)}$ is

$$\operatorname{cov}\left(\hat{b}_i^{(c)}, \hat{b}_j^{(c)}\right) = \sigma_{ij} = E\left[\left(\hat{b}_i^{(c)} - E\left(\hat{b}_i^{(c)}\right)\right)\left(\hat{b}_j^{(c)} - E\left(\hat{b}_j^{(c)}\right)\right)\right]$$

$$= \frac{1}{s^2}E\left[\left(\bar{e}_{(i+1).} - \bar{e}_{i.}\right)\left(\bar{e}_{(j+1).} - \bar{e}_{j.}\right)\right]$$

$$= \frac{1}{s^2}E\left[\bar{e}_{(i+1).}\bar{e}_{(j+1).} - \bar{e}_{(i+1).}\bar{e}_{j.} - \bar{e}_{i.}\bar{e}_{(j+1).} + \bar{e}_{i.}\bar{e}_{j.}\right] \tag{2.6}$$

For $j = i + 1$,

$$\sigma_{ij} = \frac{-1}{s^2}E\left(\bar{e}^2_{(I+1).}\right) = \frac{-1}{s^2}\left(\frac{\sigma^2}{s}\right) = \frac{-\sigma^2}{s^3} \tag{2.7}$$

For $j = i - 1$,

$$\sigma_{ij} = \frac{-1}{s^2}E\left(\bar{e}^2_{i.}\right) = \frac{-1}{s^2}\left(\frac{\sigma^2}{s}\right) = \frac{-\sigma^2}{s^3} \tag{2.8}$$

For $j = i \pm k$, $k > 1$,

$$\sigma_{ij} = 0 \tag{2.9}$$

In summary, let $R(k) = \operatorname{cov}\left(\hat{b}_{i.}^{(c)}, \hat{b}_{(i-k).}^{(c)}\right)$ and $\rho_k = R(k)/R(0)$. The results (2.5) through (2.9) can be summaries as follows.

$$R(k) = \begin{cases} 2\sigma^2/s^3, & k = 0 \\ -\sigma^2/s^3, & k = \pm 1 \\ 0, & k > 1 \end{cases} \tag{2.10}$$

$$\rho_k = \begin{cases} 1, & k = 0 \\ -1/2, & k = \pm 1 \\ 0, & k > 1 \end{cases} \tag{2.11}$$

We have shown that the sequence, $\hat{b}_i^{(c)}$, $i = 1, 2, ..., m-1$, of CBE derived variables have the covariance structure of a moving average process of order one (MA(1)). For more details on MA(1) processes, see Box et al (1994), Chatfield (2004).

3. Covariance Analysis of the FBE Derived Variables: Additive Model

Under the FBE method, the estimate of the slope $\left(\hat{b}\right)$ was calculated as the average of $\hat{b}_i^{(f)}$, $i = 1, 2, ..., m-1$ given by Iwueze and Nwogu (2004) as:

$$\hat{b}_i^{(f)} = \frac{\overline{X}_{(i+1).} - \overline{X}_{1.}}{(i-1)s}, \; i = 1, 2, ..., m-1 \tag{3.1}$$

Using (1.2),

$$\hat{b}_i^{(f)} = \frac{\overline{X}_{(i+1).} - \overline{X}_{1.}}{(i-1)s} = b + \frac{\overline{e}_{(i+1).} - \overline{e}_{1.}}{(i-1)s}, \; i = 1, 2, ..., m-1 \tag{3.2}$$

Hence, the expected value and variance of $b_i^{(f)}$ are

$$E\left(\hat{b}_i^{(f)}\right) = E(b) + \frac{1}{(i-1)s} E\left(\overline{e}_{(i+1).} - \overline{e}_{1.}\right) = b \tag{3.3}$$

$$\begin{aligned} \mathrm{var}\left(\hat{b}_i^{(f)}\right) = \sigma^2_{\hat{b}_i^{(f)}} = E\left[\left(\hat{b}_i^{(f)} - b\right)^2\right] &= \frac{1}{(i-1)^2 s^2} E\left[\left(\overline{e}_{(i+1).} - \overline{e}_{1.}\right)^2\right] \\ &= \frac{2\sigma^2}{(i-1)^2 s^3} \end{aligned} \tag{3.4}$$

$$\begin{aligned} \mathrm{cov}\left(\hat{b}_i^{(f)}, \hat{b}_j^{(f)}\right) = \sigma_{ij} &= E\left[\left(\hat{b}_i^{(f)} - E\left(\hat{b}_i^{(f)}\right)\right)\left(\hat{b}_j^{(f)} - E\left(\hat{b}_j^{(f)}\right)\right)\right] \\ &= E\left[\left(\hat{b}_i^{(f)} - b\right)\left(\hat{b}_j^{(f)} - b\right)\right] \\ &= \frac{1}{(i-1)(j-1)s^2} E\left[\left(\overline{e}_{(i+1).} - \overline{e}_{1.}\right)\left(\overline{e}_{(j+1).} - \overline{e}_{1.}\right)\right] \\ &= \frac{1}{(i-1)(j-1)s^2} E\left[\overline{e}_{(i+1).}\overline{e}_{(j+1).} - \overline{e}_{(i+1).}\overline{e}_{1.} - \overline{e}_{i.}\overline{e}_{(j+1).} + \overline{e}_{1.}^2\right] \end{aligned} \tag{3.5}$$

For $j = i + k$,

$$\sigma_{ij} = \frac{1}{(i-1)(j-1)s^2} E\left(\overline{e}_{1.}^2\right) = \frac{\sigma^2}{(i-1)(j-1)s^2} \tag{3.6}$$

Hence, the autocovariance and autocorrelation structures are:

$$R(k) = \begin{cases} \dfrac{2\sigma^2}{(i-1)^2 s^3}, & k = 0 \\ \dfrac{\sigma^2}{(i-1)(j-1)s^3}, & k \neq 0 \end{cases} \tag{3.7}$$

$$\rho_k = \begin{cases} 1, & k = 0 \\ 1/2, & k = \pm 1, \pm 2, \ldots \end{cases} \tag{3.8}$$

We have shown that the sequence, $\hat{b}_i^{(f)}$, $i = 2, 3 \ldots, m$, of FBE derived variables are not stationary and their average as an estimate of slope (b), will not give a reliable estimate in its present state.

4. Best linear unbiased estimate of slope (b) using the CBE derived variables

The CBE derived variables $\left(\hat{b}_i^{(c)}, i = 1, 2, \ldots, m-1\right)$ have been shown to be stationary and can be used for estimation, while the FBE derived variables $\left(\hat{b}_i^{(f)}, i = 1, 2, \ldots, m-1\right)$ are not stationary and estimates based on them will not be reliable. The sequence of CBE derived random variables $\hat{b}_i^{(c)}, i = 1, 2, \ldots, m-1$, are found to have the covariance structure of a first-order moving average process (MA(1) process) with the autocorrelation function given by (2.11).

Let $a_1, a_2, , a_{m-1}$ be any set of real numbers. A linear estimate of the mean $b = E\left(\hat{b}_i^{(c)}\right)$ is given by

$$T = \sum_{t=1}^{m-1} a_i \hat{b}_i^{(c)} \tag{4.1}$$

If T is unbiased, we obtain that

$$E(T) = \sum_{t=1}^{m-1} a_i E\left(\hat{b}_i^{(c)}\right) = \sum_{t=1}^{m-1} a_i b = b \sum_{t=1}^{m-1} a_i = b \tag{4.2}$$

T is unbiased if and only if

$$\sum_{t=1}^{m-1} a_i = 1 \tag{4.3}$$

The variance of T is given by

$$\operatorname{var}(T) = \sum_{i=1}^{m-1} a_i^2 \operatorname{var}(Y_i) + 2 \sum_{i} \sum_{< J} a_i a_j \operatorname{cov}(Y_i, Y_j) \tag{4.4}$$

For the second order stationary sequence of random variables $\hat{b}_i^{(c)}, i = 1, 2, ..., m-1$, with autocorrelation structure (2.11), $\text{var}(T)$ can be written as

$$\begin{aligned}
\text{var}(T) &= R(0)\sum_{i=1}^{m-1} a_i^2 + 2R(1)\sum_{i=1}^{m-2} a_i a_{i+1} \qquad (4.5)\\
&= R(0)\left\{\sum_{i=1}^{m-1} a_i^2 + 2\rho_1 \sum_{i=1}^{m-2} a_i a_{i+1}\right\}\\
&= R(0)\left\{\sum_{i=1}^{m-1} a_i^2 - \sum_{i=1}^{m-2} a_i a_{i+1}\right\}\\
&= \left(\frac{2\sigma^2}{s^3}\right)\left\{\sum_{i=1}^{m-1} a_i^2 - \sum_{i=1}^{m-2} a_i a_{i+1}\right\} \qquad (4.6)
\end{aligned}$$

Linear unbiased estimates of b that have minimum variance (among all linear unbiased estimates) are called best linear unbiased estimates (BLUE.s). Let

$$S(\mathbf{a}) = \sum_{i=1}^{m-1} a_i^2 - \sum_{i=1}^{m-2} a_i a_{i+1} \qquad (4.7)$$

From (4.6), $\min(\text{var}(T)) = R(0)\min(S(\mathbf{a}))$. Hence, the BLUE of b is obtained if we choose $a_1, a_2, , a_{m-1}$ that minimize $S(\mathbf{a})$ with respect to the constraint $\sum_{t=1}^{m-1} a_t = 1$. However, when $\rho_k = 0$, for all k, $a_i = \frac{1}{m-1}$ (see Rohatgi (1976)).

As an example of the minimization of (4.7) subject to the constraint $\sum_{i=1}^{m-1} a_i = 1$, we let $m-1 = 10 \Rightarrow m = 11$. Equation (4.7) reduces to

$$\begin{aligned}
S(\mathbf{a}) = {} & a_1^2 + a_2^2 + a_3^2 + a_4^2 + a_5^2 + a_6^2 + a_7^2 + a_8^2 + a_9^2\\
& + (1 - a_1 - a_2 - a_3 - a_4 - a_5 - a_6 - a_7 - a_8 - a_9)^2\\
& - a_1 a_2 - a_2 a_3 - a_3 a_4 - a_4 a_5 - a_5 a_6 - a_6 a_7 - a_8 a_9\\
& - a_9 (1 - a_1 - a_2 - a_3 - a_4 - a_5 - a_6 - a_7 - a_8 - a_9) \qquad (4.8)
\end{aligned}$$

By equating $\partial S(\mathbf{a})/\partial a_j = 0$, we obtain the system of linear equations given in (4.9).

$$
\begin{aligned}
4a_1 + a_2 + 2a_3 + 2a_4 + 2a_5 + 2a_6 + 2a_7 + 2a_8 + 3a_9 &= 2 \\
a_1 + 4a_2 + a_3 + 2a_4 + 2a_5 + 2a_6 + 2a_7 + 2a_8 + 3a_9 &= 2 \\
2a_1 + a_2 + 4a_3 + a_4 + 2a_5 + 2a_6 + 2a_7 + 2a_8 + 3a_9 &= 2 \\
2a_1 + 2a_2 + a_3 + 4a_4 + a_5 + 2a_6 + 2a_7 + 2a_8 + 3a_9 &= 2 \\
2a_1 + 2a_2 + 2a_3 + a_4 + 4a_5 + a_6 + 2a_7 + 2a_8 + 3a_9 &= 2 \\
2a_1 + 2a_2 + 2a_3 + 2a_4 + a_5 + 4a_6 + a_7 + 2a_8 + 3a_9 &= 2 \\
2a_1 + 2a_2 + 2a_3 + 2a_4 + 2a_5 + a_6 + 4a_7 + a_8 + 3a_9 &= 2 \\
2a_1 + 2a_2 + 2a_3 + 2a_4 + 2a_5 + 2a_6 + a_7 + 4a_8 + 2a_9 &= 2 \\
3a_1 + 3a_2 + 3a_3 + 3a_4 + 3a_5 + 3a_6 + 3a_7 + 2a_8 + 6a_9 &= 3
\end{aligned} \tag{4.9}
$$

We put the system of linear equations (4.9) in matrix form, to obtain

$$
\begin{pmatrix} a_1 \\ a_2 \\ a_3 \\ a_4 \\ a_5 \\ a_6 \\ a_7 \\ a_8 \\ a_9 \end{pmatrix} = \begin{pmatrix} 4 & 1 & 2 & 2 & 2 & 2 & 2 & 2 & 3 \\ 1 & 4 & 1 & 2 & 2 & 2 & 2 & 2 & 3 \\ 2 & 1 & 4 & 1 & 2 & 2 & 2 & 2 & 3 \\ 2 & 2 & 1 & 4 & 1 & 2 & 2 & 2 & 3 \\ 2 & 2 & 2 & 1 & 4 & 1 & 2 & 2 & 3 \\ 2 & 2 & 2 & 2 & 1 & 4 & 1 & 2 & 3 \\ 2 & 2 & 2 & 2 & 2 & 1 & 4 & 1 & 3 \\ 2 & 2 & 2 & 2 & 2 & 2 & 1 & 4 & 2 \\ 3 & 3 & 3 & 3 & 3 & 3 & 3 & 2 & 6 \end{pmatrix}^{-1} \begin{pmatrix} 2 \\ 2 \\ 2 \\ 2 \\ 2 \\ 2 \\ 2 \\ 2 \\ 3 \end{pmatrix} \tag{4.10}
$$

Evaluating (4.10) with $a_{10} = 1 - a_1 - a_2 - a_3 - a_4 - a_5 - a_6 - a_7 - a_8 - a_9$, we obtained the following weights:

$a_1 = 0.046$; $a_2 = 0.082$ $a_3 = 0.109$; $a_4 = 0.127$; $a_5 = 0.136$; $a_7 = 0.127$;
$a_8 = 0.109$; $a_9 = 0.082$; $a_{10} = 0.046$; $S(\mathbf{a}) = 0.005$.

Given in Table 3 are the weights for $m = 3, 4, ..., 21\,(m-1 = 2, 3, ..., 20)$. The plot of $S(\mathbf{a})$ against m is given in Figure 1. Also illustrated in Figure 1 is the fact that $S(\mathbf{a})$ follows an exponential distribution (Draper and Smith, 1999) given by

$$S(\mathbf{a}) = e^{0.2862 - 0.7156m + 0.0177m^2}\ ;\ R^2 = 0.99 \tag{4.11}$$

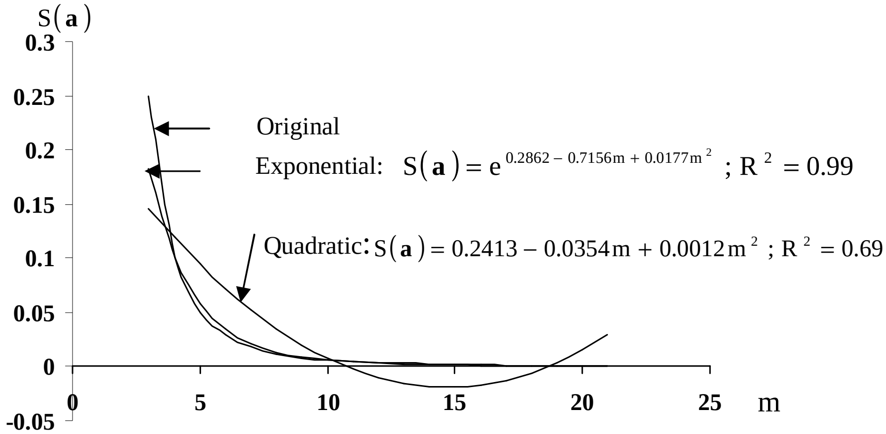

Figure 1: Plot of $S(\mathbf{a}) = \sum_{i=1}^{m-1} a_i^2 - \sum_{i=1}^{m-2} a_i a_{(i+1)}$ against m.

5. Simple Average of the CBE Derived Variables

Iwueze et al (2010) discussed the properties of the estimator based on the simple average (SAE: Simple average estimator) of the derived CBE variables given by

$$\hat{b}^{(c)} = \frac{1}{(m-1)} \sum_{i=2}^{m} \hat{b}_i^{(c)} \tag{5.1}$$

The mean and variance of (5.1) are:

$$E\left(\hat{b}^{(c)}\right) = b \tag{5.2}$$

$$\begin{aligned}
\operatorname{var}\left(\hat{b}^{(c)}\right) = \sigma^2_{\hat{b}^{(c)}} &= \frac{1}{(m-1)^2}\left\{\sum_{i=1}^{m-1} \operatorname{var}\left(\hat{b}_i^{(c)}\right) + 2\sum_{i<}^{m-1}\sum_{j}^{m-1} \operatorname{cov}\left(\hat{b}_i^{(c)}, \hat{b}_j^{(c)}\right)\right\} \\
&= \frac{1}{(m-1)^2}\left\{\sum_{i=1}^{m-1} \operatorname{var}\left(\hat{b}_i^{(c)}\right) - 2\sum_{i=1}^{m-2} \operatorname{cov}\left(\hat{b}_i^{(c)}, \hat{b}_{i+1}^{(c)}\right)\right\} \\
&= \frac{1}{(m-1)^2}\left\{(m-1)\left(\frac{2\sigma^2}{s^3}\right) - (m-2)\left(\frac{2\sigma^2}{s^3}\right)\right\}
\end{aligned}$$

(from (2.5) and (2.7))

$$= \frac{2\sigma^2}{(m-1)^2 s^3}\{m-1-m+2\} = \frac{1}{(m-1)^2}\left(\frac{2\sigma^2}{s^3}\right) \tag{5.3}$$

The SA estimate (5.1) is also a linear unbiased estimator of the slope (b) parameter.

Table 3. Sample sizes (m) and their corresponding weights(a_i, $i = 1, 2, ..., m - 1$)

a_i	Sample size = m																		
	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
a_1	0.500	0.300	0.200	0.143	0.107	0.083	0.067	0.055	0.046	0.039	0.034	0.029	0.025	0.022	0.019	0.017	0.016	0.014	0.013
a_2	0.500	0.400	0.300	0.229	0.179	0.143	0.117	0.097	0.082	0.070	0.060	0.052	0.046	0.041	0.037	0.033	0.030	0.027	0.025
a_3		0.300	0.300	0.257	0.214	0.179	0.150	0.127	0.109	0.094	0.082	0.072	0.064	0.057	0.052	0.046	0.042	0.038	0.035
a_4			0.200	0.229	0.214	0.190	0.167	0.145	0.127	0.112	0.099	0.088	0.079	0.071	0.064	0.058	0.053	0.048	0.044
a_5				0.143	0.179	0.179	0.167	0.151	0.136	0.122	0.110	0.099	0.089	0.081	0.074	0.067	0.061	0.056	0.052
a_6					0.107	0.143	0.150	0.146	0.136	0.126	0.115	0.106	0.096	0.088	0.080	0.074	0.068	0.063	0.058
a_7						0.083	0.117	0.127	0.127	0.122	0.115	0.108	0.101	0.093	0.086	0.080	0.074	0.068	0.064
a_8							0.067	0.097	0.109	0.112	0.110	0.106	0.101	0.094	0.088	0.083	0.077	0.073	0.068
a_9								0.054	0.082	0.094	0.099	0.099	0.096	0.093	0.088	0.084	0.079	0.075	0.070
a_{10}									0.046	0.070	0.082	0.088	0.089	0.088	0.086	0.083	0.079	0.076	0.071
a_{11}										0.039	0.060	0.072	0.079	0.081	0.080	0.080	0.077	0.075	0.071
a_{12}											0.034	0.052	0.064	0.071	0.074	0.074	0.074	0.073	0.070
a_{13}												0.029	0.046	0.057	0.064	0.067	0.068	0.068	0.068
a_{14}													0.025	0.041	0.052	0.058	0.061	0.063	0.064
a_{15}														0.022	0.037	0.046	0.053	0.056	0.058
a_{16}															0.019	0.033	0.042	0.048	0.052
a_{17}																0.017	0.030	0.038	0.044
a_{18}																	0.016	0.027	0.035
a_{19}																		0.014	0.025
a_{20}																			0.013
$S(\mathbf{a})$	0.250	0.100	0.050	0.029	0.018	0.012	0.008	0.006	0.005	0.004	0.003	0.002	0.002	0.001	0.001	0.001	0.001	0.001	0.001

Comparing (4.6) and (5.3), we note that the difference between the variances of the SAE and the BLUE lies in the difference between $S(a) = \sum_{i=1}^{m-1} a_i^2 - \sum_{i=1}^{m-2} a_i a_{i+1}$ for the BLUE and $\frac{1}{(m-1)^2}$ for the SAE. Figure 2 illustrates the differences. The variance of the intercept (a) is given in Iwueze et al (2010) as:

$$\operatorname{var}(\hat{a}) = \frac{\sigma^2}{n} + \left(\frac{n+1}{2}\right)^2 \operatorname{var}(\hat{b}) \tag{5.4}$$

where $\hat{b} = \hat{b}^{(c)} = \frac{1}{(m-1)} \sum_{i=2}^{m} \hat{b}_i^{(c)}$ for the SAE and $\hat{b} = T = \sum_{t=1}^{m-1} a_i \hat{b}_i^{(c)}$ for the BLUE. At $m = 3$, $S(a) = \left(\frac{1}{m-1}\right)^2$ so that variances of the estimates of the slope are the same for BLUE and SAE.

6. Empirical Examples

The first example are simulations (all simulations and computations in this section are done with MINITAB) of n = 4m $(m = 8, 11, ..., 18)$ observations from $X_t = a + bt + S_t + e_t$ with $a = 1.0$, $b = 0.2$, $S_1 = -1.5$, $S_2 = 2.5$, $S_3 = 3.5$, $S_4 = -4.5$ and $e_t \sim N(0, 1)$. The properties of the BLUE were also determined and compared with those from the Least Squares Estimation method (LSE) and Simple Average method (SAE) of the Buys-Ballot derived variables.

As Table 4 shows, BLUE recovers the values of the slope and intercept used in the simulation better than the other two methods. The variances of the estimates of the slope and intercept are also smaller for the BLUE than for the other two methods

The autocorrelation function (acf) of the residuals obtained after decomposition using the LSE, SAE and BLUE methods were used to confirm the adequacy of the fitted models. Diagnostic checks on the residuals are discussed in Box et al (1994).

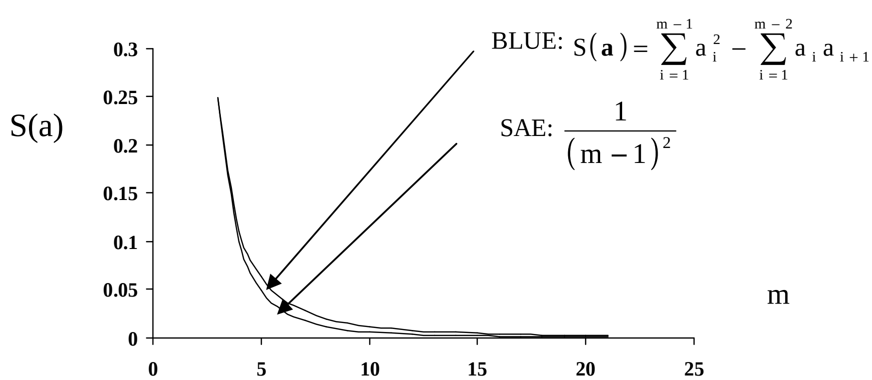

Figure 2: Plot of $S(\mathbf{a}) = \sum_{i=1}^{m-1} a_i^2 - \sum_{i=1}^{m-2} a_i a_{(i+1)}$ and $\frac{1}{(m-1)^2}$ against m

Table 4: Summary of estimates of LSE, BLUE and SAE

m	Method	$\hat{a}$	$\hat{b}$	$\hat{\sigma}_a$	$\hat{\sigma}_b$	S_1	S_2	S_3	S_4	$\hat{\sigma}$
	LSE	1.309	0.181	1.261	0.067	-1.322	2.534	3.439	-4.651	0.996
	SAE	1.490	0.170	0.459	0.025	-1.339	2.529	3.444	-4.634	1.029
8	BLUE	1.084	0.195	0.361	0.019	-1.302	2.541	3.432	-4.671	0.977
	LSE	1.174	0.191	1.196	0.056	-1.538	3.086	3.108	-4.656	0.875
	SAE	1.185	0.190	0.413	0.021	-1.539	3.086	3.108	-4.655	0.876
9	BLUE	0.965	0.202	0.313	0.015	-1.521	3.092	3.102	-4.673	0.861
	LSE	1.170	0.192	1.106	0.047	-1.347	2.403	3.518	-4.573	0.999
	SAE	0.615	0.219	0.185	0.020	-1.307	2.416	3.504	-4.614	1.019
10	BLUE	1.006	0.200	0.170	0.014	-1.515	2.347	3.574	-4.406	1.004
	LSE	1.666	0.193	1.109	0.043	-1.258	2.593	3.638	-4.973	0.963
	SAE	0.762	0.211	0.411	0.017	-1.231	2.602	3.629	-5.000	0.966
11	BLUE	0.987	0.201	0.306	0.012	-1.246	2.597	3.634	-4.985	0.957
	LSE	1.481	0.180	0.961	0.034	-1.288	2.180	3.476	-4.368	0.960
	SAE	1.478	0.181	0.403	0.015	-1.288	2.180	3.476	-4.368	0.960
12	BLUE	1.360	0.185	0.296	0.011	-1.281	2.183	3.473	-4.375	0.958
	LSE	1.199	0.193	1.026	0.034	-1.273	2.683	3.644	-5.054	0.947
	SAE	1.371	0.186	0.398	0.014	-1.283	2.680	3.648	-5.045	0.961
13	BLUE	1.056	0.198	0.524	0.009	-1.265	2.686	3.642	-5.062	0.943
	LSE	0.970	0.201	0.926	0.028	-1.393	2.622	3.363	-4.592	0.992
	SAE	0.726	0.210	0.407	0.013	-1.380	2.627	3.358	-4.605	0.992
14	BLUE	0.852	0.205	0.259	0.008	-1.387	2.625	3.361	-4.598	0.990
	LSE	1.265	0.191	0.847	0.024	-1.465	2.393	3.308	-4.236	0.982
	SAE	0.803	0.206	0.407	0.013	-1.443	2.401	3.301	-4.259	1.006
15	BLUE	1.147	0.195	0.268	0.008	-1.460	2.395	3.306	-4.241	0.962
	LSE	1.166	0.195	0.867	0.023	-1.114	2.520	3.375	-4.781	0.969
	SAE	1.358	0.189	0.396	0.012	-1.123	2.518	3.377	-4.772	0.983
16	BLUE	1.036	0.199	0.213	0.005	-1.109	2.523	3.373	-4.787	0.967
	LSE	1.130	0.193	0.848	0.021	-1.375	2.465	3.496	-4.586	1.144
	SAE	0.770	0.203	0.461	0.013	-1.359	2.470	3.490	-4.601	1.152
17	BLUE	1.034	0.196	0.260	0.006	-1.370	2.466	3.494	-4.590	1.142
	LSE	1.124	0.197	0.743	0.018	-1.424	2.280	3.217	-4.073	0.960
	SAE	0.919	1.044	0.382	0.010	-1.415	2.283	3.213	-4.081	0.962
18	BLUE	1.044	0.199	0.226	0.005	-1.420	2.282	3.215	-4.077	0.959

The second example is the 32 consecutive quarters of U.S beer production, in millions of barrels, from first quarter of 1975 to the fourth quarter of 1982, and is listed as Series W10 in Wei (1990). In order to assess the forecasting performance of our models, we use only the first 30 observations of the series for model construction.

The estimates of the parameters using Least Squares Estimation method (LSE) are again determined and compared with those from the BLUE and SAE computed from the CBE derived variables. The computational procedure for the slope (b) is laid out in Table 5 while Table 6 gives the summary of the estimates.

Table 5: Buys-ballot table for U.S. beer production.

Year	Quarter I	II	III	IV	$\bar{X}_{i.}$	$\hat{\sigma}_{i.}$	$\hat{b}_i^{(c)}$	a_i	$a_i\hat{b}_i^{(c)}$
1975	36.14	44.60	44.15	35.72	40.15	4.88	0.2550	0.083	0.0212
1976	36.19	44.63	46.95	36.90	41.17	5.43	0.3575	0.143	0.0511
1977	39.66	49.72	44.49	36.54	42.60	5.76	0.5425	0.179	0.0971
1978	41.44	49.07	48.98	39.59	44.77	4.97	0.3200	0.190	0.0608
1979	44.29	50.09	48.42	41.39	46.05	3.95	0.6800	0.179	0.1217
1980	46.11	53.44	53.00	42.52	48.77	5.35	-0.0875	0.143	-0.0125
1981	44.61	55.18	52.24	41.66	48.42	6.34	0.6600	0.083	0.0548
1982	47.84	54.27	-	-	51.06	4.55	-	-	-
$\bar{X}_{.j}$	42.04	50.13	48.32	39.19	44.99				
$\hat{\sigma}_{.j}$	4.42	4.07	3.46	2.78		5.6 6			

Table 6: Summary of estimates of LSE, BLUE and SAE for U. S beer production

Method	$\hat{a}$	$\hat{b}$	$\hat{\sigma}_a$	$\hat{\sigma}_b$	S_1	S_2	S_3	S_4	$\hat{\sigma}$
LSE	39.099	0.380	1.790	0.101	-2.692	5.018	3.592	-5.918	1.244
SAE	38.955	0.390	0.564	0.033	-2.297	5.403	3.207	-6.313	1.307
BLUE	38.885	0.394	0.461	0.025	-2.291	5.405	3.205	-6.319	1.311

Wei (1990), ignoring the stochastic trend in the series, used 30 observations of the series for Integrated Autoregressive Moving Average (ARIMA) model construction. Based on the forecasting performance of his models, he settled on the model

$$\left(1-B^4\right)X_t = \underset{(\pm 0.09)}{1.49} + \left(1-\underset{(\pm 0.16)}{0.87}B^4\right)e_t \tag{6.1}$$

with $\hat{\sigma}^2 = 2.39$.

The one step ahead and two step ahead forecasts, $\hat{X}_{30}(\ell)$ for $\ell = 1$ and 2, from the forecast origin 30 are calculated for each estimation method. The forecast errors and the corresponding summary statistics used by Wei (1990) are shown in Table 7. With respect to Table 7, MPE is the Mean Percentage Error, MSE is the Mean Square Error, MAE is the Mean Absolute Error and MAPE is the Mean Absolute Percentage Error as defined in Wei (1990).

Table 7 : Comparison of the forecasts between models

Lead time	Actual Value	Wei (1990) Forecast Value	Wei (1990) Error	LSE Forecast Value	LSE Error	SAE Forecast Value	SAE Error	BLUE Forecast Value	BLUE Error
1	52.31	54.38	-2.07	54.48	-2.17	54.24	-1.93	54.31	-2.00
2	41.83	45.37	-3.54	45.35	-3.52	45.11	-3.28	45.18	-3.35
MPE		-6.2%		-6.3%		-5.8%		-5.9%	
MSE		8.4		8.6		7.2		7.6	
MAE		2.8		2.9		2.6		2.7	
MAPE		6.2%		6.3%		5.8%		5.9%	

The results of Table 7 indicate that the SAE and BLUE give approximate results that are better than those given by the LSE and ARIMA in terms of forecasts. This example illustrates the fact that sometimes a simple descriptive model computed from the Buys-Ballot procedure may be preferred to the more complicated ARIMA and LSE methods in a series where all the methods are adequate in terms of the residuals.

7. Concluding Remarks

This study has examined the Best Linear Unbiased Estimator (BLUE) of the slope (b) of a linear trend-cycle component of time series computed from the Buys-Ballot derived variables defined by Iwueze and Nwogu (2004). The emphasis on the slope is based on the fact that estimates of the other parameters (intercept and seasonal indices) depend on it. The properties of the BLUE were also determined and compared with those from the Least Squares Estimation method (LSE) and Simple Average method (SAE) of the Buys-Ballot derived variables.

The results show that of the two derived variables (CBE and FBE), only the CBE derived variable were found to be stationary (with constant mean and variance) but are correlated with only one significant autocorrelation coefficient at lag one. The derived variable from the FBE are non-stationary with constant autocorrelation coefficient at all lags. Hence, they are considered incapable, in their present state, to give any reliable estimate.

The variance of the BLUE for the slope (b) based on the CBE-derived variables was shown to depend on the sum of squares and cross-products S(a) of the weights $\left(a_i\right)$ of the derived variables. The values of S(a), in turn, depend on the number of periods (m).

The variances of the estimates of the slope (the BLUE and SAE) are constant multiples of the variance of $\hat{b}_i \left(\frac{2\sigma^2}{s^3}\right)$ The multipliers are $\left(\frac{1}{m-1}\right)^2$ for SAE and S(a) for the BLUE. At $m = 3,\ S(a) = \left(\frac{1}{m-1}\right)^2$ so that variances of the estimates of the slope are the same for BLUE and SAE. For m>3, the variances appear to decay exponentially as m increased.

The estimate of the slope based on simple average is only a particular case of the BLUE in which all the weights are equal $\left(i.e,\ a_i \ = \frac{1}{m-1}\right)$. The multipliers of $\frac{2\sigma^2}{s^3}$ are, for every m >3, greater for SAE than BLUE. This ensures that the BLUE has minimum variance. As a consequence, the variances of the estimates of the intercept (a) are for every m>3, smaller for the BLUE than for the SAE. These are clearly supported by the results of the empirical examples shown in Table 4. Another important result is that (i) for m>3, the error variance is smaller for the BLUE than for the SAE and LSE and (ii) for most m the estimates of the slope (b) and intercept (a) from BLUE are closer to the actual values used in the simulation than those from SAE and LSE.

Therefore, when using Buys-Ballot procedure for time series decomposition, it is recommended that when trend-cycle component is linear, the BLUE for the slope computed from the CBE-derived variable be used. This leads to more precise estimates of time series components.

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Effects of Global Climate Change on Nigerian Agriculture: An Empirical Analysis

Apata, T.G[1]

This paper presents an empirical analysis of the effects of global warming on Nigerian agriculture and estimation of the determinants of adaptation to climate change. Data used for this study are from both secondary and primary sources. The set of secondary sources of data helped to examine the coverage of the three scenarios (1971-1980; 1981-1990 and 1991-2000). The primary data set consists of 900 respondents' but only 850 cases were useful. This study analyzed determinants of farm-level climate adaptation measures using a Multinomial choice and stochastic-simulation model to investigate the effects of rapid climatic change on grain production and the human population in Nigeria. The model calculates the production, consumption and storage of grains under different climate scenarios over a 10-year scenery. In most scenarios, either an optimistic baseline annual increase of agricultural output of 1.85% or a more pessimistic appraisal of 0.75% was used. The rate of natural increase of the human population exclusive of excess hunger-related deaths was set at 1.65% per year. Results indicated that hunger-related deaths could increase if grain productions do not keep pace with population growth in an unfavourable climatic environment. However, Climate change adaptations have significant impact on farm productivity.

Key words: Climate change · Adaptation · Economic consequenœs · Farm level productivity, Average Rainfall, Nigeria

INTRODUCTION

There is a growing consensus in the scientific literature that in the coming decades the world will witness higher temperatures and changing precipitation levels. The effects of this will lead to low/poor agricultural products. Evidence has shown that climate change has already affecting crop yields in many countries (IPCC, 2007; Deressa *et al*, 2008; BNRCC, 2008). This is particularly true in low-income countries, where climate is the primary determinant of agricultural productivity and adaptive capacities are low (SPORE, 2008; Apata *et a*l, 2009). Many African countries, which have their economies largely based on weather-sensitive agricultural productions systems like Nigeria, are particularly vulnerable to climate change (Dinar *et al*, 2006). This vulnerability has been demonstrated by the devastating effects of recent flooding in the Niger Delta region of the country and the various prolonged droughts that are currently witnessed in some parts of Northern region. Thus, for many poor countries like Nigeria that are highly vulnerable to effects of climate change, understanding farmers' responses to climatic variation is crucial, as this will help in designing appropriate coping strategies.

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Evidence from literature and past studies has revealed that the recent global warming has influenced agricultural productivity leading to declining food production (Kurukulasuriya & Mendelsohn, 2006; IISD, 2007; Lobell *et al*, 2008). In order to meet the increasing food and non-food needs due to population increase, man now rapidly depleting fertile soils, fossil groundwater, biodiversity, and numerous other non-renewable resources to meet his needs (Abrahamson, 1989; Ehrlich & Ehrlich, 1990). This resource depletion was linked with other human pressures on the environment. Possibly the most serious of human impacts is the injection of greenhouse gases into the atmosphere. The reality of the impact of climate change on agricultural development has started showing signs (Adams *et al*, 1988; Fischer *et al*, 2002; Spore, 2008). A substantial body of research has documented these wide-ranging effects on many facets of human societies (Wolfe *et al*, 2005; ODI, 2007; Apata *et al*, 2009.).

Rough estimates suggest that over the next 50 years or so, climate change may likely have a serious threat to meeting global food needs than other constraints on agricultural systems (IPCC, 2007; BNRCC, 2008). Specifically, population, income, and economic growth could all affect the severity of climate change impacts in terms of food security, hunger, and nutritional adequacy. If climate change adversely affects agriculture, effects on human are likely to be more severe in a poorer world. Wolfe *et al* (2005); Stige, (2006), and Orindi *et al*, (2006) worry that rising demand for food over the next century, due to population and real income growth, will lead to increasing global food scarcity, and a worsening of hunger and malnutrition problems particularly in developing countries.

Recently, international tensions and concerns are heightening over what the impact of climate will have on the environment and agricultural produce (NEST, 2004; BNRCC, 2008; Apata, *et al* 2009). Also, how agricultural and food-distribution systems will be further stressed up by the shifting of temperatures and precipitating belts, especially if changes are rapid and not planned for (NEST, 2004). The crucial issue in this study is whether agricultural output supply can keep pace with population increase under this climate variability. This will depend; both on the scope for raising agricultural productivity (including reducing waste during distribution), availability of inputs used in the agricultural sector (land, labour, machinery, water resources, fertilizers, etc.) and having sufficient information on climatic variables for possible effective adaptation and mitigation strategies.

Consequently, attempt is being made in this study to investigate the effects of climate change on food demand and production as well as population increase in Nigeria. Past studies that have examined the impact of climate change on food production at the country, regional, or global scale (such as: Pearce *et al*. 1996; McCarthy *et al*. 2001; Parry *et al*. 2004; Nkomo *et al*, 2006; Stern 2007; Deressa, *et al*, 2008; BNRCC, 2008; Apata *et al*, 2009), have failed to provide critical insights in terms of effective and future adaptation strategies, although insights from these studies created the background for the present study.

Studies on the impact of climate change (particularly rainfall and temperature) and climate-related adaptation measures on crop yield are very scanty. Studies by Liu *et al*, (2004) Mendelsoln *et al*, (2004), De-wit *et al* (2006), Kurukulasuriya & Mendelsohn, (2006), Deresa (2007), Yesuf *et al* (2009) and Apata *et al* (2009) are some of the economic studies that attempt to measure the impact of climate change on farm productivity. These studies imputed the cost of climate change as a proxy for capitalized land value and which are captured from farm net revenue. However, while these studies were conducted using sub-regional agricultural data as well as household-level it did not identify the determinants of effective adaptation methods to predict efficient adaptive measures. Also, its likely future effects on food production and population growth were not assessed. . Consequently, the objectives of this study are to examine effects of key climatic variables on food production and its likely effect on population increases and to identify the determinants of effective adaptation methods to predict efficient adaptive measures in a typical developing country, using household-specific survey data from Nigeria.

Quantification of Major Indicators of Climate Change on agriculture

Past studies have used a variety of approaches to capture climate change effects on agriculture (Parry *et al*, 2009; Wang *et al*, 2009; Deressa and Hassan, 2010). These approaches range from simply equating average future impacts to yield losses observed in historical droughts to more quantitative crop simulation modelling, statistical time series and cross-sectional analyses. To date, simulation studies have been limited by a lack of reliable data on soil properties and management practices, and have provided only `best-guess' estimates with little to no information on uncertainties that result from choices in model structure, parameter values and scaling techniques (Frost and Thompson, 2000; Fischer *et al* 2002). In addition past studies have observed that statistical analyses have been limited by the poor quantity and quality of historical agricultural data relative to other regions, resulting in model estimates with wide confidence intervals (Naylor *et al*, 2007; Wang *et al*, 2009). Besides, studies have shown that Statistical and econometric techniques can be employed to establish a logical association between climate variation and change (Tebaldi and Knutti, 2007; Niggol and Mendelsohn, 2008).

A substantial amount of research has been conducted on the potential impacts of climate change on agricultural productivity (Parry *et al.* 1999; Lobell and Burke, 2008 and Deressa and Hassan, 2010). Attempts are made in these studies to link the state-of-the-art models developed by researchers in separate disciplines, including climatology, agronomy and economics, in order to project future impact of climate change on agriculture and implication for population growth. Some of these studies include Kane et al. 1992; Rosenzweig et al. 1993; Rosenzweig & Parry 1994; Reilly *et al*. 1996 and Ayinde *et al,* 2010, that used climate induced changes in crop yields to estimate potential global economic impacts. Others have examined the indirect impact on economic variables such as farm revenue and income, e.g. Mendelsohn *et al*. (1994) and Adams et al (1998). The review of these studies helped to have an understanding of the physical and economic responses, and adjustments on climate change and agricultural production. However, in line with adaptation scenario of how farmers are coping or surviving under this climate variability, these studies assumed that farmers could adapt to climate change by changing crop varieties and timing of planting and harvesting, while in the without adaptation scenario it is assumed that farmers do not make any adjustments over time.

The conversion of land to agricultural use and exploitation of diverse other natural resources has generally increased the capacity of Earth to support human beings. In recent decades, however, the human enterprise has grown so large that it is seriously altering the global environment (Holdren & Ehrlich 1974; FAO, UNFPA and IIASA 1982; Kane et al, 1992; Fischer et al, 2002 and Wang *et al*, 2009). Humanity is now rapidly depleting fertile soils, fossil groundwater, biodiversity, and numerous other non-renewable resources, to support its growing population (Ehrlich & Ehrlich 1990; Adams *et al.* 1998). This resource depletion, coupled with other human pressures on the environment (e.g., production of toxic wastes, changing the composition of the atmosphere) is undermining the capacity of the planet to support virtually all forms of life (Ehrlich *et al.* 1989).

The magnitude and pace of change that climatologists believe probable are unprecedented in human history (Abrahamson 1989; Cairns & Zweifel 1989; Lashof 1989; NAS 1987; Schneider 1989). Should such change occur, there will inevitably be wide-ranging effects on many facets of human societies. Current patterns and future plans of energy use and industrialization will require major revision (Rosenzweig, 1994, Reilly, 1996 and Mendelsohn *et al.* 1994). International tensions are likely to heighten over claims on freshwater where scarce supplies are further reduced (Fischer, et al, 2002; Lobell and Burke, 2008 and Ayinde *et al*, 2010), transnational migration of environmental refugees (Jacobson 1988), and ultimate responsibility for global warming and its effects (Adams *et al*, 1998).

The global production and distribution of food is inadequate for a large fraction of the rapidly expanding global population of 5.8 billion people under present and foreseeable economic systems (WRI 1987; Brown 1988; Brown & Young 1990; Ehrlich & Ehrlich 1990). The agricultural and food-distribution systems may be further stressed by shifting of temperature and precipitation belts, especially if changes are rapid and not planned for (see, for example, Adams *et al.* (1990). In this paper investigation of the possible positive or negative effects of climate change on Nigerian food security was carried out by using a computer model and Statistical software packages of LIMDEP 6.0. Focus was on grain because it supplies over half of the calories in the average diet (of developing countries Nationals) and accounts for the vast majority of the international trade in food (WRI, 1989). The model adopted in the study is a simple, aggregate representation of agricultural systems and human populations that have been used by Daily & Ehrlich 1990.

METHODOLOGY

Area of Study

Nigeria has a population of about 140 million and an area of 923.000 square kilometres. Nigeria has a variety of ecosystems; from mangroves and rainforests on the Atlantic coast in the south to the savannah in the north. Whether dry or wet, these ecosystems are being battered by global warming. While excessive flooding during the past decade has hurt farming in coastal communities, desertification is ravaging the Sahel. Traditionally, desertification in the Sahel has been blamed on overgrazing practices of the local population. But it has been discovered that the real problem is climate change. Peoples' livelihoods are being harmed, and people who are already poor are becoming even more impoverished. Climate refugees are being created.

Method of Data Collection

Both primary and secondary data were used for this study. Secondary data came from National Core Welfare Indicator (NCWI)/National living Standard Survey (NLSS)/National Consumer Survey/Demographic/Health Survey (DHS)/National Population Commission (NPC), and National Bureau of Statistics. These set of secondary sources of data helped to examine the coverage of the three climate scenarios (1971-1980/1981-1990/1991-2000) used for this study. The primary data consists of 900 respondents' (150 respondents from each zone) but only 850 responses were useful. In addition weather alerts, forecast and measurements over these periods were examined. This study analyzed determinants of farm-level climate adaptation measures in Nigeria using a Multinomial choice model in all the six zones in Nigeria. Also, a simple, nationally aggregated, stochastic-simulation model was constructed to investigate the effects of rapid climatic change on agriculture (grain production) and the human population in Nigeria.

The level of grain consumption in each year to the scenario is calculated as the product of the current population size and the average consumption per person per year. Our estimate of average consumption, 0.35 T grain per person-year, is equal to the average global per-capita production level over 1955-88 (FAO 1956, 89; PRB 1988; UN 1987). Grain lost to wastage estimated to be 40% between production and consumption; (ANAP, 2006 and Akinyosoye, 2006), diverted to livestock, and otherwise not consumed directly. The grain carry-over stock is set at the beginning of each simulation. For most runs, the initial stock was set at 35,003T, an intermediate level equal to 21 % of consumption for the initial year.

ANALYTICAL PROCEDURE

Model of Effect of Stochastic Perturbations in Food Production on Population Size

The model is used to simulate the effect of stochastic perturbations in food production on population size. In yearly increments, the model calculates human population size, number of hunger related deaths, and the production, consumption and storage of grain under different climatic scenarios. Parameters that may vary in each run of the model include the initial population size, the initial level of grain production and grain stores, and the rate of change in population size. It is hypothesised that climate change will have unfavourable impact on agricultural production. Therefore, there is the need to capture the frequency and magnitude of changes in the harvest. The climate scenarios are described in terms of two parameters: the frequency and the magnitude of changes in grain production caused by changing weather patterns. All of the parameters in the model represent aggregates for the whole.

The model is adapted from the study of Daily and Ehrlich, (1990) and was modified to capture the scope of the study.

$$\mathrm{N}_{t+1} = (1 + 0.01 \times \Delta\mathrm{N}) \times \mathrm{N}_{t} \quad (1)$$

Where, N = Population size, and ΔN is the annual percentage rate of increase of population size.

$$\mathrm{G}_{p,t+1} = (1 + 0.01 \times \Delta\mathrm{G}) \times \mathrm{G}_{p,t} \quad (2)$$

$$\mathrm{G}_{nf,t+1} = \mathrm{G}_{p,t+1} + 0.01 \times v \times \mathrm{G}_{p,t+1} \quad (3)$$

$$\mathrm{G}_{a,t+1} = \mathrm{G}_{nf,t+1} + 0.01 \times m \times \mathrm{G}_{nf,t+1} \quad (4)$$

Where;

G_p = potential grain production and ΔG the annual percentage rate of increase of grain production;

G_{nf} = potential grain production modified by 'normal fluctuations';

v = is a number selected randomly (and uniformly) from the set (-4.0, -2.0, 0, 2.0, 4.0) to produce an expected variance of 7.5%;

G_a. = actual production for the given year;

m = the amount by which grain production is enhanced or reduced in years where climatic events affect agriculture (determined stochastically).

Grain consumption (C) is calculated asC_t = (0.33 T per capita) × N_t.

Grain stock (S) has a lower bound of zero and is calculated as follows:

T: $S_{t+1} = S_t + G_{a,t+1} - C_{t+1}$

The number of hunger-related deaths (D) occurring in a year is assumed in this study as a function of grain stocks and distribution. In the case of a huge grain surplus, where stocks constitute greater than 40% of consumption (i.e. $S \times 100/C > 40$), it is reported that about 25, 605 death occurs between 1991-2000 (Demographic and Health Survey(DHS), 2003), 21, 819 deaths were reported during, 1981-1990 (DHS, 1990) and 35,003 deaths from 1971-1980 (National Population Commission, 1983). It is estimated that 82427 deaths were recorded during the 3 scenarios covered. If there is a grain surplus (i.e. $S > 0$) but stocks constitute no more than 40% of consumption (i.e. $S \times 100/C > 40$), then $D_t = 2 \times 10^6 + d - (d/40) \times x$, where d = number of deaths per year when stocks equal zero, and is set at 35,003 here; $x = 5 \times 100/C$. If there is a grain deficit, then D_t, $= 2 \times 10^6 + d + 2x$ (deficit).

Based on monthly/annually meteorological weather related data collected from the Nigerian Meteorological station/Unit and Central Bank of Nigeria (CBN) annual reports, the model was used to calculate the production, consumption and storage of crops (grains) under different climate scenarios over a 30-year period. In most scenarios, either an optimistic baseline annual increase of agricultural output of 1.85% or a more pessimistic appraisal of 0.75% was used. The rate of natural increase of the human population exclusive of excess hunger-related deaths was set at 1.65% per year.

The model has several important limitations. First, it accounts for local heterogeneity only by including deaths caused by mal-distribution. This is a crude approximation because inequitable distribution of food (and wealth in general) and extreme heterogeneity in population density, in agricultural productivity (over space and time), in climate regimes, and in the variability of weather patterns are key factors in generating regional famine. Secondly, the model does not include mechanisms whereby compensation for imminent food shortages could be made.

Thirdly, the model implicitly assumes that the underlying ' trend' (rate of change) in grain production will remain constant even in the face of the social and economic turmoil. Furthermore, maintaining a growth rate in agricultural output of 1.7% per year embodies a series of optimistic assumptions of success in the development and implementations of better agricultural practices and technologies. In addition, the effects of climate change are assumed to be constant. These assumptions would all have the effect of underestimating the number of deaths that may result from the impacts of deleterious climate change. Finally, a few comments relative to our validation of the model must be made. It is very difficult to quantify the actual number of people that have starved to death over the past two decades. Aside from poor censoring in famine-stricken areas, malnutrition compromises the immune system and the immediate cause of death of severely malnourished people is thus usually reported as disease. The rough estimate of over 82 thousand deaths is considerably lower. The numbers of deaths produced by the distributional aspects of the model are therefore probably conservative. Despite these limitations, however, the model still captured the scope of the study

Choice of the Multinomial Logit Model for Adaptation Scenery

The analyses presented in this study identify the important determinants of adoption of various adaptation measures for policy direction. The analytical approaches that are commonly used in an adoption decision study involving multiple choices are the Multinomial Logit (MNL) and Multinomial Probit (MNP) models. Both the MNL and MNP are important for analyzing farmer adaptation decisions, and are also appropriate for evaluating alternative combinations of adaptation strategies, including individual strategies. This study uses a MNL logit model to analyze the determinants of farmers' decisions because it is widely used in adoption decision studies involving multiple choices and is easier to compute than its alternative, the MNP (Hausman & Wise, 1978; Wu & Babcock, 1998). MNL has computational simplicity in calculating the choice probabilities that are expressible in analytical form (Tse, 1987). The main limitation of the model is the Independence of Irrelevant Alternatives (IIA) property, which states that the ratio of the probabilities of choosing any two alternatives is independent of the attributes of any other alternative in the choice set (Hausman & McFadden, 1984; Hassan & Nhemachena, 2008).

Model Specification

Let A_i be a random variable representing the adaptation measure chosen by any farming household. We assume that each farmer faces a set of discrete, mutually exclusive choices of adaptation measures. These measures are assumed to depend on a number of climate attributes, socioeconomic characteristics and other factors X. The MNL model for adaptation choice specifies the following relationship between the probabilities of choosing option A_i and the set of explanatory variables X as (Greene, 2003):

$$\text{Prob}(A_i = j) = \frac{e^{\beta'_j x_i}}{\sum_{k=0}^{j} e^{\beta'_k x_i}}; \quad j = 0, 1, ..., J \tag{5}$$

A ‘universal’ logit model avoids the IIA property while maintaining the multinomial logit form by making each ratio of probabilities a function of the attributes of all the alternatives. After considering all the economic model and interpretation, the effects of explanatory variables on the probabilities, marginal effects are usually derived as:

$$\delta_j = \frac{\partial \text{P}_j}{\partial x_i} = \text{P}_j\left[\beta_j - \sum_{k=0}^{J} \text{P}_k \beta_k\right] = \text{P}_j\left(\beta_j - \overline{\beta}\right) \tag{6}$$

The marginal effects measure the expected change in probability of a particular choice being made in respect to a unit change in an explanatory variable (Long, 1997; Greene, 2000). The signs of the marginal effects and respective coefficients may be different, as the former depend on the sign and magnitude of all other coefficients.

The explanatory variables used in the Multinomial Logit Models and hypothesized as determinants of respondents poor in the level of perception and adaptation to climate change (that is specialized in only (mono) cropping *)*are:, 1 for mono and 0 otherwise. Increased temperature (X_1), fall temperature (X_2), altered climate range (X_3), changed timing of rains (X_4), frequency of droughts (X_5), noticed climate change (X_6), cereal/legume intercropping (X_7), mulching (X_8), practiced zero tillage (X_9), making ridges across farms (X_{10}), farm size (X_{11}), own heavy machines (X_{12}), household size (X_{13}), farming experience (X_{14}), education (X_{15}), age of farmers

(X_{16}) access to extension facilities (ACEXT) (X_{17}) Dummy, if access 1, otherwise 0, access to credit facilities (ACCRE) (X_{18}) and Sex (X_{19}).

RESULTS AND DISCUSSIONS (Econometrics Estimation)

The Simulations Run Model of the climate scenarios (1971-2000)

T

o generate the output presented here, the model was iterated three-times per simulation (i.e., 3 scenarios), a run is a set of simulations done under the same initial conditions. The annual rate of natural increase of the population size (ΔN) is a constant percentage. For most runs, the initial population size and growth rate were set at 45576200 and 1.7% per scenario, respectively. Population size may be sharply reduced by grain shortages (which might likely cause rapid increases in deaths by starvation). These periods of population increase are assumed to be instantaneous. Following such scenarios, the constant rate of increase is applied to the new lower population size.

For most scenarios, initial production was set at 2374 metric tons (T) grain. The underlying rate of change in grain production (the ' trend ') also remains constant. For reference, the average value of the trend was 2.6 % per scenario from 1981 to 1990, and 1.4% per year from 1991 to 2000 (ANAP, 2006). To simulate normal stochastic fluctuations in production, the amount harvested in a given year is caused to deviate from the trend by one of five values (0.0, +2.0, -2.0, +4.0, or -4.0%) selected at random each year. These values were selected to create a pattern resembling a relatively favourable decade for local agriculture. The fluctuations in grain production generated by the model (expected variance 8.0%) are roughly comparable to those that actually occurred over the decade 1971-80 (observed variance 8.5%) a decade with little variation in the upward production trend. By contrast, the observed variances in grain production in the preceding (1981-1990) and following (1991-2000) decades were 51.0% and 20.4%, respectively. Thus the choice of the magnitude of 'normal' fluctuations was conservative

The model iterates a set of equations describing this system for a projection time of ten years for each scenario. We consider that period sufficiently long to reflect trends, but not so long that agricultural and economic systems are likely to change fundamentally. The mean and the standard deviation of several statistics are recorded on the completion of each run: the total number of deficits, the total number of deaths and maximum that occurred, and the final population size were studied. To determine the number of simulations required per run, we produced multiple sets of runs consisting of 100 and 1000 simulations each using initial conditions with high variance in output parameters (run E, table 1). The coefficient of variation of the mean number of deaths was 2.4, 1.3 and 0.3 respectively. We therefore considered 1000 simulations per run sufficient to produce reasonably consistent results.

The output of the model under a variety of scenario' is displayed in Tables 1-3. In most cases we contrast the output under different scenarios with reference to the average number of deaths produced in a run, a figure that reflects both the frequency and magnitude of changes in grain stocks. Generally, in what follows 'deaths' here refers to hunger-related deaths in excess of those subsumed in the natural rate of increase. The model was done in the absence of unfavourable climatic events and under the assumption that annual growth in grain production (ΔG) would keep pace with that of the population (ΔN), which was 1.7% in 1981-1990 scenarios (ΔN is now 1.8%). Over the 10-year projection time under this scenario (run A, Table1), although there are no grain deficits (0.0±0.0), 31±14 thousand deaths occur because of mal-distribution of food. The variance in the output statistics is quite high, as indicated by the occurrence of over 35 thousand hunger related deaths in one of the 1000 simulations. Thus, there will be increase in the population size at a constant growth rate of 1.7%, with no hunger-related reductions.

The model was run under several climatic scenarios with negative changes in harvest ranging from 3 to 10% per event. These seem reasonable values, because a reduction of about 5% (from the 1971-80 trend of 2.1% growth per annum) can be attributed to weather-caused harvest failure during 1961-1970 scenarios. The first set of the following runs assumes that ΔN = ΔG = 1.7% and that the initial carry-over stocks totaled 35,003 T (table 1). Under these growth rates, a 5% reduction in harvest every five years (on average; probability of event, P_e = 20% causes 0.1 (Δ0.3). Current trends in agriculture suggest that assuming grain production levels can increase by 1.7% annually is very optimistic. Growth averaged just 1.4% annually from 1981-90. Achieving either of these growth rates (1.7 or 0.9%) could well require substantial technological innovation, and maintaining productivity in the long run will clearly require major changes in farming practices.

Therefore, we repeated the set of runs presented in table 1 under the assumption that ΔG = 0.9 % over the 10 year projection time. Table 2 displays the output of these simulations. Even in the absence of unfavourable climatic conditions (run J, table 2), the imbalance between ΔN (1.7%) and ΔG (0.9%) leads to a staggering 82, 427 thousand deaths over the 30-year projection time. Under each scenario with climate-induced reductions (runs K-R), over 20 thousand people die on average. However, imposing various deleterious climatic regimes (runs K-R) on grain production does not increase the resulting average number of deaths as much as when ΔG equals ΔN runs

Table 1 Each run represents 1,000 simulations of the same conditions: (1971-1980)

Run	Net p/n	Δ *N and* Δ *G*	Probab of event	Mag. of change	Initial stock ('000 tonnes)	No. of Deficit Per simulation mean ± s.d	Number of deaths per simulation ('000 tonnes) Mean ± s.d.	MAX
A	*N*	1.7	0	0	35	0.0 ±0.0	31 ± 10	36
B	*N*	1.7	10	5	35	0.1 ±0.3	33 ± 19	42
C	*N*	1.7	10	10	35	0.6 ±0.8	41 ± 11	31
D	*N*	1.7	20	5	35	0.2 ±0.9	42 ± 16	41
E	*N*	1.7	20	10	35	1.2 ±1.1	71 ± 08	33
F	*N*	1.7	30	5	35	0.1 ±0.0	46 ± 10	48
G	*N*	1.7	30	10	35	0.8 ±1.0	38 ± 22	30
H	*N*	1.7	50	5	35	2.4 ±1.3	31 ± 14	45
I	*N*	1.7	50	10	35	3.3 ±1.1	43 ± 13	51

Source: Computer Output Results 2008

To test the sensitivity of the model to different rates of increase in grain production relative to those of population growth, we ran an identical set of climate scenarios on both the conditions that ΔN = 1.7% and ΔG = 1.3% (runs S-U, table 3), and that ΔN = 1.7% and ΔG = 2.4% (runs V-X, table 3). The number of deaths that occur with ΔG = 1.3 is appreciably less than under the comparable scenarios with ΔG = 0.9 (runs K, M, and L, table 2). The number of deaths that occur when ΔG = 2.4% (runs V-X, table 3) is roughly comparable to that where $\Delta N = \Delta G$ = 1.7 and no unfavourable weather patterns occur (run A, table 1). The number of deaths produced with ΔN = ΔG = 0 9 % is only slightly less (7%, on average) than under the same climatic scenarios with ΔN =ΔG = 1.7% (runs B, D and C, Table 1).

Table 2 Each run represents 1,000 simulations of the same conditions: (1981-1990)

J	*N*	1.7	0.9	0	0	35	2.4 ±1.9	43 ± 16 41
K	*N*	1.7	0.9	10	5	35	4.1 ±2.6	47 ± 21 35
L	*N*	1.7	0.9	10	10	35	1.6 ±1.8	51 ± 14 41
M	*N*	1.7	0.9	20	5	35	3.2 ±1.9	48 ± 10 38
N	*N*	1.7	0.9	20	10	35	4.7 ±2.2	32 ± 12 51
O	*N*	1.7	0.9	30	5	35	3.1 ±0.8	31 ± 12 45
P	*N*	1.7	0.9	30	10	35	2.1 ±2.1	44 ± 31 32
Q	*N*	1.7	0.9	50	5	35	3.4 ±1.3	45 ± 17 32
R	*N*	1.7	0.9	50	10	35	2.6 ±1.1	51 ± 23 41

Source: Computer Output Results 2008

Table 3 Each run represents 1,000 simulations of the same conditions: (1991-2000)

Run	Net p/n	Δ ***N***	Δ ***G***	Probab of event	Mag. of change	Initial stock ('000 tonnes)	No. of Deficit Per simulation mean ± s.d	Number of deaths per simulation ('000 tonnes) Mean ± s.d. MAX
S	*N*	1.7	1.3	10	5	35	2.1 ±1.1	31 ± 11 41
T	*N*	1.7	1.3	10	5	35	3.1 ±2.5	42 ± 10 33
U	*N*	1.7	1.3	20	10	35	1.6 ±1.2	32 ± 14 37
V	*N*	1.7	1.3	20	5	35	1.2 ±1.0	46 ± 15 30
W	*N*	1.7	1.3	30	5	35	1.2 ±1.1	41 ± 18 43
X	*N*	1.7	1.3	30	10	35	2.3 ±0.7	20 ± 12 46

Source: Computer Output Results 2008

Climate Change measurement (average rainfall) population growth and grain production

Tables 4 & 5 present the results of climate change (captured by average rainfall), population growth and food production (grain production). The climate change scenarios (1971-2000) analysis revealed that population growth during the 1^{st} -2^{nd} scenarios (1971-1980 & 1981-1990) increased by 58.04%, while food production during the same period increased by 68.69% (Table 4). However, in the 3^{rd} scenario, analysis revealed a decline in food production by 76.92% as population continues to grow. This portrays an alarming situation that food production does not keep pace with population growth. Average rainfall according to the study reflects a fairly steady growth during these periods. This finding corroborated with other past studies that at this period, 1981-1990; poverty levels in the country recorded the highest (CBN 2006).

Table 5 presented the disaggregation analysis results. Results show that all the zones in Nigeria experienced about 23.04% population growth across the 3 scenarios. However, grains production and rainfall have been declining. For instance, in the Northern regions there is a decline in food production to about 178.37% with high deficit recorded in the North West zone of the country (339%). The Southern part shows a decline of about 20%, while the South-south recorded a high decline (281%). The impact of climate change or global warming (as captured by average rainfall) revealed that all the Northern regions experienced decline (11.03%) during period under review (1971-2000), with North West region most affected (13.32%). The Southern region however, climate change (as captured by average rainfall) show a beneficial response with the exception of South east that recorded a decline (9.09%), while the South west show a high figure of 20.58% and South-south of 2.45%. Findings indicate that the agricultural impacts of climate change in Nigeria need a holistic and quickly interventions. The total average impact may be positive or negative depending on the climate scenarios and zones. They are positive in the South particularly in the Southwest in most scenarios, but negative in the North in some scenarios

Table 4 Frequency Distribution of Average Total Rainfall, Population and Food Production for all the Scenarios considered.

Scenarios	Average Total Rainfall (mm)	Population	Food Production (Grain) (‘000 Tonnes)
1971-1980	1257.02	45576200	147.30
1981-1990	1415.88	78524000	214.60
1991-2000	1436.64	102081200	58.20

Farmer’s Actual Adaptation Measures and Practises

Table 6 presents farmers’ *actual* adaptation measures and practices actually followed, thus, grouped into ten categories. These strategies, however, are mostly followed in combination with other strategies. These are grouped into the following adaptation options: diversifying into multiple and mixed crop-livestock systems, and switching from crops to livestock and from dry land to irrigation, practicing zero tillage, making ridges across farms and cereal/legume intercropping. Table 6 reveals that making ridges across farms is the dominant system (18.75%). Multiple crops under dry land is the second most common strategy ((18.46%), and Multiple cropping mixed with livestock rearing under dry land conditions (15.41%) comes third. Change use of chemicals, fertilizers and pesticides is the most common adaptation practise (14.56%). The implication is that when necessary inputs are available at the right time and are utilized, it tends to improve productivity. The main adaptation strategic measures followed Food and Agriculture Organization (FAO) classification (Dixon et al., 2001) and were used to classify the strategic measures into thirteen.

Table 5: Frequency Distribution of Average Total Rainfall, Population and Food Production (Grains) 1971-2000

Zone	North Central (7) NC	North West (7) NW	North East (5) NE	South West (6)	South East (5)	South-South (6) SS
1971-1980						
Average Total Rainfall (mm)	1074.85	952.03	783.68	1696.41	-	3034.15
Population	7346380	11649891	5427094	8978946	-	12175889
Food production (Grain) ('000 Tonnes)	23.74	37.65	17.54	29.02	-	37.34
1981-1990						
Average Total Rainfall (mm)	1173.43	762.50	762.52	1226.20	2194.50	2376.10
Population	12657202	20071793	9350432	15469976	9188059	11786539
Food production (Grain) ('000 Tonnes)	34.59	54.85	25.55	42.28	25.11	32.21
1991-2000						
Average Total Rainfall (mm)	1087.43	840.15	701.06	1543.90	2011.70	2435.59
Population	16454363	26093331	12155561	20110969	11944476	15322500
Food production (Grain) ('000 Tonnes)	11.56	12.48	11.16	11.91	11.13	11.46

Source: Central Bank of Nigeria Statistical Bulletin, 2008 and National Bureau of Statistics, 2008

Table 7 presents the estimated marginal effects and t-levels from the MNL model. The results show that most of the explanatory variables considered are statistically significant at 10%. This study uses specialized (mono) cropping as the base category for no adaptation and evaluates the other choices as alternatives to this option. The results show that altered climate change, frequency of droughts, age and sex all had no significance effect on adaptation. While the increased temperature, intercropping of cereal/legume, mulching, zero tillage making ridges, farm size, farming experience, educational status access to extension and credit facilities are factors influencing adaptation positively (Table 9). However, fall in temperature, change timing of rains, own heavy machines and household size are also significant factors that influence adaptation negatively. This result suggests that the larger the occurrence of these variables, the poorer the adaptation.

Summary of the results revealed that fall in temperature influences the probability of switching away from mono-cropping more than changes in increased temperature. Similarly, the magnitudes of the marginal coefficients suggest that low outputs warming is a strong factor influencing the probability of switching to other systems that are better adapted to changes in temperature. Better access to extension and credit services seems to have a strong positive influence on adaptation. In addition, access to other farm assets such as heavy machinery is found to promote the use of large –scale farming. These results suggest that capital, land and labour serve as important factors for coping. The choice of the suitable adaptation measure depends on factor endowments (i.e. family size, land area and capital resources). The more experienced farmers are, the more likely to adapt. Sex of the farmer did not seem to be of significance in influencing adaptation, as the marginal effect coefficient was statistically insignificant and signs do not suggest any particular pattern. These results suggest that it is the experience rather than sex that matters for adaptation.

Table 6: Actual adaptation measures used by farmers (N= 850)

Adaptation measures	Respondents (%)
Specialized crop under dry land	121 (8.97)
Specialized crop under irrigation	15 (1.11)
Specialized livestock under dryland	13 (0.96)
Specialized livestock under irrigation	5 (0.37)
Multiple crops under dryland	249 (18.46)
Multiple crops under irrigation	14 (1.04)
Mixed mono-crop/livestock under dryland	144 (10.67)
Mixed mono-crop/livestock under irrigation	25 (1.35)
Mixed multiple crops/livestock under dryland	208 (15.41)
Mixed multiple crops/livestock under irrigation	31 (2.30)
Practiced zero Tillage	47 (3.48)
Making ridges across farms	253 (18.75)
Cereal/legume intercropping	182 (13.49)
Number of observations	**1349***

***** Multiple Responses indicated

Table 7: Marginal Effects of Explanatory Variables from Multinomial Logit Adaptation Model

Variable	Estimate	t-value
Increased Temperature (X_1)	0.090E-02	5.107***
Fall in Temperature (X_2)	-0.308E-01	-2.917**
Altered Climate Range (X_3)	0.4211	0.128
Changed timing of rains (X_4)	-0.161E-01	-3.427***
Frequency of Droughts (X_5)	-0.8851	-0.315
Noticed Climate Change (X_6)	0.6272	1.7061
Cereal/legume Intercropping (X_7)	0.5783	2.408**
Mulching (X_8)	0.22E-05	2.1371*
Zero Tillage (X_9)	933E-06	3.412***
Making Ridges across Farms (X_{10})	0.717	2.762**
Farm size (X_{11})	0.827E-07	2.1262*
Owned heavy machines (X_{12})	-0.923E-01	- 4.4262***
Household size (X_{13})	-0.135E+11	-4.4262***
Farming experience (X_{14})	0.5196E-04	2.5931*
Educational status (X_{15})	0.1162	5.011***
Age (X_{16})	0.2364	0 .3472
Access to extension facilities (X_{17})	0.3681	2.5272**
Access to credit facilities (ACCRE) (X_{18}).	0.2606	1.9621*
Sex (X_{19})	-0.5190	-0.9428

Source: Computer Printout of Logit Regression Analysis

*** = Significant at p<0.01, ** = Significant at p<0.005, * Significant at p<0.001

Log-likelihood function: -201.44, Significance level: . (P<00001) Constant = 0.71

Conclusion

Findings from this study indicated that agricultural impacts of climate change in Nigeria are uncertain. The total average impact may be positive or negative depending on the climate scenario. But in most scenarios it was shown that climate change will have an overall positive impact on Nigeria's agriculture. Impacts also vary both quantitatively and qualitatively by zone and season. They are positive in the Southern region of Nigeria in most scenarios, but negative in some Northern part of the country in some scenario. Farmers appear to be abandoning mono-cropping for mixed and mixed crop-livestock systems, considering risky, mono-cropping practicing under dry land. Farming experience and access to education were found to promote adaptation. This implies that education to improve awareness of potential benefits of adaptation is an important policy measure for future adaptation and mitigation strategies.

Moreover, the study found out that lack of effective access to information on climate change. Thus, there is need for effective and reliable access to information on changing climate. In addition, empowerment (credit or grant facilities) is crucial in enhancing farmers' awareness. This is vital for adaptation decision making and planning. Combining access to extension and credit ensures that farmers have the information for decision making and the means to take up relevant adaptation measures.

It is evidenced from this study that grain crop farmers are experiencing change in climate and they have already devised a means to survive. It is from this point that policy of reliable and effective measures of adaptation need to be implemented and must be accessible to the end users. People responses to the issue of climate change are at low pace. Thus, there is a need to design strategies that could help the farmers/rural communities' responses effectively to global warming through early warming alerts and interpretations in the language useful to farmers/rural communities.

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Robust Linear Classifier for Unequal Cost Ratios of Misclassification

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This paper focuses on the robust classification procedures when the assumption of equal cost of misclassification is violated. A normal distribution based data set is generated using the Statistical Analysis System (SAS) version 9.1. Using Barlett's approximation to chi-square, the data set was found to be homogenous and was subjected to three linear classifiers namely: Maximum Likelihood Discriminant Function (MLDF), Fisher's linear Discriminant Function and Distance Based Discriminant Function. To Judge the performances of these procedures, the Apparent Error Rates for each procedure is obtained for different cost ratios 1:1, 1:2, 1:3, 1:4 and 1:5 and sample sizes 5:5, 10:10, 20:20, 30:30, and 50:50. The results shows that the three procedures are insensitive to cost ratio exceeding ratio 1:2 and that MLDF was observed as robust discriminant function among classification functions considered.

Key Words: Apparent Error Rates, Maximum Likelihood Discriminant Function, Distance Based Discriminant Function, Fisher's linear

1.0 Introduction

Fisher (1936) was the first to suggest a linear function of variables representing different characters, hereafter called the linear discriminant function (discriminator) for classifying an individual into one of two populations. Fisher's linear discriminant function (LDF) method is well established for equal covariance multivariate normal predictors (Aderson, 1958).It optimally deteriorates, however, as the assumption of normality gets unrealistic (Krzanowski, 1988). Qian Du and Chein-I Chang (2001) used distance-based discriminant function (DBDF) that uses a criterion for optimality derived from Fisher's ratio criterion. It not only maximizes the ratio of inter-distance between classes to intra-distance within classes but also imposes a constraint that all class centers must be aligned along predetermined directions. A method of discrimination, based on maximum likelihood estimation, is described. On a variety of mathematical models, including and extending the models most commonly assumed in discriminant theory, the discriminant reduces to multivariate logistic analysis. Even when no simple model can be assumed, other considerations show that this method should work well in practice, and should be very robust with respect to departures from the theoretical assumptions. The method is compared with others in its application to a diagnostic problem. The consideration of Cost-sensitive Studies in linear discriminant function has received growing attention in the past years. (Elkan, 2001; Margineantu and Dietterich, 2000). One way to incorporate such costs is the use of a cost matrix, which specifies the misclassification costs in the

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class dependent manner. (Elkan, 2001). Brefeld *et al*, (2003) discuses the ideal to let the cost depend on the single example and not only on the class of the example. Authors also presented a natural cost-sensitivities extension of the Support Vector Machine (SVM) and discused its relation to Bayes rule. Ariyo and Adebanji (2010) compared the performance of both Linear and Quadratic classifier under unequal cost of misclassification and concluded that both classifiers are insensitive to the cost ratio exceeding ratio 1:2. Adebanji et al (2008) investigated the performance of the homoscedastic discriminant function (HDF) under the non-optional condition of unequal group representation (prior probabilities) in the population and the asymptotic performance of the classification function under this condition. The results obtained showed that the misclassification of observation from the smallest group escalate when the sample size ratio 1:2 is exceeded and this increases in error rate is not corrected by increasing the sample size. They observed that the performance of the function is more susceptible to higher variability in the reported error rates. Several Authors had looked into issue of cost-sensitivity when costs and prior probabilities are both unknown (Zandrozny and Elkan, 2001) and its application in different areas especially in neural Network (Berardi and Zhang., 1999; Xingye, and Yufeng, 2008 and Zheng, *et al*, 2007). The issue of different misclassification costs for balanced data has not been given much attention. Hence, the study is motivated to evaluate the performance and robustness of selected linear classifiers when the assumption of equal cost of Misclassification is violated.

2.0 Methodology

A Simulated data from SAS 9.1 was used for this study. The data consists of two groups with four variables (x_1 , x_2, x_3, x_4). The Simulation process creates a data set by simulated random variables from two normal populations**.**

The above procedure was repeated for n = 5, 10, 20, 30, 50. For each value of n the, procedure returned 10, 20, 40, 60 and 100 sample sizes. To test the equality of mean by multivariate methods, Hotelling T^2 and Wilks's lambda was used. The Barlett's Likelihood ratio test was also used to test the homogeneity or other wise of the data sets and the data set was found to be homogenous and was subjected to three (3) selected linear classifiers namely: Maximum Likelihood Discriminant Function(MLDF), Fisher's linear Discriminant Function (FLDF) and Distance Based Discriminant Function (DBDF). To Judge the performances of these procedures, the Apparent Error Rates (APER) for MLDF, FLDF and DBDF under different cost ratio 1:1, 1:2, 1:3, 1:4 and 1:5 were obtained.

2. 1 Discriminant rules

A discriminant rule d corresponds to a division of R^p into disjoint region $R_1, \dots, R_n$

$$(UR_i=R^n)$$

The rule d defined by allocate x to π_j if x ε R_i for j=1 ,…,n. Discriminant will be more accurate if π_j has most of its probability concentrated in R for each j.

2. 2 Maximum Likelihood rule (ML rule)

The maximum likelihood discriminant rule for allocating an observation x to one of the population $\pi_1, \ldots, \pi_n$ is to allocate x to the population which gives the largest likelihood to x. That is the maximum likelihood rule says one should allocate x to π_j when

$$L_i = \max L_i(x) \text{ .} \qquad \text{(Anderson, 1984)} \qquad (1)$$

Theorem 1 If π_i is the $N_p(\mu_i, \Sigma)$ population, i =1,…, g and $\Sigma > 0$, then the maximum likelihood discriminant rule allocate x to π_j where $j \epsilon \{1, \ldots, n\}$ is that value of i which minimized the mahalanobis distance $(x-\mu)^{\prime}\Sigma^{-1}(x-\mu_1)$ where g=2 the rule allocate x to π_1. If $\alpha^{\prime}(x-\mu) > 0$ and $a^{\prime}\left\{x - \frac{1}{2}(\bar{x}_1 + \bar{x}_2)\right\} > 0$, where $\boldsymbol{\alpha}=\Sigma^{-1}(\mu_1 - \mu_2)$ and $\mu = (\mu_1 + \mu_2)$ and to π_2 otherwise.

2.3 Fisher's Linear Discriminant rule (FDL rule)

Once the linear discriminant function has been calculated, an observation x can be allocated to one of the n population on the basis of its "discriminant scores"$a^{\prime}x$. The samples $\bar{x}_i$ have scores $a^{\prime}\bar{x}_i=\bar{y}_i$. The x is allocated to that population where mean scores is closest to $a^{\prime}x$ that is allocate x to π_j if $|a^{\prime}x\text{-}a^{\prime}\bar{x}_j| < |a^{\prime}x\text{-}a^{\prime}\bar{x}_i|$ for $i \neq j$ (Giri,2004)

Fisher's discriminant function is most important in the special case of g=2 groups. Then B has rank one and can be written as $B = \left(\frac{n_1 n_2}{n}\right) dd^{\prime}$ where $d = \bar{x}_1 - \bar{x}_2$. Thus, $W^{-1}B$ has only one zero eigenvalue. This eigenvalue equals to $tr\ W^{-1}B = \left(\frac{n_1 n_2}{n}\right) d^{\prime}\, W^{-1}d$. The corresponding eigenvalue is $a = W^{-1}d$.Then the discriminant rule becomes; allocate x to π_1 if $d^{\prime}\, W^{-1}\left\{x - \frac{1}{2}(\bar{x}_1 + \bar{x}_2)\right\} > 0$ and to π_2 otherwise.

2.4 Distance –based discriminant Function

This approach requires a definition of distance between the single observation x and each training sample. One possibility is to define a squared distance by the Mahalanobis qualities:

$$D_i^2 = (x - \mu_i)^{\prime} S^{-1}(x - \mu_i). \qquad (2)$$

Where μ_i is the mean of ith training set (i=1,2),and S is the covariance matrix pooled within the training set.

2.5 Testing Adequacy of discriminant coefficient

Consider the discriminant problems between two multinormal populations with mean μ_1, μ_2 and common matrix $\sum$. The coefficient of the MLD discriminat function $a^{\mid}x$ are given by $\boldsymbol{\alpha}=\sum^{-1}\delta$ where $\delta = \mu_1 - \mu_2$. In practice of course the parameters are estimated by $\bar{x}_1, \bar{x}_2$ and $S = m^{-1}\left((n_1 - 1)S_1 + (n-1)S_2\right)$, where $m = n_1 + n_1 - 2$. Letting $d = \bar{x}_1 - \bar{x}_2$,the coefficients of the sample MLDF given by $a = m\ W^{-1}d$.

A test of hypothesis $H_0; \alpha_i = 0$ using the sample Mahalanobis distances $D_p^2 = md^{\mid}W^{-1}d$ and $D_1^2 = md_1^{\mid}W_{11}^{-1}d_1$ has been proposed by Rao (1965) this test statistics uses the statistic:

$$\left\{\frac{m-p+1}{p-k}\right\} c^2(D_p^2 - D_k^2)/(m + c^2D_p^2)\} \qquad (3)$$

Where $c^2 = \frac{n_1 n_2}{n}$. Under the null hypothesis (3) has $F_{p-k,m-p+1}$ distribution and we reject H_0 for large value of this statistics.

2.6 Evaluating of Classification Function

One important way of judging the performance of any classification procedure is to calculate the "error rates" or misclassification probabilities (Richard and Dean, 1988). When the forms of parent populations are known completely, misclassification probabilities can be calculated with relative ease. Because parent populations are rarely known, we shall concentrate on the error rates associated with the sample classification functions. Once this classification function is constructed, a measure of its performance in future sample is of interest. The total probability of misclassification (TPM) is given as:

$$TPM = P_1 \int_{R_1} f_1\ dx + P_2 \int_{R_2} f_2\, dx \qquad (4)$$

The smallest value of this quantity obtained by a judicious choice of R_1 andR_2 is called the optimum error rate (OER).

OER = Minimum TPM .

Probability of Misclassification

The probability of allocating an individual to population π_i , when in fact he comes from π_j is given by:

$$P_{ij} = \int \phi_i(x) L_j(x) dx \tag{5}$$

If the parameters of the underlying distribution are estimated from the data, then we get estimated probability $\check{P}_{ij}$. Consider the case of two normal population $N_p(\mu_1, \sum)$ and $N_p(\mu_2, \sum)$. If

$\mu = \frac{1}{2}(\mu_1 + \mu_2)$, then when x comes from π_1, $a^{\prime}(x-\mu) \sim N_p(\frac{1}{2}a(\mu_1 - \mu_2), a^{\prime}\sum \boldsymbol{\alpha})$.Since the disccriminant function is given by $l_2(x) = a^{\prime}(x-\mu)$ with $a = \sum^{-1}(\mu_1 - \mu_2)$,we see that if x comes from π_1, $h_2(x) \sim N\left(\frac{1}{2}\Delta^2, \Delta^2\right)$,where:

$$\Delta^2 = (\mu_1 - \mu_2)^{\prime} \sum^{-1} (\mu_1 - \mu_2) \tag{6}$$

Equation (6) is the square Mahalanobis distance between the positions, similarly, if x comes from π_1, $h_2(x) \sim N\left(\frac{1}{2}\Delta^2, \Delta^2\right)$.Thus, the misclassification probabilities are given by:

$$\begin{aligned} P_{12} &= p(h(x) > 0/\pi_2 \\ &= \phi(-E(h)/\pi_2) \\ &= \phi(\tfrac{-1}{2}\Delta) \quad \text{(Giri,2004)} \end{aligned} \tag{7}$$

where ϕ is the standard normal distribution function.

2.7 Error Rates

Optimal error rates (OER) are error rate associated with the best possible allocation rule that could be used, if all assumption made are appropriate. This error rate can be calculated when the population density functions are known it given by:

$$\text{OER} = \text{ minimum TPM} = \frac{1}{2}\phi(\tfrac{-1}{2}\Delta) + \frac{1}{2}\phi\left(\frac{-1}{2}\Delta\right) = \phi\left(\frac{-1}{2}\Delta\right) \tag{8}$$

The performance of sample classification function can be evaluated by calculating the actual error rate (AER).

$$\text{AER} = P_1 \int_{R_2} f_1(x)\, dx + \int_{R_1} f_1(x) dx \qquad (9)$$

Where R_1 and R_2 represent the classification regions determined by sample size n_1, n_2 respectively.

The AER indicates how the sample classification function will perform in future samples. Like the OER, it cannot, in general, be calculated because it depends on the unknown density functions $f_1(x)$ and $f_2(x)$.There is a measure of performance that does not depends on the form of the parent populations and that can be calculated for any classification function procedure. This measure is called the apparent error rate (APER) is defined as the fraction of observation in the training sample that are misclassified by the sample classification function. It can be easily calculated from the confusion matrix which shows actual versus predicted group membership. For n_1 observation from π_1 and n_2 observations from π_2, the confusion matrix has the form.

Actual Membership	Predicted Membership	
	n_{1c}	n_{1M}
	n_{2c}	n_{2M}

Where

n_{1c}= Number of π_1 items correctly as π_1 items.

n_{2c}= Number of π_2 items correctly as π_2 items.

n_{1M} = Number of π_1 items misclassified as π_2 items.

n_{2M} = Number of π_2 items misclassified as π_1 items.

This is called the Apparent Error Rate (APER) and is defined as:

$$\text{APER}= \frac{n_{1M}+n_{2M}}{n_{1c}+n_{2c}} \quad \text{(Richard and Dean, 1998)} \qquad (10)$$

3.0 Results

Table1 shows that Likelihood test (Barlett's approximation to Chi-square) statistics is not signification at 5% level of significant, we accept the null hypothesis that the simulated data has equal variance covariance matrix.

Table 1: The Test results for testing Equality of Variance.

Data	Chi – square	Df	P-value (5%)	Null Hypothesis
A	6.411	10	0.7796	Equal Variance

Table 2 shows the error for the three classification procedures under different cost ratio, the APER for the three discriminant rules becomes unchanged as the cost assign C_{21} is tripled. For cost ratio 1:1 and 1:2 MLDF rule gave the least "error rate" compared to the classification rules considered.

Table 2 : Apparent Error rate for the classification rules under different cost ratio.

Cost ratio	ML rule	FL rule	DB rule
1:1	47.83	48.00	49.67
1:2	50.17	51.67	50.00
1:3	50.00	50.33	50.00
1:4	50.00	50.00	50.00
1:5	50.00	50.00	50.00

In Table 3, the value of Apparent Error rate (APER) for diffract Sample size under different cost ratios was presented. The result shows that on only the Distance based Discriminnat Function (DBDF) is sensitive to Small Sample sizes. At Sample size 5:5, DBDF had that least APER but this value increases as the sample size increases. It is also clear that sample sizes considered has little effect on the performance of classification functions considered under different cost ratio.

Table 3: The Apparent Error rate for the Classification rules for different Sample sizes and cost Ratio

Sample ratio															
	n; 5:5			**n; 10:10**			**n; 20:20**			**n; 30:30**			**n; 50:50**		
	ML	FL	DB	ML	FL	DB	ML	FL	DB	ML	FL	DB	ML	FL	DB
Cost ratio															
1:1	39.4	49.0	30.3	41.9	48.0	30.3	38.0	50.1	30.2	39.0	50.0	39.2	47.8	48.0	49.7
1:2	40.1	49.0	48.0	43.0	47.0	49.0	51.0	50.2	49.1	49.9	51.0	50.0	50.2	51.7	50.0
1:3	49.7	50.0	50.3	51.0	53.0	50.0	50.1	50.0	49.0	50.0	50.0	50.0	50.0	50.3	50.0
1:4	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0
1:5	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0

4.0 Conclusion/Recommendation

Three Linear dicsriminant rules: MLDF, FLDF, and DBDF were studies when classical cost assumption is violated. In each allocation rule, introduction of different cost ratios causes imbalances in the proportion of misclassification also the error rates. At cost ratio 1:1, 1:2 all classification rules except MLDF gave equal misclassification proportion. The APER for the three classification rules under different cost ratio were also examined in this study, for cost ratio 1:1 and 1:2 MLDF gave the least error rate. At cost ratio exceeding ratio 1:3, the APER remain unchanged for all classification rules. We conclude that APER for all classifications considered is insensitive to cost ratio exceeding ratio 1:3.

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Stock Market Reaction to Selected Macroeconomic Variables in the Nigerian Economy

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This study examines the relationship between the stock market and selected macroeconomic variables in Nigeria. The all share index was used as a proxy for the stock market while inflation, interest and exchange rates were the macroeconomic variables selected. Employing error correction model, it was found that a significant negative short run relationship exists between the stock market and the minimum rediscounting rate (MRR) implying that, a decrease in the MRR, would improve the performance of the Nigerian stock market. It was also found that exchange rate stability in the long run, improves the performance of the stock market. Though the results for Treasury bill and inflation rates were not significant, the results suggests that they were negatively related to the stock market in the short run thus, achieving low inflation rate and keeping the TBR low could improve the performance of the Nigerian stock market. Specifically, the study concludes that, by achieving stable exchange rates and altering the MRR, monetary policy would be effective in improving the performance of the Nigerian stock market.

Key Words: Stock Market, Macroeconomic variables, Error Correction Model

JEL Classification: G10; E44; C22;

1. INTRODUCTION

The stock market houses a large chunk of the nation's wealth and has continued to be the major discuss of various studies since the advent of the global financial crisis. With the recent decline observed in the Nigerian stock market, various studies have examined the effectiveness of monetary policy on improving the performance of the Nigerian stock exchange. While maintaining financial system stability remains a core objective of the Central Bank of Nigeria, the evidence concerning the relationship between the stock market and monetary policy variables in Nigeria still offers some methodological gaps. This study aims at providing empirical evidence concerning the relationship between the stock market and selected macroeconomic variables in Nigeria. The study builds on the works of Islam (2003); Maysami *et al* (2004); and Osuagwu (2009).

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The rest of the paper is organized as follows: section two reviews relevant literature for the study, while the research methodology is presented in section three. In section four, the results obtained from the analysis are discussed and finally, section five presents the summary and conclusion.

2 THEORETICAL AND EMPIRICAL LITERATURE

There are several schools of thought that offer theoretical explanations for the behaviour of stock prices. Some of them include: the fundamentalist school, the technical school, the random walk hypothesis school and the macro-economic hypothesis school. Detailed explanations of these theories are presented in Maku and Atanda (2009).

According to the fundamentalist, the value of a corporation's stock is determined by expectations regarding future earnings and by the rate at which those earnings are discounted. The technical school on the other hand, oppose the fundamentalists' and argue stock prices tend to follow definite pattern and each price is influenced by preceding prices, and that successive prices depend on each other.

The random-walk hypothesis is based on efficient market assumption that investors adjust security rapidly to reflect the effect of new information. The theory postulates that stock prices are essentially random and therefore, there is no chance for profitable speculation in the stock market. The macroeconomic approach argues that stock prices are sensitive to changes in macroeconomic variables.

Other author's, have proposed more formal theories that explain the behaviour of asset prices. One of such theories is the capital asset pricing model (CAPM). This theory relates the expected price of an asset to its riskiness measured by the variance of the asset's historical rate of return relative to its asset class (Sharpe 1964; Lintner 1965). The CAPM takes the following linear form:

$$R_t = \alpha + \beta X_t + \varepsilon_t \qquad (2.1)$$

where R_t represents the return to an asset, X_t represents the return of an underlying portfolio of assets (often measured as a domestic market index), and ε_t represents the asset-specific return, all at time t. The key term in the model is β (i.e. beta), which indicates the statistical relationship between the asset's return and the return on the total portfolio of assets.

An alternative framework to the CAPM is the arbitrage pricing model (APM), in which the return on an asset is specified as a function of a number of risk factors common to that asset class. The model assumes that investors take advantage of arbitrage opportunities in the broader market; thus, an asset's rate of return is a function of the return on alternative investments and other risk factors. A standard arbitrage model takes the following form:

$$R_t = \alpha + \beta_1 X_{1t} + \beta_2 X_{2t} + ... + \beta_k X_{kt} + \varepsilon_t \quad (2.2)$$

The model is similar in form to equation 2.1, except that the X's represent a set of risk factors common to a class of assets, and the betas represent the sensitivity of the asset's return to each factor. As argued by Ferson and Harvey (1998) the CAPM and APM have advantages and disadvantages as models of asset returns. The CAPM is seen as parsimonious and commonly employed by equity analysts, but it requires a precise identification of the portfolio against which the asset is compared.

The APM, on the other hand, accommodates multiple sources of risk and alternative investments, suffers from a similar challenge of identification since many factors, both international and domestic, that could influence an asset's performance (Mosley and Singer, 2007). Thus this study will employ the asset pricing model as its theoretical framework where the all share index of the Nigerian stock exchange would be used to represent the asset price and exchange rates, inflation rates and interest rates will be viewed as their associated risk factors.

Islam (2003) examined the short-run dynamic adjustment and the long-run equilibrium relationships between four macroeconomic variables (interest rate, inflation rate, exchange rate, and the industrial productivity) and the Kuala Lumpur Stock Exchange (KLSE) Composite Index. The study found that there was significant short-run (dynamic) and long-run (equilibrium) relationships among the macroeconomic variables and the KLSE stock returns.

Maysami *et al* (2004) examined the long-term equilibrium relationships between selected macroeconomic variables and the Singapore stock market index (STI), as well as with various Singapore Exchange Sector indices. The study concluded that the Singapore's stock market and the property index form cointegrating relationship with changes in the short and long-term interest rates, industrial production, price levels, exchange rate and money supply.

Kandir (2008) investigated the role of macroeconomic factors in explaining Turkish stock returns from July 1997 to June 2005. Macroeconomic variables used were growth rate of industrial production index, change in consumer price index, growth rate of narrowly defined money supply, change in exchange rate, interest rate, growth rate of international crude oil price and return on the MSCI World Equity Index. The analysis was based on stock portfolios rather than single stocks. It was found that exchange rate, interest rate and world market return seem to affect all of the portfolio returns, while inflation rate was significant for only three of the twelve portfolios. On the other hand, industrial production, money supply and oil prices had no significant effect on stock returns.

Osuagwu (2009) investigated the impact of monetary policy variables on the performance of the stock market in Nigeria using quarterly data from 1984 to 2007. In his methodology, a linear combination of stock market index and monetary policy variables were estimated using ordinary least squares; co-integration and error-correction specification. It was found that stock market performance was strongly determined by broad money supply, exchange rates and consumer price index in the short and long-run. On the other hand, minimum rediscount rate and Treasury bill rates showed mixed results and their relationship to changes in stock market index was not significant. The present study differs from Osuagwu (2009) in three ways: (1) it has an extended data set reaching 2008, (2) it makes use of annual data rather than quarterly data to see if consistent results will be yielded, and (3) it employs the engle-granger two step error correction model that rests on granger representation theorem to arrive at case specific results rather than the parsimonious error correction model employed in Osuagwu (2009).

Cointegration and Error Correction Models

The concept of cointegration and error correction model is extensively discussed in Rao (2005:9-25). The link between cointegration and error correction model stems from the Granger representation theorem (Engle and Granger, 1987). The theorem states that two or more integrated time series that are cointegrated have an error correction representation, and two or more time series that are error correcting are cointegrated.

There are three important points in this definition. First, cointegration refers to a linear combination of nonstationary variables. Secondly all variables must be integrated of the same order. However, this is only true for a two-variable case, if these two variables are integrated at different orders of integration, then these two series cannot possibly be cointegrated. However it is possible to have a mixture of different order series when there are three or more series under construction in which various subsets may be cointegrated. Thirdly, if Xt has n components, there may be as many as *n-1* linearly independent cointegrating vectors. If X_t contains only two variables, there can be at most only one independent cointegrating vector.

Engle and Granger (1987), proposed a two step procedure to test for cointegration. Prior to estimation, the variables are pre-tested for their order of integration. Based on the definition given by Engle and Granger (1987), cointegration necessitates that the variables be integrated of the same order. Therefore, each variable has to be pre tested by using the augmented dickey fuller (ADF) and Phillip Perron (PP) test to determine its order of integration. If the variables are integrated of different orders, possibly these variables are not integrated.

If the variables are cointegrated, the second step of the EG procedure involves specifying an error-correction model (ECM) for each equation in the system. The multivariate EG two-step procedure for estimating ECM however, requires that there are only two variables in the system.

The multivariate maximum likelihood cointegration testing procedure was developed by Johansen (1988) and Stock and Watson (1988) and Johansen and Juselius (1990). There are two basic test statistics involved in Johansen and Juselius's maximum likelihood test. The first test statistic is the *trace test* while the second is the maximal *eigenvalue test*. The Johansen's multivariate maximum-likelihood procedure though more robust in models involving more than two variables, is not applied in two variable cases. In such cases, the Engle-Granger two step ECM procedures are preferred (Rao, 2005). In this study, the EG two – step procedure is followed.

3. RESEARCH METHODOLOGY

Time series data were collected for the all share index of the Nigerian stock exchange and selected macroeconomic variables in Nigeria from 1985 to 2008. The data were collected from the 2008 50^{th} anniversary version of the Central Bank of Nigeria statistical bulletin downloadable from www.cenbank.org.

For the Nigerian stock exchange, the all share index was used as proxy while interest rates (minimum rediscounting and Treasury bill rates), inflation and exchange rates were the selected macroeconomic variables. The choice of the macroeconomic variables selected is to capture monetary policy variables of the Central Bank of Nigeria.

The all share index (ASI) was specified as the dependent variable while exchange rate (ER), minimum rediscounting rate (MRR) – sometimes referred to as the monetary policy rate, treasury bill rate (TBR) and the 12month moving average inflation rate (INF) were specified as the independent variables.

Though the study adopts the Ferson and Harvey (1998) Asset Pricing Model as the theoretical framework, the Engle-Granger (1987) two-step error correction model procedure discussed in Rao (2005), was adopted for the estimation of the models. The models are specified below:

$$\Delta LogASI_t = a_0 + a_1 LogMRR_t + a_2 U_{t-1} + \varepsilon_t \quad (3.1)$$

$$\Delta LogASI_t = b_0 + b_1 LogTBR_t + b_2 U_{t-1} + \varepsilon_t \quad (3.2)$$

$$\Delta LogASI_t = c_0 + c_1 LogER_t + c_2 U_{t-1} + \varepsilon_t \quad (3.3)$$

$$\Delta LogASI_t = d_0 + d_1 LogINF_t + d_2 U_{t-1} + \varepsilon_t \quad (3.4)$$

Where Δ denotes the first difference operation on the respective variables; a_1, b_1, c_1, and d_1 are the coefficients showing the short run equilibrium relationship connecting the independent and the dependent variable; a_2, b_2, c_2, and d_2 are the coefficient showing the long run relationship connecting the explanatory variables and the dependent variable. It has an a priori expectation sign of minus.

U_{t-1}, is the residual obtained from the linear regression of the I(1) variables and lagged by one as a requirement of the *granger representation theorem*. Lastly, ε_t, v_t, u_t and e_t are the disturbance term for the models. The estimation of the models were done using Eviews software.

4. RESULT AND DISCUSSION

When tested for stationarity using the augmented dickey fuller (ADF) unit root test, all the variables were found to be stationary at first difference i.e. I (1), Table 1. Thus, a simple linear regression was estimated connecting the independent variables to the dependent variable and their residual obtained. The residual was tested for unit root using the ADF statistic.

Table 1: STATIONARITY TEST Results Using Augmented Dickey Fuller (ADF) Procedure

Level test I(0)		Critical Values		
ADF Stat	Variables	1%	5%	10%
-1.1982	All Share Index (ASI)	-3.7497	-2.9969	-2.6381
-2.9637	Exchange Rate (ER)	-3.7497	-2.9969	-2.6381
-2.6474	Minimum Rediscount Rate (MRR)	-3.7497	-2.9969	-2.6381
-1.8261	Treasury Bill Rate (TBR)	-3.7497	-2.9969	-2.6381
-2.5629	Inflation Rate (INF)	-3.7497	-2.9969	-2.6381
First Difference Test I(1)				
-5.3646	All Share Index (ASI)	-3.7667	-3.0038	-2.6417
-3.9891	Exchange Rate (ER)	-3.7667	-3.0038	-2.6417
-5.8455	Minimum Rediscount Rate (MRR)	-3.7667	-3.0038	-2.6417
-5.5479	Treasury Bill Rate (TBR)	-3.7667	-3.0038	-2.6417
-3.8275	Inflation Rate (INF)	-3.7667	-3.0038	-2.6417

Source: Researchers Estimation - Eviews Output

Table 2: Residual Test for Stationarity

ADF Test Statistic	-2.940034	1% Critical Value*	-3.7497
		5% Critical Value	-2.9969
		10% Critical Value	-2.6381

*MacKinnon critical values for rejection of hypothesis of a unit root.

Augmented Dickey-Fuller Test Equation
Dependent Variable: D(RES)
Method: Least Squares
Sample(adjusted): 1986 2008
Included observations: 23 after adjusting endpoints

Variable	Coefficient	Std. Error	t-Statistic	Prob.
RES(-1)	-0.585588	0.199177	-2.940034	0.0078
C	279.3568	1496.671	0.186652	0.8537

R-squared	0.291589	Mean dependent var	406.5995
Adjusted R-squared	0.257855	S.D. dependent var	8328.451
S.E. of regression	7174.781	Akaike info criterion	20.67747
Sum squared resid	1.08E+09	Schwarz criterion	20.77621
Log likelihood	-235.7909	F-statistic	8.643799
Durbin-Watson stat	1.926043	Prob(F-statistic)	0.007821

Source: Researchers Estimation - Eviews Output

The result showed that, the variables were co-integrated at 10 percent level of significance (see Table 2) Following the granger representation theorem, the error correction models (i.e. equations 3.1 to 3.4) were then estimated. The results are presented in Tables 3 to 6 respectively.

Table 3: Estimated Result for Equation 3.1

Dependent Variable: D(ASI)
Method: Least Squares
Sample(adjusted): 1986 2008
Included observations: 23 after adjusting endpoints

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.102384	0.035979	2.845697	0.0100
D(MRR)	-0.703333	0.351157	-2.002902	0.0589
RES(-1)	-0.067320	0.045212	-1.488980	0.1521

R-squared	0.198610	Mean dependent var	0.105199
Adjusted R-squared	0.118471	S.D. dependent var	0.183567
S.E. of regression	0.172351	Akaike info criterion	-0.557463
Sum squared resid	0.594096	Schwarz criterion	-0.409355
Log likelihood	9.410819	F-statistic	2.478324
Durbin-Watson stat	2.567501	Prob(F-statistic)	0.109254

Source: Researchers Estimation - Eviews Output

Table 4: Estimated Result for Equation 3.2

Dependent Variable: D(ASI)
Method: Least Squares
Sample(adjusted): 1986 2008
Included observations: 23 after adjusting endpoints

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.101933	0.038827	2.625281	0.0162
D(TBR)	-0.293754	0.321375	-0.914054	0.3716
RES(-1)	-0.056344	0.051343	-1.097405	0.2855

R-squared	0.069371	Mean dependent var	0.105199
Adjusted R-squared	-0.023692	S.D. dependent var	0.183567
S.E. of regression	0.185729	Akaike info criterion	-0.407949
Sum squared resid	0.689905	Schwarz criterion	-0.259841
Log likelihood	7.691411	F-statistic	0.745417
Durbin-Watson stat	2.336428	Prob(F-statistic)	0.487267

Source: Researchers Estimation - Eviews Output

Table 5: Estimated Result for Equation 3.3

Dependent Variable: D(ASI)				
Method: Least Squares				
Sample(adjusted): 1986 2008				
Included observations: 23 after adjusting endpoints				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.101192	0.042149	2.400849	0.0262
D(ER)	0.014909	0.239304	0.062300	0.9509
RES(-1)	-0.263445	0.117432	-2.243385	0.0364
R-squared	0.209102	Mean dependent var		0.105199
Adjusted R-squared	0.130013	S.D. dependent var		0.183567
S.E. of regression	0.171219	Akaike info criterion		-0.570641
Sum squared resid	0.586318	Schwarz criterion		-0.422533
Log likelihood	9.562373	F-statistic		2.643860
Durbin-Watson stat	2.317475	Prob(F-statistic)		0.095764

Source: Researchers Estimation - Eviews Output

Table 6: Estimated Result for Equation 3.4

Dependent Variable: D(ASI)				
Method: Least Squares				
Sample(adjusted): 1986 2008				
Included observations: 23 after adjusting endpoints				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.105604	0.036960	2.857235	0.0097
D(INF)	-0.181238	0.113627	-1.595024	0.1264
RES(-1)	-0.064015	0.046035	-1.390570	0.1796
R-squared	0.156062	Mean dependent var		0.105199
Adjusted R-squared	0.071669	S.D. dependent var		0.183567
S.E. of regression	0.176867	Akaike info criterion		-0.505731
Sum squared resid	0.625638	Schwarz criterion		-0.357623
Log likelihood	8.815910	F-statistic		1.849217
Durbin-Watson stat	2.311333	Prob(F-statistic)		0.183275

Source: Researchers Estimation - Eviews Output

For equation 3.1, it was found that MRR had a significant negative short run relationship with the stock market at 10 percent significance level, while its long run component was not significant. This implies that, while lowering the MRR would improve the performance of the stock market in the short run, it is not certain that lowering the MRR would improve stock market performance in the long run.

For equation 3.2, the short run relationship between the stock market and exchange rate was positive but not significant. The long run coefficient however, was significant; implying that, stable exchange rates would in the long run help to improve the performance of the Nigerian stock market. The result was significant at 5 percent level. The results for equations 3.3 and 3.4 relating stock market performance to Treasury bill and inflation rates respectively were not significant.

The long run equilibrium coefficients for all the equations however, had the expected *a priori* negative sign implying that, the models where appropriately specified. Only the coefficient (with a value of 0.2634) relating the stock market to exchange rate however, was significant. This further implies that 26.34 percent of the short run distortions affecting the performance of the stock market, could be corrected in the long run (in approximately four years) if stable exchange rate policies are consistently pursued.

5. SUMMARY AND CONCLUSION

This study examined the relationship between the stock market and macroeconomic variables in Nigeria. The all share index was used as a proxy for the stock market while inflation, interest and exchange rates were the selected macroeconomic variables considered. Employing error correction model, it was found that a significant negative short run relationship exists between the stock market and the minimum rediscounting rate (MRR) implying that, a decrease in the MRR, improves the performance of the Nigerian stock market. It was also found that exchange rate stability in the long run, improves the performance of the stock market. Though the results for Treasury bill and inflation rates were not significant, the results suggests that they were negatively related to the stock market in the short run thus, achieving low rates of inflation and keeping the TBR low might be good for the performance of the Nigerian stock exchange. The conclusion is that by achieving stable exchange rates and maintaining low monetary policy rates, monetary policy could be effective in improving stock market performance in Nigeria.

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A Kalman Filter Approach to Fisher Effect: Evidence from Nigeria

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This paper investigates evidence of a Fisher effect in Nigeria by employing quarterly CPI inflation and Nominal interest rates data. For a more robust result we conducted integration and cointegration tests in order to examine time-series properties of the variables. Using Co-integration and Kalman filter methodologies, the study did not find evidence of a full Fisher effect from 1961:1-2009:4. This result indicates that nominal interest rates do not respond one-for-one to changes in inflation rates in the long run despite the presence of positive relationship among the variables. Our study recommends the adoption of potent policies aimed at checking inflation so as to help reduce high interest rates in order to stimulate growth in the economy.

Keywords: Fisher Effect, Kalman Filter, Inflation, Interest rates, Structural breaks, Cointegration

JEL Classification: C32; E31; E43; E58.

1 Introduction

Interest rates and inflation are among the most important variables in the economy. The Fisher hypothesis (a relation linking the two variables) was first introduced by Irving Fisher [3](1930). He postulates that the nominal interest rate in any given period is equal to the sum of the real interest rate and the expected rate of inflation. The Fisher relation suggests that when expected inflation rises, nominal interest rate will rise with an equal amount leaving the real interest rate unaltered. The hypothesis has important policy implications for the behavior of interest rates, efficiency of financial markets and the conduct of monetary policy.

Over the years, Central Banks have raised and cut interest rates in order to check inflation and to pursue their monetary policy objectives. Recently, rising interest and inflation rates have become a source of concern over their potential to stifle growth. Hence, the Central Bank of Nigeria (CBN) raised the Monetary Policy Rate (MPR)[4] by 25 basis points, from 6% to 6.25% in the fourth quarter of 2010. This decision, by the CBN, was to check rising inflation and to influence

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[3] Irving Fisher (1867 - 1947) is an American economist who first pointed out the relationship between expected inflation and interest rates in his book: *The Theory of Interest*, published in 1930.

[4] The MPR previously called the Minimum Rediscount Rate (MRR) is the anchor rate at which the Central Bank of Nigeria (CBN) lends to the Deposit Money Banks (DMBs) - DMBs comprises commercial and Merchant Banks. In December, 2006 the CBN introduced the MPR. It is the benchmark interest rate in Nigeria.

economic activities. Nigeria's inflation rate has since moved from 13% in the second quarter to 13.7% in the third quarter of 2010 (CBN, 2010).

Despite general acceptance of the Fisher hypothesis, empirical evidence has been difficult to establish even with massive literature generated from studying the relationship. While studies by Engsted (1995) and Hatemi-J (2008), among others, found no support for the hypothesis, Mishkin (1992), Evans and Lewis (1995), Wallace and Warner (1993), and Crowder and Hoffman (1996), finds evidence in favour of long-run Fisher effect. Cooray (2002), and Million (2003), reported weak and conflicting results. There are several reasons behind the inability to find evidence of a full Fisher effect. Tobin (1969) noted that investors re-balance their portfolios in favour of real assets during high inflationary periods. In addition, are the different types of interest rates and sample periods used in the empirical analysis. It may also be due to structural changes in the co-integrating vector. Mishkin (1986) noted that the relationship between interest rate and inflation, shift with changes in monetary policy regimes.

A long-run Fisher effect implies that when interest rate is higher for a long period of time, the expected inflation rate will also tend to be high; this implies that the two variables are cointegrated; while a short-run effect indicates that a change in the interest rate is associated with an immediate change in the expected inflation rate (Mishkin, 1992).Interest rates affect the demand for and allocation of credits as well as the exchange and inflation rates. They also serve as incentive to savers..

Interest rates represent the cost of borrowing and return on deposits. They range from Monetary Policy Rates, Treasury bills, Deposit to Lending rates. Real interest rates are usually adjusted for changes in the price level while nominal rates are not adjusted and are usually equal to or greater than real interest rates. The divergence between the two rates is affected by inflation, risk, taxes, investment policy, and term to maturity (Uchendu, 1993).

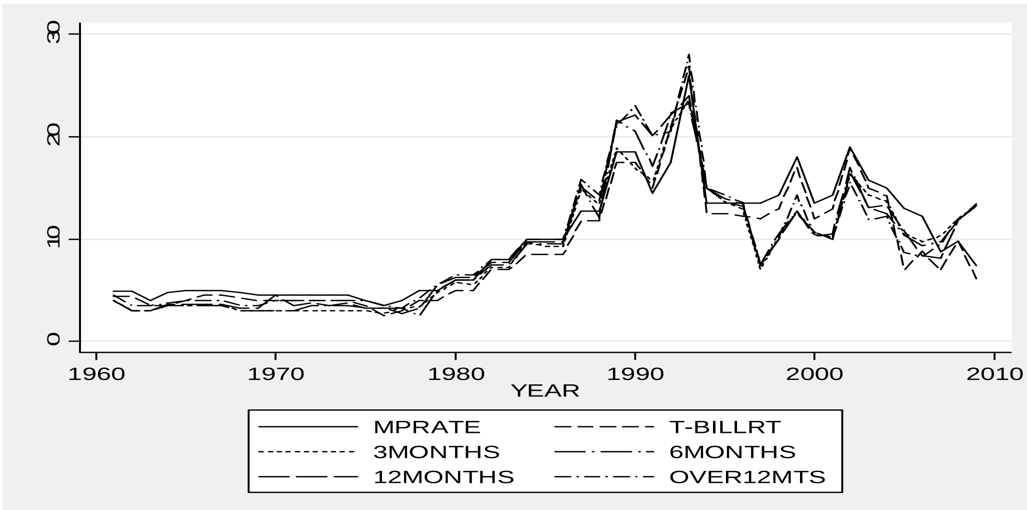
From Figure I, it can be observed that interest rates broadly move together from 1961-2009 in Nigeria. Interest rates were largely stable and moving together between 4-6%throughout 1960s to the late 1970s. The rates however showed substantial rise from 1980 to 1987 which was largely attributed to government's policy of interest rates deregulation in the mid-1980s. They also witnessed high increments in 1993 with average interest rates hovering around 26%. The CBN made concerted efforts to reduce the rate in the mid-1990s, leading to a 13% drop in 2000. Policy rates declined further from2000 to 2007 despite noticeable divergence between the key interest rates compared to the pre-deregulation rates.

Studies show that businesses consider interest rate an important factor in investment and would borrow at high rates of return if the investment would justify the high rates[5]. Similarly, Oresotu's

[5] Recently, the Central Bank of Nigeria (CBN) decided to make public on a weekly basis the average deposit and lending rates obtainable in all Deposit Money Banks (DMBs) to help guide business decisions in the economy. This decision took effect in 2010.

(1992) findings reveal that the key factor affecting nominal lending rate is persistent currency depreciation, through pressure on domestic liquidity.

Figure I: Short and long-term interest rates in Nigeria (1961-2009)



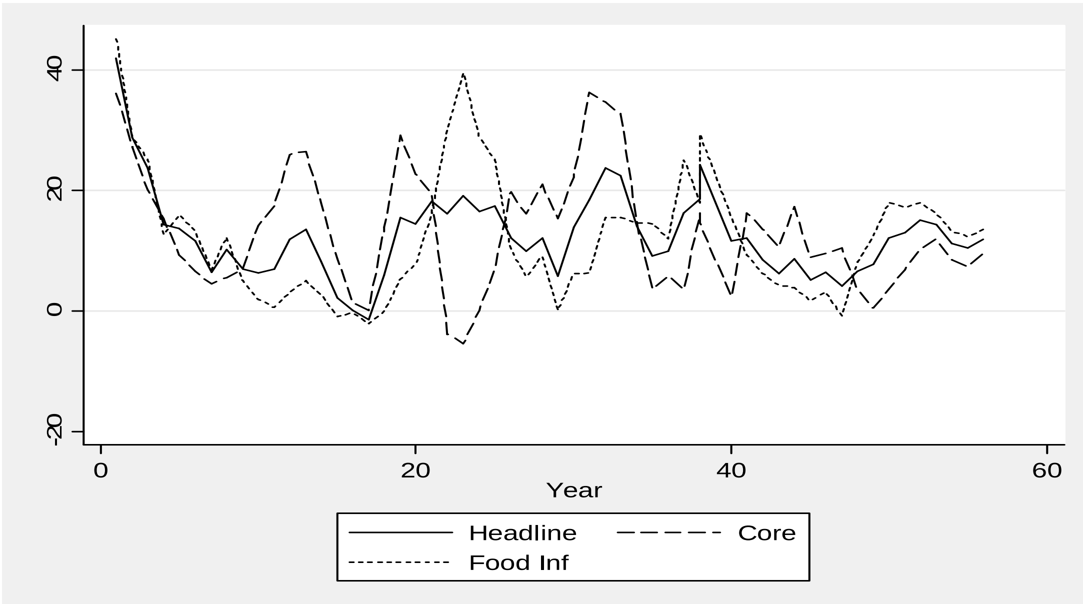
Presently, literature from developed countries on Fisher effect has concentrated on the dangers arising from either very low or high interest rates that include: a distorted allocation of capital, excessive risk-taking, and destabilizing surges in capital flows. The phenomenon of low and negative interest rates presents new challenges to monetary authorities in the US, the EU and Japan. Negative interest rate implies willingness to pay more for a bond today than will be received for it in the future[6].

Nigeria's inflation experience since the mid-1990s has been mixed. This is depicted in Figure II which shows the plot of quarterly headline, food and core inflation rates for the last one and a half decades. The headline inflation rates (the solid line) stood at 41.9% in 1996:1, before witnessing substantial decline between 1997 and 1998. This reduction in inflation was due to tight monetary policy posture of the CBN in the mid-1990s. However, there were major increases in headline inflation to 13.55% in 1999:1 and a substantial drop to -1.43% in 2000:1. There were large increases between 2000 and 2002 with inflation rate hovering around 12.25% to19% respectively. A major decline was recorded around 2003:1 (5.8%) before rising substantially to 23.84% and 22.47% in 2003:4 and 2004:1. The inflation rate drops consistently from 2006:1 to 2008:1 and by mid-2008 the rates increased again (see figure 1). The core and food inflation

[6] In October, 2009 the Bank of Japan (BOJ) cut its benchmark interest rate to almost zero percent in order to stimulate the economy. Rates had been held at 0.1% since the end of 2008. However, the BOJ earlier lifted the zero interest rate policy in July 2006. In late 1998, interest rates on Japanese six-month treasury bills became negative, yielding an interest rate of -0.004%, with investors paying more for the bills than their face value[6] (Mishkin and Eakins, 2006, pp52).

rates[7] (the dotted lines in the graph) equally mimics movement of the headline rate except around 2000 to 2004 periods. Persistent inflation reduces purchasing power of a currency, and rising interest rates could depress economic activities.Among emerging economies, Nigeria exhibits the highest inflation and exchange rate variability (Batini, 2004).

Figure II: Inflation rates in Nigeria (1996-2009)



The objective of this study is to investigate the Fisher hypothesis using cointegration and the Kalman filter approaches for the 1961-2009 periods. To examine the dynamic relationship between inflation and nominal interest rates, we first test for their order of integration. This paper considers the effects of structural breaks, long-run Fisher effects and the nature of functional forms of the models employed. This is one of the early studies that examine the Fisher hypothesis using Kalman Filter Methodology in Nigeria and it attempts to fill gaps in the empirical literature on developing countries. The rest of the paper is organized as follows: section 2 reviews the literature and discusses the methodology. Section 3 presents the data and results of the study, while Section 4concludes.

2 Methodology

Several studies have analyzed the Fisher effect using different techniques. Atkins (1989), Wallace and Warner (1993),and Choudhry (1994)applied unit root and co-integration tests while others applied the Vector Autoregression (VAR)and Granger causality methodologies in their analysis (see, Engsted (1995), Mitchener and Weidenmier (2008),etc). Recently, Hatemi-J (2008) employs the Kalman filter approach in testing for Fisher effect. Atkins (1989) tests for Fisher

[7] The inflation rate is designed to measure the rate of increase of a price index like the CPI. It is a percentage rate of change in price level over time. The computation of Food and Core CPI rates however, started in 1995 by the CBN.

effect and found that post-tax nominal interest rates and inflation are co-integrated, and that interest rate influences changes in inflationary expectation set equilibrium.

Mishkin (1992), in resolving the puzzle of why a strong Fisher effect occurs for some periods and not for others, identifies the lack of empirical evidence for a short-run Fisher effect to be due to the fact that a strong Fisher effect will only appear in samples where inflation and interest rates have stochastic trends. He claimed that empirical evidence finds no support for a short-run Fisher effect, but supports the existence of a long-run effect in which inflation and interest rates exhibit common trends.

Wallace and Warner (1993) applied the expectations model of the term structure of interest rates to establish the conditions under which innovations in short-term inflation will be transmitted to short and long-term interest rates. Their co-integration test finds support for both the Fisher effect and the expectations theory of the term structure. Earlier, Sargent *et al.*(1973) incorporates rational expectations in their analysis of the Fisher model and finds several implications suggesting that real interest rate was independent of the systematic part of the money supply. However, they did not recommend the adoption of a systematic policy of pegging the nominal interest rate at some fixed level over many periods because such a policy would either be very inflationary or deflationary.

Choudhry (1994) analyses the long-run interest-inflation relationships in the USA during the gold standard period (1879-1913) andhis results show that there exists Fisher effects on both the nominal short- and long-term interest rates. Mitchener and Weidenmier (2008) also got the same results with Choudhry (1994), in favour of the existence of Fisher effect in the USA during the same period.

Engsted (1995) examines whether long-term interest rates predict future inflation by assuming the existence of rational expectations and constant *ex-ante* real rates and finds that for the sampled countries, inflation and interest rates may be regarded as non-stationary $I(1)$ processes that cointegrate to stationary spreads. Evans and Lewis (1995) noted that findings which suggest that nominal interest rate and expected inflation do not move together in the long run can be deceptive when the inflationary process shifts infrequently. They characterize the shifts in inflation by a Markov switching model but were unable to reject long-run Fisher effect. Mishkin and Simon (1995) examine the Fisher effect for Australia and finds weak evidence in support of the hypothesis. Their results indicate that while long-run Fisher effect seems to exist, there is no evidence of a short-run effect, since short-run changes in interest rates reflect changes in monetary policy, while long-run levels indicate inflationary expectations.

Yuhn (1995) tests the relation for five countries and reveals that the Fisher effect was not robust to policy changes. His results indicate strong evidence of a long run Fisher effect except for the UK and Canada. However, short-run Fisher effect was only detected in Germany. Crowder and Hoffman (1996) argue that pre-tax nominal interest rates will not move one-for-one with inflation in the long-run if real interest rates are supposed to be unaffected by permanent shocks to inflation. They suggested calculating variable marginal tax rates for the countries and testing the fisher effect with tax-adjusted interest rates. Darby (1975) equally incorporates tax into interest-inflation interactions.

Hamori (1997) employs the Generalized Method of Moments (GMM) technique to test for Fisher effect using Japanese data from 1971–1994as this alternative approach makes it unnecessary to formulate the expected inflation rate explicitly as well as making it possible to simultaneously analyze the returns of multiple assets. Cooray (2002) surveys the literature by analyzing the techniques employed, as well as offering explanations for failure of the Fisher hypothesis. Cooray’s review finds that although studies for the US appear to suggest positive relationship between interest rates and inflation, they do not establish a one-to-one relationship as postulated by Fisher (1930). Million (2003) revisits the Fisher hypothesis, and attributes the inability of some empirical studies to recognize the Fisher effect to be due to errors in inflation expectations. Hatemi-J and Irandoust (2008) were also unable to find empirical support for a full Fisher effect using the Kalman filter algorithm. Their results were however consistent with many existing literature on the subject that found the estimated slope coefficients in the fisher equation to be less than the hypothesized value of one. Busari (2007) used the Hodrick and Prescott filter to analyse inflation into its trend, cyclical, seasonal and random components and finds that past behaviour of the trend component of inflation and money supply are the main determinants of long-run inflation in Nigeria.

Marotta (2009) investigates whether size and speed of pass-through of market rates into short-term business lending rates have increased with the introduction of the Euro..His results were contrary to the intuition that a reduced volatility in money market rates is bound to mitigate uncertainty and to ease the transfer of policy rate changes to retail rates. Beyer *et al.* (2009) tests the long-run Fisher effect for 15 countries.. Their results reveal evidence of breaks in the cointegrating relationship for most of the countries studied. Though Beyer *et al.* finds support for cointegration between inflation and interest rates, the two variables do not move one-for-one in the long run for all cases.

Ito (2009) examines the Fisher hypothesis in Japanese long-term interest rates by analyzing the asymmetric impacts of inflation expectations on interest rates. His co-integration test shows that all interest rates move together with expected inflation in long-run equilibrium. The implication of Ito’s result is that nominal interest rates in Japan were sensitive to inflationary expectations. Obi *et al.* (2009) investigates the existence of Fisher effect in Nigeria and confirm the existence of a long run partial Fisher effect from 1970-2007.

2.1 Unit root tests without a structural break

Prior to modeling our time series data, we determined the order of integration of the variables. The application of cointegration requires that time series data have the same stochastic structure.

If the order of integration of inflation rate is different from that of interest rate, the data becomes inconsistent with the cointegration procedure. The augmented Dickey-Fuller (ADF) test is the most applied statistical test for determining order of integration of macroeconomic time series. In the case of trending data, it is based on the following regression:

$$\Delta y_t = \mu + \beta t + \alpha y_{t-1} + \sum_{i=1}^{k} d_i \Delta y_{t-i} + \varepsilon_t \qquad (1)$$

Where ε_t is a pure white noise error term and where $\Delta y_{t-1} = y_{t-1} - y_{t-2}$, $\Delta y_{t-2} = y_{t-2} - y_{t-3}$, etc. The lagged difference terms are added to make the error term well-behaved.[8] Equation (1) tests the null hypothesis of a unit root against a trend stationary alternative. To achieve the most parsimonious model compatible with white-noise residuals, we selected k through the 'tsig' approach proposed by Hall (1994). This is a data dependent method that uses a general-to-specific recursive procedure based on the value of the t-statistic on the coefficient associated with the last lag in the estimated autoregression.[9] Ng and Perron (1995) demonstrates through a simulation study that the 't sig' approach is preferable to the information based criteria. For our quarterly data, we set the maximum number of lags (k) to be equal to 12 (see Table 1 in the Appendix).

2.2 Unit root tests with structural break

2.2.1 Zivot-Andrews unit root test

Perron (1989) demonstrates through a simulation experiment that the augmented Dickey-Fuller (hereafter, ADF) test is biased towards non-rejection of the unit root hypothesis if the data are characterized by stationary fluctuations around a trend function that exhibits a structural change. Perron's methodology involves incorporation of dummy variables in the ADF test to account for one exogenous (known) structural break. The exogenous imposition of break date was criticized by Zivot-Andrews (hereafter, ZA) (1992). ZA (1992) proposes a data dependent algorithm to determine the breakpoint. Their unit root test procedure transforms Perron's unit root test, which is conditional on a known breakpoint, into an unconditional unit- root test. Thus, following Perron's ADF testing strategy, the ZA unit root test is carried out with the following regression equations:

Model A (Crash Model):

$$y_t = \mu + \beta t + \theta DU_t + \alpha y_{t-1} + \sum_{i=1}^{k} c_i \Delta y_{t-i} + \varepsilon_t \qquad (2)$$

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[8] In statistical parlance, the error term is said to be well-behaved when it is independently and identically normally distributed.

[9] This procedure involves starting with a predetermined maximum k say k_{max}, if kmax is significant, it is chosen. Else, it is reduced by one recursively, until the last lag become significant. However, k is set equal to zero if no lags are significant.

Model B (Changing Growth Model):

$$y_t = \mu + \beta t + \gamma DT_t + \alpha y_{t-1} + \sum_{i=1}^{k} c_i \Delta y_{t-i} + \varepsilon_t \tag{3}$$

Model C (Mixed Model):

$$y_t = \mu + \beta t + \theta DU_t + \gamma DT_t + \alpha y_{t-1} + \sum_{i=1}^{k} c_i \Delta y_{t-i} + \varepsilon_t \tag{4}$$

Where $DU_t = 1$ if $t > TB$, 0 otherwise; $DT_t = t - TB$ if $t > TB$, 0 otherwise, TB is the date of the endogenously determined break. Model A, referred to as the "crash model" allows for a one-time change in the intercept of the trend function, model B, referred to as the "changing growth model" allows for a single change in the slope of the trend function without any change in the level; and model C, the "mixed model" allows for both effects to take place simultaneously, i.e., a sudden change in the level followed by a different growth path.[10] The null hypothesis for the three models is that the series is integrated (unit root) without structural breaks (α = 1). The test statistic is the minimum "t" over all possible break dates in the sample. ZA (1992) suggested using a trimming region of (0.10T, 0.90T) to eliminate endpoints. The k extra regressors in the preceding regressions are determined by the 't sig' approach proposed by Hall (1994).

2.2.2 Perron (1997) Unit root test with a structural break

The ZA unit root test only allows for structural break in the null hypothesis, this omits the possibility of a unit root with structural break.[11]Due to criticism of the Perron (1989) exogenous (known) break test by Zivot-Andrews (1992) and Christiano (1992)[12], Perron (1997) re-visits this issue and proposes an endogenous one-break unit root test where the break point is perfectly correlated with the data and the structural break is included in both the null and alternative hypotheses. We consider the innovational outlier model that allows for change in the intercept

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[10] In our empirical analysis, we report results of model A and model C because Perron (1989) suggests that most macroeconomic time series can be adequately modeled using either model A or model C. In addition, Sen (2003) argued that if one assumes that the location of the break is unknown, it is most likely that the form of the break will be unknown as well. Sen (2003) assesses the performance of the minimum t statistics when the form of the break is mis-specified. His simulation experiment revealed that the loss in power is quite negligible if the mixed model specification is used when in fact that the break occurs according to the crash model or changing growth model, and concluded that practitioners should specify the mixed model in empirical applications.

[11]Perron (1989) allows for structural break under the null and alternative hypothesis. Lee and Strazicich (2004) noted that if a break exists under the null, undesirable results will inevitably occur. The ZA unit root test will exhibit size distortions leading to spurious rejections of the unit root null hypothesis. Hence, researchers may incorrectly conclude that a series is stationary with break when in fact the series is nonstationary with break.

[12] Christian (1992) argued that the choice of the break date to a large extent has to be viewed as being correlated with the data. This is important because both the finite sample and asymptotic distributions of the test statistics depend upon the extent of correlation between the break point and data.

and the slope of the trend function to take place gradually.[13] In model A (Crash Model), unit root test is performed using the t-statistic for testing $\alpha = 1$ in the following regression:

Model A:

$$y_t = \mu + \theta DU_t + \beta t + dD(T_b)_t + \alpha y_{t-1} + \sum_{i=1}^{k} c_i \Delta y_{t-i} + \varepsilon_t \quad (5)$$

Where $DU_t = 1$, if $t > T_b$ (0 otherwise), $D(T_b)_t = 1$, if $t = Tb + 1$ (0 otherwise), and T_b is the time of the structural break. The above regression is estimated by OLS and it is in the spirit of the Dickey-Fuller test (1979) and Said and Dickey (1984) methodology, whereby autoregressive moving average (ARMA) processes are approximated by autoregressive processes. For Model C, the test is performed, the t-statistic for testing $\alpha = 1$ in the following regression:

Model C:

$$y_t = \mu + \theta DU_t + \beta t + \gamma DT_t + dD(T_b)_t + \alpha y_{t-1} + \sum_{i=1}^{k} c_i \Delta y_{t-i} + \varepsilon_t \quad (6)$$

$DT_t = t$ if $t > T_b$ (0 otherwise). Perron (1997) noted that selecting T_b based on the parameter of the change in intercept or slope is likely to allow tests with greater power. We followed this recommendation in our empirical analysis.

2.3 Cointegration Analysis

2.3.1 Cointegration without structural break

If the interest rate (denoted by N_t) and inflation rate (denoted by F_t) are both integrated of order 1, they are said to be cointegrated if a linear combination of them is integrated of order zero. Statistically, N_t and F_t are cointegrated, if both are $I(1)$ and if ε_t is $I(0)$ in the following cointegrating regression:

$$N_t = \alpha + \beta F_t + \varepsilon_t \quad (7)$$

Cointegration tests are carried out using the Engle and Granger (1987) two-step estimation procedure[14]. The procedure involves estimating the cointegrating regression equation above using Ordinary Least Squares (OLS) and then conducting unit root tests for the residuals $\hat{\varepsilon}_t$. Long-run Fisher effect implies that interest rates and inflation are cointegrated. Enders (1996) noted that the Engle and Granger (hereafter, EG) procedure, though can be easily implemented, have some

[13] The additive outlier model assumes that the change to the series occurs instantaneously, which may be a poor description of the data generating process.

[14] Co-integration is a concept that captures the co-movements of variables towards long-run equilibrium.

limitations. The two-step procedure can lead to multiplicity of errors; any error generated in the first step is automatically transferred to the second stage. In addition, the technique requires specifying the dependent and explanatory variables. In practice, it may be possible to find that one regression indicates that the variables are cointegrated; however, reversing the order indicates no cointegration. Again, the test is deficient when there are three or more variables; hence, there may be more than one cointegrating vector. To circumvent these inherent problems of the EG test; we supplemented the estimation of the cointegration relationship with Johansen (1988) Maximum-Likelihood Estimators. The Johansen cointegration test circumvents the use of two-step estimators, it is also invariant to the choice of variable selected for normalization and can estimate and test for the presence of multiple cointegrating vectors. For description of this procedure, see Johansen (1988).

2.3.2 Cointegration with structural break

The EG and Johansen traditional tests have limitations especially when dealing with a long data span that may have been affected by major economic events such as policy changes, economic, financial or energy crises. Gregory, Nason, and Watt (1996) demonstrate that the power of the ADF based cointegration tests fall sharply in the presence of a structural break (intercept shift). Gregory and Hansen (1996) argue that if a model is cointegrated with a one-time regime shift in the cointegrating vector, the traditional tests discussed in section 2.2.2 may not reject the null and the researcher may falsely conclude that there is no long-run relationship. To obtain robust cointegration results, we also apply the Gregory and Hansen (1996) cointegration test that allows the cointegrating vectors to change at a single unknown time during the sample period. The null hypothesis (no cointegration) is the same with the conventional test, and the alternative is cointegration with structural break. Kasman and Ayhan (2008) noted that the Gregory and Hansen (hereafter, GH) test could especially be insightful when the null hypothesis of no cointegration is not rejected by the conventional tests. GH (1996) estimated three models; the *level shift* model denoted by C, the second model the *level shift with trend* (C/T); introduce a time trend into the level shift model and the third model *regime shift* allows the slope vector and the intercept to change. The three models are given by the following regression equations:

Model 1: Level shift (C)

$$y_{1t} = \mu_1 + \mu_2 \varphi_{t\tau} + \alpha^T y_{2t} + e_t, \ t = 1, \dots, n. \tag{8}$$

where μ_1 represents the intercept before the shift, and μ_2 represents the change in the intercept at the time of the shift. y_{1t} and y_{2t} are integrated variables of order 1.

Model 2: Level shift with trend (C/T**)**

$$y_{1t} = \mu_1 + \mu_2 \varphi_{t\tau} + \beta t + \alpha^T y_{2t} + e_t, \ t = 1, \dots, n. \tag{9}$$

Where t denotes the time trend.

Model 3: Regime shift (C/S)

$$y_{1t} = \mu_1 + \mu_2\varphi_{t\tau} + \alpha_1^T y_{2t} + \alpha_2^T y_{2t}\varphi_{t\tau} + e_t,\ t = 1,\dots,n. \quad (10)$$

in this case, μ_1 and μ_2 are as in model 1, α_1 denotes the cointegrating slope coefficients before the regime shift, and α_2 denotes change in the slope coefficients. The dummy variable that captures structural change is given by:

$$\varphi_{t\tau} = \begin{cases} 0 & if \ \ t \le [n\tau] \\ 1 & if \ \ t > [n\tau] \end{cases} \quad (11)$$

Where the unknown parameter $\tau \in (0,1)$ denotes the relative timing of the change point, and [ ] denotes integer part. The cointegration test statistic for each possible regime shift $\tau \in T$ is the smallest value (the largest negative values i.e., the value that provides the strongest evidence against the null hypothesis) across all possible break points. GH (1996) suggests computing the test statistic for each break point in the interval ([0.15n], [0.85n]).

2.4. The Kalman Filter (KF)

The cointegrating regression equation (7) specified in section 2.2.2 assumes that the slope coefficient is constant throughout the data span. Hence, it does not allow the parameter to change across time. This specification may be highly deficient especially in economic and business applications where the level of randomness is high, and also where the constancy of patterns or parameters cannot be guaranteed. Thus, a more flexible model is the time-varying parameter model; it allows the slope parameter to vary randomly across time. In statistical arena, this flexible model is popularly referred to as the *state space model*. The state space representation of equation (7) is given by:

$$\begin{aligned} N_t &= \alpha + \beta_t F_t + \varepsilon_t \\ \beta_t &= \beta_{t-1} + \eta_t \end{aligned} \quad (12)$$

The first equation in 12 is called the observation equation or measurement equation while the second is the state or transition equation. The measurement equation relates the observed variables (data) and the unobserved state variable (β_t), while the transition equation describes the evolution of the state variable. The observation error ε_t and state error η_t are assumed to be Gaussian white noise (GWN) sequences. The overall objective of state space analysis is to study the development of the state (β_t) over time using observed data. When a model is cast in a state space form, the Kalman filter is applied to make statistical inference about the model[15]. The

[15]The Kalman Filter is a computationally efficient method of updating the estimates of the time-dependent parameters of a multiple regression model as successive values of the dependent variable become available. Exponential smoothing provides an extremely simple example of the recursive calculations involved. The procedure was introduced by Kalman, Rudolf Emil in 1960(see Upton, G and Cook, I (2008)).

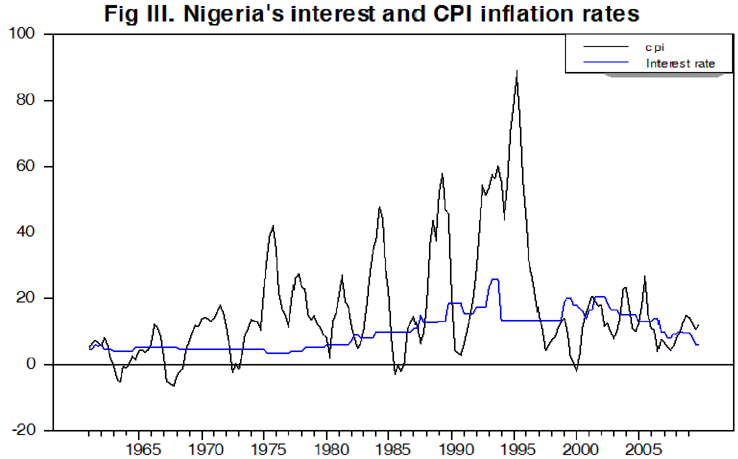
Kalman filter (hereafter, KF) is simply a recursive statistical algorithm for carrying out computations in a state space model. A more accurate estimate of the state vector or slope coefficient can be obtained via Kalman Smoothing (K.S). The unknown variance parameters (σ_{ε}^{2} and σ_{η}^{2}) in model 12 are estimated by the maximum likelihood estimation via the Kalman filter prediction error decomposition initialized with the exact initial Kalman filter. Harvey and Koopman (1992) demonstrate that the auxiliary residuals in the state space model can be very informative in detecting outliers and structural change in the model. For a complete exposition of the state space model and Kalman filter, see Durbin and Koopman (2001) and Hamilton (1994).

3. Data, Results and Discussion

3.1 The Data

The data used in this study are obtained from the *International Financial Statistics* database CD-ROM (June, 2010) and the Central Bank of Nigeria *Statistical bulletin* (2009). The data employed are on quarterly basis for the periods1961:1–2009:4. The quarterly observation of Nigeria's interest rate (MPR) and the rate of change in the consumer price index (CPI) are expressed in percent per quarter. A time series plot of the series is depicted in Fig III.

Fig III. Nigeria's interest and CPI inflation rates



3.2. Unit root tests

Cointegration tests require the same stochastic structure of the time series involved as the unit root tests. Specifically, the series should be nonstationary but have the same degree of integration. The first step of the analysis is to determine the order of integration; hence, the augmented Dickey-Fuller (ADF) unit root test is conducted. The test results are reported in Table 1. The two series are not stationary in levels form but after first differencing we are able to reject the unit root null hypothesis with or without trend. This implies that the nonstationary series are integrated of order 1.

Table 1. Unit root test (without structural break): ADF

	LCPI Inflation		Lint rate	
	Trend	No trend	Trend	No trend
Level	-2.290(4)	-2.271(4)	-0.705(0)	-1.360(0)
1^{st} diff	-5.883*(3)	-5.592*(7)	-13.483*(0)	-13.428*(0)

Notes:LCPI and Lint denote the natural logarithm of the CPI inflation and interest rates respectively. Significant lags are in the parenthesis. *denotes significance at 1% level. The 1% and 5% critical values for the model with trend and no trend (only constant) are -3.99 , -3.43 and -3.46 , -2.88 respectively.

Since the conventional ADF test is biased towards non-rejection in the presence of structural break, we further analyse the series using unit root tests with structural break. The ZA test and Perron (1997) test are used to capture the possibility of a single endogenous break. The results are displayed in Table 2. Both tests cannot reject the unit root null hypothesis. Based on the results of Zivot-Andrews (1992) and Perron (1997) tests, we further confirm the results from the ADF test that the interest rate and CPI inflation rates are integrated of order 1.

Table 2. Unit root test (with break): Zivot-Andrews (1992) and Perron (1997) One-break Test

	Zivot-Andrews test		Perron test	
Model A (Crash Model)				
	t-statistic (k)	break-date (T_b)	t-statistic (k)	break-date (T_b)
LCPI	-4.147(4)	1997:01	-4.128(4)	1996:03
Lint	-2.458(0)	1982:01	-0.509(8)	1977:04
Model C (Mixed Model)				
LCPI	-3.924(12)	1991:02	-3.106 (4)	1990:01
Lint	-2.956 (0)	1999:01-2.961 (0)	1998:03	

Notes: Critical values for the ZA test at 1% and 5% significance level are -5.340 and -4.800 respectively for model A, and -5.570 and -5.080 respectively for model C. The critical values for the Perron (1997) test at 1% and 5% significance level are -5.340 and-4.840 respectively for model A, and -5.570 and -4.91 respectively for model C. k is the lag length and is determined according to the '$t\ sig$' approach proposed by Hall (1994).

3.3 Cointegration tests

Since the two variables are both $I(1)$, it implies that they satisfy the condition for cointegration test. Hence, we first tested for cointegration without structural change in the framework of Engle-Granger (1987) and Johansen (1988) maximum likelihood test. The results of the tests are displayed in Table 3.

Using the two conventional tests for cointegration, we cannot reject the null hypothesis of no cointegration at 5% significance level. We therefore, conclude that interest rate and inflation rate are not cointegrated. Evidence was not foundfor long-run Fisher effect in this case for Nigeria. However, Gregory, Nason, and Watt (1994) have demonstrated that the power of the conventional cointegration tests fall sharply in the presence of a structural break. To allow for the possibility of changes in the cointegrating vector over the sample period, we test for cointegration that accounts for structural breaks under the framework of Gregory and Hansen (1996). Since the type of structural break is unlikely to be known, we consider the three models of Gregory-Hansen (1996) in our empirical analysis. The results are displayed in Table 4.

Table 3. Cointegration tests

Engle-Granger Cointegration test

Model	$t-statistic$	k
$L\text{int}_t = \alpha + \beta \text{LCPI}_t + \varepsilon_t$	-1.045	4

Johansen Cointegration test

Vectors	Trace test	$\lambda-$max test	Trace-95%	k
Interest rate (Lint) and inflation rate (CPI)				
$r \leq 0$	8.236	6.037	15.4102	
$r \leq 1$	2.199	2.199	3.840	2

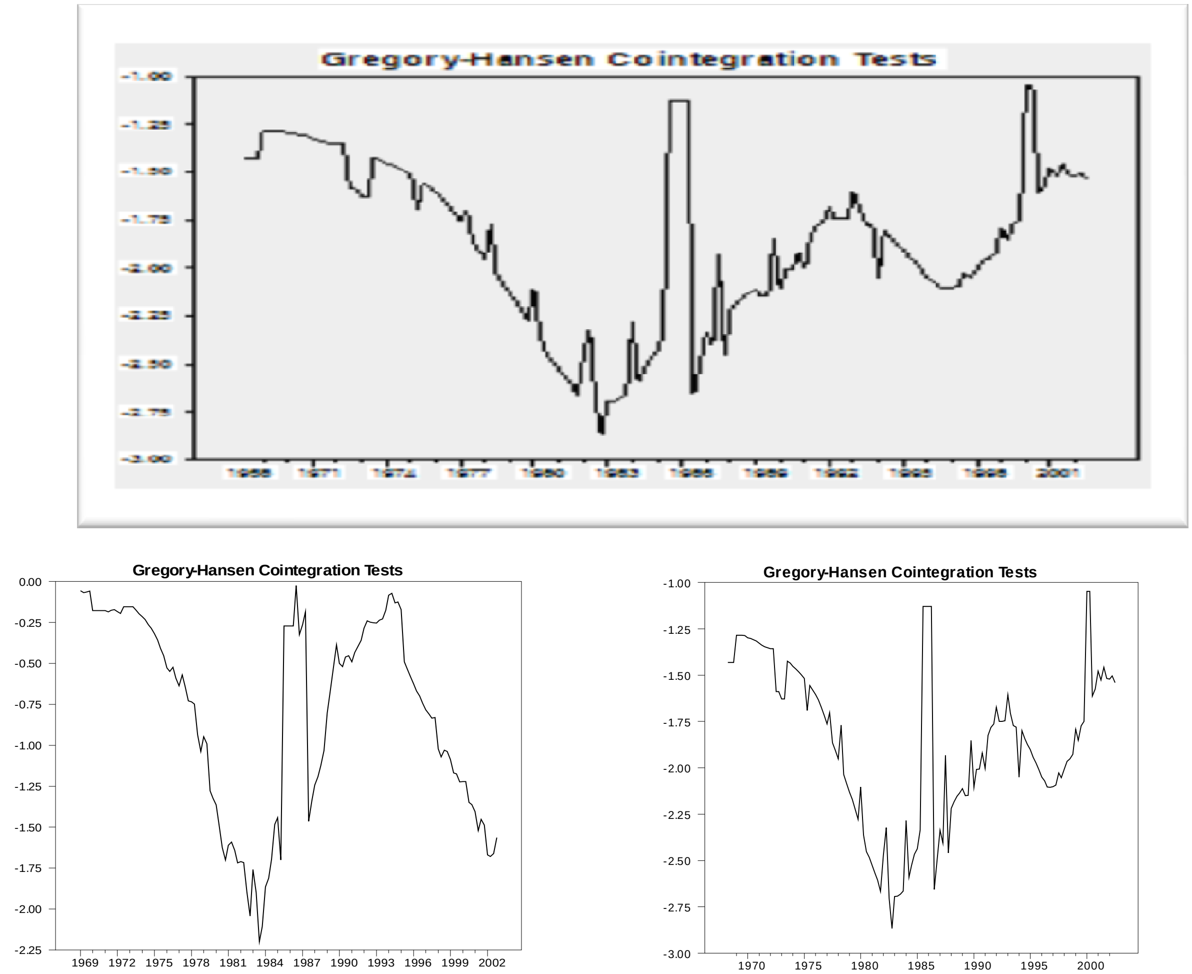
Notes: The critical values for the Engle-Granger test are -3.97 and -3.38 at 1% and 5% significance level respectively. The lag length (k) is also chosen according to Hall's criterion.

Table 4. Gregory and Hansen (1996) Cointegration tests

Models	min $t-statistic$	T_b	k
$L\text{int}_t = \alpha + \beta \text{LCPI}_t + \varepsilon_t$			
Model C	-2.866	1982:04	0
Model C/T	-2.199	1983:03	4
Model C/S	-2.315	1983:03	4

Notes: L indicates that we used the natural logarithms of both series. The critical values for the Gregory-Hansen (Model C) test are -5.13 and -4.61 at 1% and 5% significance levels respectively. For Model C/T, -5.45 and -4.99 at 1% and 5% levels respectively and for Model C/S -5.47 and -4.95 at the 1% and 5% significance levels respectively. T_b and k are the break date and lags respectively.

Figure 4. Gregory and Hansen test: A plot of $t - statistic$ for Model C, C/T and C/S



The results of Gregory-Hansen (1996) test for cointegration with structural breaks cannot reject the null hypothesis of no cointegration for the three cases of structural breaks. Hence, after allowing for the possibility of one structural shift in the cointegrating vector, we did not find evidence of long-run fisher effect in the relationship. Another million dollar question is: what if there are multiple structural breaks in the relationship? To gain further insights, it suffices to analyze the relationship using the time-varying parameter model estimated via the Kalman filter.

3.4 The Kalman Filter Estimation Results

Prior to Kalman filtering and smoothing, we estimate the unknown variance parameters (hyperparameters) of the model using maximum likelihood method. This is maximized using the BFGS (Broyden-Fletcher-Goldfarb-Shannon) optimization method. The estimation results are given below:

```
DLM - Estimation by BFGS
Convergence in    18 Iterations. Final criterion was  0.0000010 <=  0.0000100
Quarterly Data From 1961:01 To 2009:04
Usable Observations    196
Rank of Observables    178
Log Likelihood              -3.70297

    Variable                    Coeff       Std Error      T-Stat      Signif
*******************************************************************************
1.  A                       2.0777080910 0.0526593030     39.45567  0.00000000
2.  EPSI                    0.0436834443 0.0052190614      8.36998  0.00000000
3.  ETAA                    0.0006231914 0.0001879319      3.31605  0.00091300
```

In the estimation results shown above, A represents the estimate of the constant (α) in model 12, EPSI and ETAA denotes the maximum likelihood estimates of the measurement equation variance (σ_{ε}^2) and transition equation variance (σ_{η}^2) respectively. We then perform the Kalman filter and smoother recursion based on the estimate of the hyperparameters. We present the results of the Kalman filter and Kalman smoothed estimates in figure V and figure VI respectively. The Kalman filter and smoothed estimates of the time path for the slope coefficient (β_t) depicted in Fig. V and Fig. VI indicates that a one-for-one relationship between interest rates and inflation does not exist in Nigeria over the period under consideration. As such, we did not find evidence of full fisher effect using the Kalman Filter methodology. However, our study suggests a positive relationship between inflation and interest rates (i.e. an increase in inflation leads to a rise in interest rates).Our conclusion about the non-existence of long-run Fisher effect implies that inflation and interest rates do not trend together and thus there will be no strong correlation between these two series in the long run.

Fig V. K.F Estimate of Slope Coefficient & 95%Confidence Limit

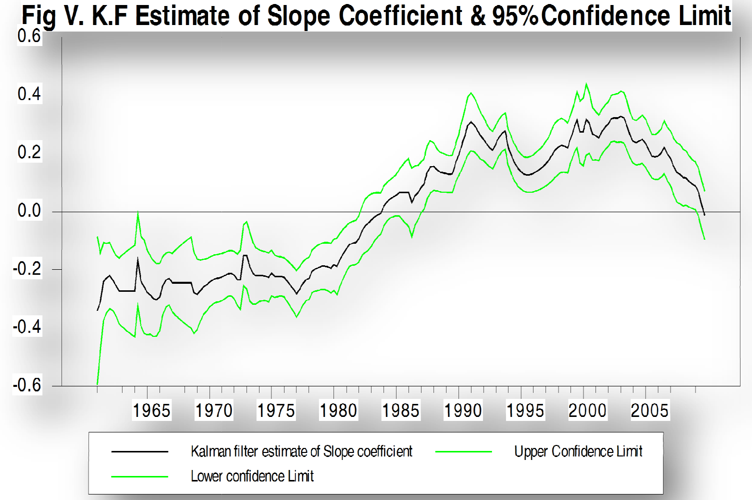


Fig VI. K.S Estimate of Slope Coefficient & 95% Confidence Limit

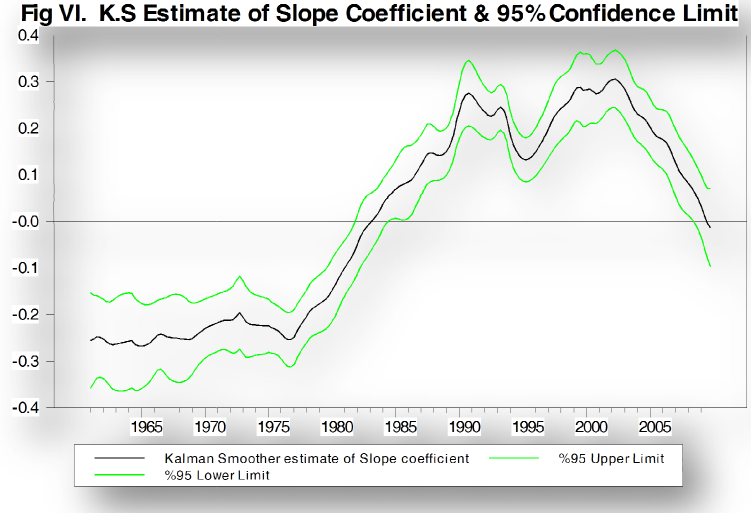
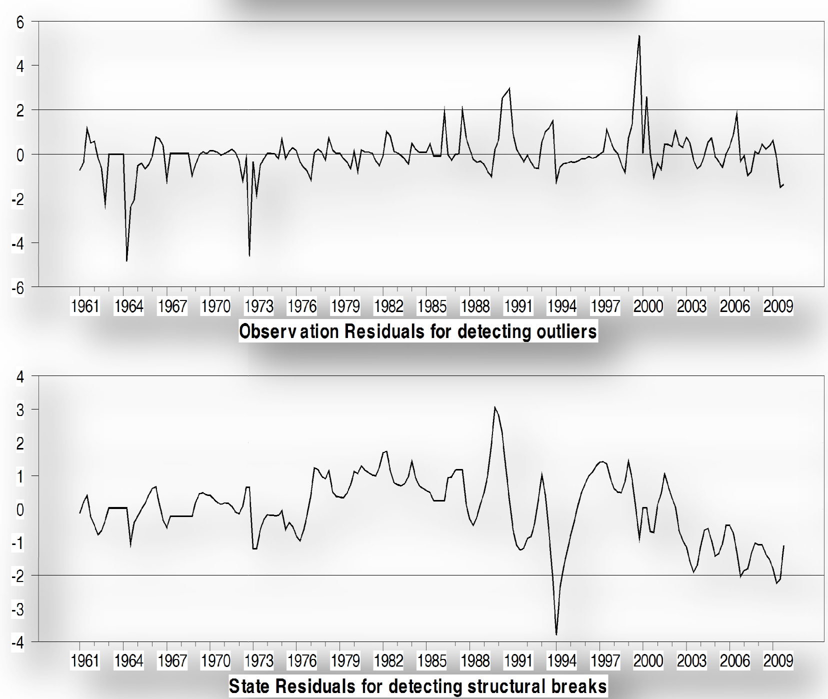


Fig VII. Kalman Filter Residuals



We further consider the possibility of outliers and structural breaks in our time-varying parameter model using the framework of Harvey and Koopman (1992). The duo demonstrates that the auxiliary residuals in state space models are useful tools for detecting outliers and shifts in the state space model. The detection procedure is to plot the standardized residuals. Since the model is Gaussian, indications of outliers and structural breaks arise for values greater than 2 in absolute value. We plot the standardized auxiliary residuals in Fig VII. The plots of the residuals indicate the presence of outliers in the inflation-interest rates relationship in 1964, 1973, 1991 and 2000.

We find strong evidence of structural breaks in the relationship in 1990 and 1994, and weak evidence of structural break around 2008.

4 Conclusion

This paper tests the existence of Fisher effect in Nigeria. Employing unit root tests, co-integration analysis, and the Kalman filter algorithm, we did not find evidence of a long-run Fisher effect from 1961-2009. This is consistent with majority of existing literature on the hypothesis. The results of our unit root tests show that interest rates (MPR) and CPI inflation are integrated of order 1, while the co-integration analysis shows that the two variables are not co-integrated. This article, apart from employing a more flexible time-varying parameter model which allows the slope parameter to vary randomly across time, utilizes the longest available quarterly inflation and interest rate series. Therefore, after allowing for the possibility of one structural shift in the co-integrating vector, we did not find evidence of a long-run Fisher effect in the relationship. Our study recommends the adoption of potent policies by the monetary authorities aimed at checking inflation so as to help reduce high interest rates in order to stimulate growth in the economy.

ACKNOWLEDGEMENTS

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Global Financial Meltdown and the Reforms in the Nigerian Banking Sector[1]

Sanusi L. Sanusi[2]

1. Protocol

Distinguish Ladies and Gentlemen, let me begin by thanking the organizers for honouring me with this invitation. First of all, I must thank the Vice-Chancellor, the Senate and Council of the Abubakar Tafawa Balewa University (ATBU) for this wonderful privilege and for inviting me to give this lecture titled "***Global Financial Meltdown and Reforms in the Nigerian Banking Secto***r". I am aware that the highly regarded ATBU Public Lecture Series focuses on developments on topical issues in our nation. Therefore, my invitation to this highly regarded event in the ancient city of Bauchi, and the hometown of our great Prime Minister, late Alhaji Abubakar Tafawa Balewa, is greatly appreciated.

As the International Monetary Fund, IMF observed, the extent and severity of the crisis that began with the bursting of the housing bubble in the United States in August 2007 reflects the confluence of myriad of factors some of which are familiar from previous crises, while others are new. As in previous times of financial turmoil, the pre-crisis period was characterized by (i) surging asset prices that proved unsustainable; (ii) a prolonged credit expansion leading to accumulation of debt; (iii) the emergence of new types of synthetic financial instruments; and (iv) regulatory failure. This time around the rapid expansion of securitization (not itself a new phenomenon), which changed incentives for lenders and lowered credit standards caused the crisis. Systems became fragile because balance sheets became increasingly complex (further complicated by increased use of off-balance-sheet instruments). Financial market players were highly leveraged and relied on wholesale funding and external risk assessments. Cross-border spillovers intensified after the crisis started because financial institutions and markets across borders were closely linked and risks highly correlated.

No doubt, the world is inextricably linked by globalization. Thus, the economic and financial crisis, which started in the United States, destabilized markets and economies (developed, developing and underdeveloped) around the globe and, has continued to dominate discussions on the global economy. These days one would hardly watch the television or browse through national and international newspapers, magazines and journals without stumbling upon headline news of how political leaders are scrambling for strategies to mitigate the impact of the financial crisis on the domestic and global economy.

As rightly pointed out in several quarters, the global financial crisis has been a major constraint to growth in most countries, a situation that has been aggravated by banking system crisis. The theme

[1] (Being the full text of a Public Lecture delivered at the Convocation Square, Abubakar Tafawa Balewa University, Bauchi, Friday, December 10, 2010

[2] Sanusi L. Sanusi is the Governor, Central Bank of Nigeria

of this lecture is, therefore, very pertinent as it provides opportunity for the academia, researchers and policy makers to explore alternative policy and practical steps that can be taken to stem the tide of recession, especially in developing countries like Nigeria.

Carl Menger in his 1871 seminal work on economic principles opined that "All things are subject to the law of cause and effect". It is imperative to argue here that, there is no exception to this great principle in the light of the origin and cause(s) of the global financial crisis and its consequences. As a corollary, we live today, in an era in which economic liberalism and small governments is so much propagated, and in which, it is generally expected that self regulation of markets is the best way of promoting competition, productivity, efficiency and growth. An unarguable guide for lovers of freedom and adventure is the fact that '*freedom has responsibility'*. While the freedom to innovate has led to the rapid development of the financial market in major industrialized countries and emerging markets, it has become clear that there is an inherent danger in the manner the markets were developing without proper supervision and moderation. Innovation has worked in the financial markets and has contributed significantly to the process made possible by *laissez faire*. However, the same innovation that *deepened* the financial markets also accentuated predatory, unsecured and irresponsible lending behavior among financial institutions thus, exacerbating the global meltdown.

The focus of this lecture is on the Nigerian experience. I believe that my audience at this lecture today will share some perspectives on the subject, drawing from their individual experiences. The critical challenge that Nigeria faces today as a nation is how to create some irreducible minimum standards of financial system stability that will promote strong financial institutions and the emergence of budding banking system, and hence ensure sustained growth and development in Nigeria and indeed in the rest of Africa.

The lecture is intended to stimulate discussions, and enable policy makers to come up with ways of identifying specific institutional arrangements and practical mechanisms that would expand financial services to economic agents in Nigeria. The focus is on developing, over time, an efficient and sustainable banking sector for economic activities to thrive. The vision is for a system that integrates the domestic, foreign, short and long term sources, where banks can exploit each others' comparative advantages in cost-effective financial services delivery.

2. Global Financial Meltdown: Nature and Origin

Let me start with a discussion of the nature and origin of the global financial meltdown or crisis. The term *financial meltdown* defines moments when financial networks and markets suddenly become markedly unstable or strained to the point where it may collapse. It features sudden change in expectations, speculative bubbles, falling prices and frequent bankruptcies. The literature is replete with 'what constitute a crisis or financial meltdown, but as related to the issues in discourse Eichengreen and Portes (1987) have defined crisis 'as a sharp change in asset prices that leads to distress among financial markets participants.' As Eichengreen (2004) noted, it is not very 'clear where to draw the line between sharp and moderate price changes or how to distinguish severe financial distress from financial pressure.' Commentaries on the origin of the crisis noted myriadcauses including excessive and corrupt practices of 'sub prime mortgage lending' (that led to high mortgage default and delinquency rates in the United States), massive funding of the "war on terrorism" and the erroneous belief that "free market" principle is perfect, fair and efficient (The New York Times, November 20, 2008). It is to be noted that because it was global, its consequences affected national, regional and global markets and economies.

The financial instability and panics caused in part by the sub-prime mortgage lending difficulties and consequent failure of the investment banking industry in the United States, notably Lehman Brothers, Merrill Lynch, Morgan Stanley and JP Morgan-Chase, as well as government-backed Mortgage giants Fannie Mae and Freddie Mac are widely recognized to be at the root of the current global financial meltdown. Most commentators agree that the origin of the sub-prime crises is due to a constellation of factors notably:

i. Low real interest rates in the US which was maintained for a long-time prior to the crises thereby encouraging accommodating monetary policy;

ii. Extreme confidence about the continued rise in housing prices and low volatility in the US housing market. Between 1996 and 2005, US housing prices nationwide went up about 90 per cent. They went up 60 per cent between 2000 and 2005, and in the 30 year run-up to the crisis, rarely did housing prices fall.

iii. A shift in mortgage lending toward the less creditworthy, marginal borrowers, or sub-prime borrowers who do not qualify for prime mortgage. Also, in the sub-prime market, more than half of the loans were made by independent mortgage brokers who were not supervised at the federal level, unlike banks and thrift institutions.

iv. Incentive problems associated with the securitization model for the mortgage loans into mortgage backed securities. There were also incentive problems for the so-called "independent" credit rating agencies, who were equally heavily involved in developing the structured product they rated.

The sub-prime crises actually broke out in 2007; however its effect was not dramatic then due to write-down of losses by the affected investment banks thereby eroding their capital. The realized losses dramatically increased when the contagion spread to other counterparties such as insurance companies, hedge funds, finance companies, and mutual and pension funds that invested heavily in the structured products. The contagion became globalized because the investors were not only US companies. European banks, and emerging market institutions, in particular, bought just about as many as US banks, which led to contagion around the globe.

Perhaps, a brief synopsis of the stages of the global financial meltdown would suffice in explaining the origin of the global meltdown within an appropriate context. Historically, there have been four major crises. These are The Great Depression, the crash of 1987, the crisis of the 1990s and the 1987 Asian Financial Crisis. There was also the *dot com* crisis which was a fall out of the crises of the 1990s. In August 2007, there were reported cases of liquidity constraints as financial institutions faced difficulties raising funds in the United States so much so that, by March 2008, there was an unprecedented credit contraction or credit crunch as financial institutions tightened credit in the US. During this time, there were wide spread cases of defaults in many markets which by July 2008 had spread to other economies. By the last quarter of 2008, the US and European countries officially declared that they were in economic recession. Consequently, the magnitude of distortions to national economies became unprecedented in what was later referred to as the worst economic crisis in human history.

Thus, from 2002 to early 2007, the decline in volatility in the global economy and financial markets was reflected in lower measures of market risk, which encouraged firms to increase their risk-taking. However, in September 2008, the economic downturn particularly in the United States and a number of industrialized economies signaled the beginning of a recession triggered by the credit crunch that resulted from the crisis.

In Nigeria, like in many developing countries particularly in Africa, the initial impact of the crisis (the first round effect) was not felt because Nigeria was not a major player in the global economy.

The banking system was less integrated with the global financial market, and the sound macroeconomic policies adopted by the country also helped to cushion the effect of the crisis. In addition, the banking system operated with simple financial products but had strong capitalization as a result of the recapitalization exercise of 2005. However, as the recession in advanced countries deepened, Nigeria became affected with consequences for the economy as a whole and the financial sector in particular.

3 Impact of the Global Financial Meltdown on Nigeria

3.1 Impact on the Nigerian Economy

It is by now very clear that Nigeria was not insulated from the crisis, especially the second round effect. The crisis which manifested itself globally in the form of liquidity and credit crunch, breakdown of confidence in the banking system, de-leveraging and banks inability to improve capital adequacy, weak consumer demand, and fall in global output, affected Nigeria through both the financial and real (trade, remittances and aid) channels. The undiversified nature of the Nigerian economy and the high dependence on exports of crude oil as well as foreign capital inflows compounded the impact of the external shock arising from the crisis. In specific terms, Nigeria experienced low demand for its oil export due to recession in the economies of her major trading partners. The Nigeria's Bonny Light Crude Oil Spot Price FOB which was $95.16 per barrel in January 2008 rose to $146.15 in July 2008 before declining to $76.24 per barrel by October 17 2008. Thus, within four months, it had lost 50% of its peak price. This, coupled with the collapse in the international price of oil, led to severe decline in foreign exchange receipts and consequently, government revenue contraction. The low accretion to foreign exchange reserves and demand pressure in the foreign exchange market led to volatility and substantial depreciation of the naira exchange rate. Government resorted to Excess Crude Account drawdown and domestic borrowing to finance its activities. Within the period, there was substantial decline in foreign capital inflows (foreign direct investment (FDIs); portfolio investment, and remittances from Nigerians in Diaspora) just as foreign trade finance reduced significantly for some banks while for others credit lines literally dried-up. It is perhaps in the capital market that the greatest impact was felt. The prolonged downturn in the capital market induced by significant divestment by foreign investors and compounded by lingering liquidity tightness, waning public confidence, and panic selling by domestic investors lead to significant losses by investors. The stock market which remained bullish between December 2005 and March 2008, suddenly became bearish in April 2008 and has remained nearly so since then with only marginal recovery. At the height of the bull-run in early March 11, 2008, equity market capitalization hit ₦12.64 trillion while the Nigerian Stock Exchange All Share Index (ASI) which rose by 37.8 per cent in 2006 and 1.01 per cent in 2005 gained a record 74.73 per cent in 2007. Between 31st December 2007 and the peak of the bull-run in early March 2008, the market gained 14.45 per cent. By year end 2008, the NSE All Share Index which gained 74.73 per cent the previous year, had declined by 45.8 per cent while equity market capitalization declined by 32.4 per cent from ₦10.3 trillion at year- end 2008 to ₦6.96 trillion at the close of 2008. Thus, between 2007 and 2008 the ASI declined by 42.5 per cent compared to 33.8 per cent decline between 2008 and 2009. The corresponding figures for market capitalization were 27.5 and 28.3 per cent, respectively. The capital market downturn also had negative impact on the banks balance sheet through increased provisioning for bad debts and lower profitability.

In spite of the debilitating impact of the crisis, Nigeria's growth trajectory was not significantly impaired. The real Gross domestic Product (GDP) growth rate which averaged 6.29 per cent between 2004 and 2007 declined marginally to 5.99 per cent in 2008 rising thereafter to 6.9 per cent in 2009. This is often attributed to the impressive performance of the non-oil sector, particularly, agriculture and the continuous implementation of sound macroeconomic policies. The external reserves was, however, still able to support at least 15 months of imports.

3.2 Impact on the Banking Sector

Recall that in 2004, the Central Bank of Nigeria (CBN) embarked on banking sector reform (Bank Consolidation) which sought, among other things, to strengthen the banking system and improve the operational efficiency of the Nigerian banks. At that time, the Nigerian banks were generally weak and inefficient. CBN surveillance report as at end-March 2004 indicated that 62 banks out of 89 were classified as sound/ satisfactory and 14 as marginal. The number of unsound banks had risen from 9 as at end-December 2003 to 11 in May 2004. There was serious over-dependence on public sector funds and CBN credits as well as income from foreign exchange trading on the part of the banks. Besides being grossly undercapitalized, the banking industry was characterized by several weaknesses including poor corporate governance, poor asset quality, inaccurate reporting and non-compliance with regulatory requirements, falling ethics and de-marketing of other banks in the industry, gross insider abuses resulting in huge non-performing insider related credits, oligopolistic structure with 10 of the 89 banks controlling more than 50 per cent of the industry assets and liabilities, lack of capacity to support the real sector of the economy, and lack of competition by banks in savings mobilization to boost the level of deposits. The situation was such that weak banks were paying higher interest rates in a bid to attract more deposits. As at end-May 2004 banks indebtedness to the CBN was about ₦71.36 billion. The bank consolidation exercise was meant to address these weakness through recapitalization of banks with minimum paid-up capital of ₦25 billion: ensuring minimal reliance on public sector for funds; adoption of risk focused and rule-based regulatory framework; adoption of zero tolerance in regulatory framework in data/information rendition/reporting and infractions; stricter enforcement of corporate governance principles for banking; expeditious process for rendition of returns by banks and other financial institutions through e-FASS[3]; revision and updating of relevant laws for effective corporate governance; ensuring greater transparency and accountability in the implementation of banking laws and regulation; and the establishment of an asset management company as an important element of distress resolution.

There is no doubt that the consolidation exercise had some positive impacts on the banking sector. The banking system was transformed from 89 banks to 25 through regulatory merger and acquisition and latter to 24 through market-induced merger and acquisition. Bank branches grew from 2,900 in 2005 to almost 5,500 in mid-2009. Besides deepening of the capital market, the banks were positioned to actively participate in a wider range of activities, including financing of infrastructure and the oil sector.

However, while the consolidation exercise lasted, certain developments in the economy and within the banking system itself put the banking sector at serious risk. Between 2004 and 2008, Nigeria enjoyed unprecedented increase in oil price which resulted in huge inflow of foreign exchange and robust economic growth. This, coupled with appreciable level of foreign direct investment inflows, resulted in huge liquidity in the economy which the real sector of the economy could not absorb. The excess liquidity found its way into the stock market as shown in the unprecedented rally in the stock prices on the Nigerian Stock Exchange between 2006 and March 2008. The excess liquidity also allowed banks to raise capital. Fresh capital raised between 2006 and first quarter of 2008 amounted to ₦1,603 billion. The increase in capital supported banks' balance sheet growth with banking sector assets as percentage of GDP increasing rapidly to 60 per cent from about 30 per cent in 2004. With significant capital and greater liquidity, banks were increasingly under pressure to create risk asset amidst limited product innovation and diversification. This, coupled with poor risk management practices, ultimately led to a concentration of assets in certain areas, in particular margin lending and oil trading/marketing. As at end-December 2008, banks' total exposure to the

[3] Electronic Financial Analysis and Surveillance System, used to render report by commercial banks to the CBN

oil industry stood at over ₦754.0 billion, representing over 10.0 per cent of the banking sector total and over 27.0 per cent of the shareholders' funds.

Thus, in mid-2008 when the global financial and economic crisis set in, the domestic financial system was already engulfed by several interdependent factors that led to the re-emergence of an extremely fragile financial system similar to pre-consolidation era. These factors included macroeconomic instability caused by large and sudden capital inflows, major failures in corporate governance at banks, lack of investor and consumer sophistication, inadequate disclosure and transparency about financial position of banks, critical gaps in regulatory framework and regulations, uneven supervision and enforcement, unstructured governance and management processes at the CBN/weaknesses within the CBN, and weaknesses in the business environment.

It is clear, therefore, that when the global crisis eventually hit Nigeria, the banking sector was ill-equipped to weather the storm in spite of recapitalization. As we are all aware, the financial crisis had an adverse effect on both the oil and gas sector and the capital market where the Nigerian banks were exposed to the tune of ₦1.6 trillion as at December 2008. The result was a sharp deterioration in the quality of banks' assets which immediately led to concerns over banks' liquidity. Indeed, the Nigerian banking sector was thrown into severe crisis as many of the banks became distressed.

3.3 Remedial Measures to Mitigate the Impact on the Banking Sector

The initial diagnosis of the distress in the banking system amplified by the global financial crisis as a liquidity problem led to the introduction of several measures by the CBN between 2008 and 2009. These measures included, among others, the reduction in the Monetary Policy Rate (MPR), cash reserve ratio (CRR) and liquidity Ratio (LR). The MPR was gradually reduced from 10.25 per cent to 6 per cent to its present level between September 18, 2008 and July 7, 2009 and subsequently raised to 6.25 per cent on September 21, 2010. Similarly, the CRR was reduced from 4.0 per cent to 2.0 per cent and further to 1.0 per cent while the LR was progressively reduced from 40 per cent to 25 per cent. The CBN also issued directive to banks to restructure their margin loans up to 2009, and expanded its discount window to allow additional instruments as well as allow banks to borrow up to 360 days (currently suspended) in addition to stoppage of liquidity mopping-up. Greater emphasis was placed on enforcement of the CBN Code of Corporate Governance to promote transparency and accountability in banks as well as the review of contingency plan for systemic distress in banks.

These measures did not fully resolve the problems as the system remained fragile. It was discovered that nine banks were the main users of the Expanded Discount Window (EDW) over a nine-month period ending June 2009. Accordingly, when the CBN eventually closed the EDW in July 2009, and in its place, guaranteed interbank placements, it was observed that these nine banks were the main net-takers under the guarantee arrangement. At this point it was clear that the issue was far beyond the liquidity problem and if drastic actions were not taken, the financial system could collapse.

4 Current Banking Sector Reforms

4.1 Diagnosis and Initial Stabilization Steps

Given the precarious state of the Nigerian banks, the CBN in June 2009, took a three pronged approach to assess the financial condition of the 24 banks. The first was the special examination exercise jointly conducted by the CBN and the Nigerian Deposit Insurance Corporation (NDIC). This exercise highlighted inadequacies in capital asset ratios and liquidity ratios as well as weaknesses in corporate governance and risk management practices in 9 banks. These banks were found to be in a grave situation as a result of capital, liquidity and corporate governance concerns. They failed to meet the minimum 10 per cent capital adequacy ratio and 25 per cent minimum LR. Apart from accumulating high non-performing loans (NPL), these banks were seriously exposed to the oil and gas sector as well as the capital markets. Poor risk management practices in the form of absence of necessary controls measures were prevalent as the board and management of the banks had failed to observe established controls. The remaining 14 banks were found to be in a sound financial state and did not require the CBN to take any action.

The second approach was to carry out diagnostic audit through independent consultants. The report of the audit exercise revealed greater magnitude of weak financial condition of the nine banks. All of them were "technically" insolvent with significant negative asset value. It also exposed several illegal activities that had been taking place in five of the affected banks.

It was against this background that the CBN moved decisively to strengthen the industry, protect depositors and creditors, restore public confidence and safeguard the integrity of the Nigerian banking industry. The initial measures/ initiative taken by the CBN in conjunction with NDIC and the Federal Ministry of Finance (MOF) included injection of ₦620 billion into the nine banks; the replacement of the chief executive /executive directors of eight of the nine banks with competent managers with experience and integrity; reaffirmation of the guarantee of the local interbank market to ensure continued liquidity for all banks; and guaranteeing of foreign creditors and correspondent banks' credit lines to restore confidence and maintain important correspondent banking relationships.

When the new management of the banks took office, it became necessary to also carry out further detailed and independent assessment of the financial conditions of the banks. Thus, the third approach was to carry out management account audit of the affected banks by their new management. The outcome was very much in line with that of the audit report. Consequently, the management took numerous actions under the CBN guidance to ensure that the banks operated effectively with particular emphasis on improving transparency and operations. To improve operations, the new management took steps to: (i) improve reporting infrastructure, internal governance and risk management procedures; (ii) increase transparency and disclosure; (iii) ensure effective and continuous communication with all stakeholders; (iv) ensure weekly reporting between the MDs and the CBN on financial performance, loan recoveries, and; (v) immediate report of any material developments to the CBN. Measures taken to improve operations included continued focus on loan recovery to improve NPL ratios; reducing cost to income ratio; avoiding unnecessary costs; focus on de-risking and de-leveraging the balance sheet and liquidity management.

There is no doubt that these initiatives enabled the nine banks to continue normal business operations and prevented a total collapse of the banking sector.

4.2 Long Term Reforms Measures

The focus of the CBN is first of all to ensure that there is financial sector stability and, secondly, that the financial system assists in growing the real sector of the economy. It is important to note that any economy that cannot create jobs on a continuous basis, reduce poverty, and guarantee its citizens functional and qualitative education as well as world class infrastructural facilities is not only unsustainable but would remain globally uncompetitive.

Attainment of this fit goes beyond short term palliative measures. It requires a strategic medium to long term measures. This explains why the focus of the recent CBN reforms is in the following four areas (pillars) namely: enhancing the quality of banks, establishment of financial stability, enabling healthy financial sector evolution, and ensuring that the financial sector contributes to the real economy. A brief discussion of each of these pillars is very critical to an understanding of where we are going.

4.2.1 Enhancing the quality of banks

This consists of a five part programme to enhance the operations and quality of banks in Nigeria. These are industry remedial programmes to fix the key causes of the crisis, implementation of risk-based supervision (RBS), reforms to regulations and regulatory framework, enhanced provisions for consumer protection, and internal transformation of the CBN.

The industry remedial programmes include a set of initiatives to fix the key causes of the crisis, namely, data quality, enforcement, governance, risk management and financial crime. These initiatives are structured in such a manner that the banks do most of the work to entrench new behaviours in the industry, with the CBN playing a cross-industry management role. The focus is to ensure that governance best practices are embedded in the industry including the CBN as well as ensuring that risk-based supervision (RBS) principles, methodology and processes are established across the CBN and NDIC. Under the RBS, the intention is to establish a programme management structure within the CBN to ensure that there is a high level of communication with the industry, implementation quality is measured and examiners acquire the necessary skills. A monitoring mechanism to measure the programme's impact and ensure a high level of responsiveness to issues raised by the industry will also be established.

The regulation and regulatory framework reform programme involves systematic review of regulations and guidelines around the key causes of the crisis by industry regulators; harmonization and raising to world-class standards of the supervision processes, technology and people within the various financial regulators; and establishment of a centre of competence for International Financial Reporting Standard (IFRS) and N-GAAP+ implementation.

In the area of consumer protection, the aim is to ensure that consumers receive appropriate protection with the CBN acting as the consumer's advocate, setting standards of customer service for the industry and ensuring that customers are treated fairly in all their dealings with the industry. Already, there is a Consumer Protection Unit in the newly created Financial Policy and Regulation Department of the Bank. This Unit will work with supervisors to ensure that appropriate rules and regulations are enforced by the banks.

Under the reform, the CBN will be transformed to ensure good corporate governance, stronger information management system, people development, and enhanced disclosure to levels expected in major investor countries such as the United States, the United Kingdom, South Africa, China and India.

4.2.2 Establishing Financial Stability

The main thrust of this pillar is for the CBN to provide leadership in some areas and championing some causes. The key features of this pillar centre around strengthening the Financial Stability Committee (FSC) within the CBN, establishment of macro-prudential rules, development of directional economic policy and counter-cyclical fiscal policies by the government and further development of capital markets as alternative to bank funding. The creation of a new macro-prudential framework designed to ensure that monetary policy is not only shaped by systemic risk trends but also consistent with the expanded goals for product and asset stability is a major component of this pillar. This will be complemented by the establishment of the FSC which will work together with the Monetary Policy Committee in achieving these objectives. It is the intention of the CBN to champion the development of the capital market through the improvement of its depth and accessibility as an alternative to bank funding as well as encourage implementation of directional economic policy, particularly counter-cyclical fiscal policies, that will reduce oil-related volatility in the system. It is time to make better use of our oil endowment by harnessing it for strategic investment and also ensure that lending and investment get to the real economy, especially the priority sectors, instead of being used to inflate financial asset bubbles.

4.2.3 Enabling Healthy Financial Sector Evolution

The focus here is on ensuring the emergence of a competitive banking industry structure; provision of the required infrastructure for financial system such as the credit bureau and registrars; improvement in the cost structure for banks through cost control and business process outsourcing; reliable and secure payments system; reduction of the informal sector and greater financial inclusion. Foreign bank participation would be encouraged in order to improve and strengthen the financial system provided such entry does not affect the development of the local banking sector. Market-based merger and acquisitions activities that would create stronger banks would be supported while other banks that would drive regional economic development will be licensed. In the area of infrastructure provision, three private credit bureaux (XDS Solutions, CRC Limited and CR Services Limited) have been licensed while the CBN would work with the Securities and Exchange Commission (SEC) towards the creation of an acceptable number of Registrars for all securities in the country. Central to the reform is the need to check the excessive costs in the banking system which is attributable, in the main, to infrastructure cost, high salaries/emoluments for executives and poor operational efficiencies. It is the intention of the CBN to encourage the development of electronic channels to drive down industry cost structure while working with the banks to improve on the quality of service delivery in order to improve customer confidence.

Nigeria presently has a large informal sector which has been estimated by the World Bank to constitute about 57.9 per cent of Nigeria's Gross National Product (GNP). This is higher than what obtains in Brazil, Ghana, Turkey, Malaysia and South Africa. Developing a financial system that will take care of this large segment of the economy is of utmost necessity. Thus, enhanced financial inclusion strategy would result in more accurate measurement of economic outputs, increase in tax base and tax revenue, more effective policy development and more efficient use of financial infrastructure. All these will in turn improve policy efficiency and help in poverty reduction.

Central to healthy financial sector evolution is the establishment of the Asset Management Corporation of Nigeria (AMCON) as part of a broad banking sector crisis resolution strategy. The AMCON Act 2010 was signed into law on July 19, 2010. When operational, AMCON would serve as a vehicle to free the banks from the weight of their non-performing assets and accelerate the process of financial revitalization of the banking sector. Besides, the CBN is currently reviewing the basic one-size-fits-all model of banking that has emerged since consolidation. In addition to reviewing the universal banking model, we consider it appropriate to introduce greater diversity in bank mandates. In the near-term, it should be possible to have international, national, regional, mono-line and specialised banks such as Islamic banks in the country. Already the guidelines for specialized institution have been fixed as follows: non-interest bank (regional), ₦5 billion, noninterest bank (National), ₦10 billion, and primary mortgage institutions, ₦5 billion. The commercial banks have also been restructured into regional, national, and international banks with paid-up share capital of ₦10 billion, ₦25 billion, and ₦50 billion, respectively.

4.2.4 Ensuring the Financial Sector Contributes to the Real Economy

The last and final pillar of the reform blue print is ensuring that the financial sector contributes to the real economy. Rapid financialisation in Nigeria did not benefit the real economy as much as had been anticipated. Development financial institutions set up for specific purposes such as housing finance, trade finance and urban development have not fulfilled their mandates. Many successful emerging markets have witnessed proactive government actions to ensure that the financial sector contribute to the real economy. Nigeria can learn from countries with successful track records in creating financial accommodation for economic growth through initiatives such as development finance, foreign direct investment, venture capital and public-private partnerships. In this regard, the CBN through the reforms shall (i) evaluate on continuous basis, the effectiveness of existing development finance institutions and initiatives in agriculture, manufacturing, and import-export credits, (ii) take a public lead in encouraging the examination of critical issues for economic development, such as the impact of infrastructure e.g. power, port and railway, (iii) lead further studies on potentials of venture capital and private-public partnership initiatives in Nigeria, and (iv) cooperate with State governments in running pilot programmes that are aimed at directing the financial sector's contribution to the State's socio-economic development.

So far, the CBN has taken concrete measures to finance the real sector of the economy. Some of these measures include:

(i) **₦500 Billion Critical Infrastructure Fund**: The Infrastructure Intervention Fund was introduced in April 2010 by the CBN to provide long-term support to finance critical infrastructure projects. The Fund is a 15-year debenture investment in the Bank of Industry (BOI) for on-lending to all eligible deposit money banks (DMBs) and Development Finance Institutions (DFIs) at 1%. These DMBs and DFIs will in turn lend to promoters of the projects at a maximum of 7.0%;

a. **₦ 200 Billion Refinancing/Restructuring of SME/Manufacturing Fund**: Out of the ₦500 billion Critical Infrastructure Fund approved, ₦200 billion was set aside for refinancing/ restructuring of SME/Manufacturing Fund in April 2010 to enable banks refinance and restructure their existing loan portfolio to SMEs and manufacturing. The 15-year facility has a 3-year moratorium with loan amounts ranging from ₦5 million (minimum) to ₦1 billion (maximum) to single obligor at an interest rate of 7.0 per cent annually repayable quarterly. On July 28, 2010, the ₦130 billion programme for refinancing and restructuring of loans to SMEs and manufacturing sector was launched. Already, 317 beneficiaries have been screened for the disbursement of the money.

b. **₦ 300 billion for long term funding of Power and Aviation.** The balance of ₦300 billion was also approved to provide long term funding to Power (₦250 billion) and Aviation Industry (₦50 billion).

4.3 The Journey so Far

In the last seventeen months, the implementation of the various aspects of the reforms has been vigorously pursued. Far reaching measures and initiatives have been put in place. New prudential guidelines were issued in May 2010. The AMCON Act has been signed into law and the Board inaugurated. These and several other measures have positively impacted on the banking sector. In spite of several challenges, it is gratifying to note that no single bank in Nigeria has collapsed and no depositor has lost his/her money as a result of the banking sector crisis. The banking system has been stabilized and the nine most affected banks have continued normal operation while modalities for injecting fresh capital into them either by shareholders or through acquisition and merger arrangements are being finalized.

To a large extent the reforms have succeeded in returning macroeconomic and financial system stability. Overall output in 2010 is expected to be higher than in 2009. Projections by the National Bureau of Statistics, showed that real GDP in 2010 will grow by 7.85 per cent compared to 6.66 per cent in 2009. The growth rate appears robust but there is need to ensure it translates into job creation and poverty reduction.

Between 2009 and 2010, the volatility in inflation has moderated significantly. Headline inflation declined steadily from 15.1 per cent in end-2008 to 10.4 per cent in September, 2009, rising thereafter to 15.6 per cent in February, 2010. Since then, it has maintained a downward trend to 13.4 per cent in October, 2010. Food inflation rose from 18 per cent at end-2008 to 20 per cent in February, 2009 before declining to 14.1 per cent in October, 2010. It is only non-food (core) inflation that has increased to 13.2 per cent in October, 2010, having declined from 10.4 per cent in end-December 2008 to 7.4 per cent in September, 2009.

Inter-bank rate and other key money market rates have moderated significantly compared to the pre-reform period. Weighted average inter–bank call rate and other key money market rates fell to below the end-December 2008 level by end-August 2009 after the sharp increase between January and July 2009. As at 28 July 2010, the inter–bank rate had fallen to 1.12 per cent while the Open Buy-Back (OBB) rate stood at 1.10 per cent. In response to the increase in MPR of September 21, 2010, both the Inter-bank call rate and OBB have trended upward averaging 10.56 and 8.23 per cent, respectively by November 15, 2010. In spite of the fluctuation in money market rates, the lending rates have remained consistently high. The prime lending rate stood at between 18 and 19 per cent while the maximum lending rate hovered between 22.56 and 23.91 per cent over March 2009 and May 2010. The average prime lending rate remained at 16.66 per cent in both October and September 2010, declining from 16.89 per cent in August 2010. The average maximum lending rate, however, declined to 21.85 per cent in October 2010 from 22.20 per cent in September 2010 and 22.31 per cent in August 2010. The weighted average savings rate equally declined marginally to 1.48 per cent in October, 2010 from 1.49 per cent in September, 2010 and 1.41 per cent in August, 2010 while the consolidated deposit rate increased to 2.31 per cent in October 2010, up from 2.07 per cent in September and 2.27 per cent in August 2010. The spread between the average maximum lending rate and the consolidated deposit rate, however, narrowed to 19.54 per cent in October, 2010 from 20.14 per cent in September 2010, and 20.04 per cent in August 2010.

The exchange rate has stabilized. The high exchange rate volatility noticed before July 2009 has disappeared. For a long time now the exchange rate has remained at between ₦148/₦152 per US$ compared with up to ₦180 per US$ between March and May 2009.

The confidence in the financial system is gradually being restored. External exposure to Nigerian banks has improved considerably. EXIM Bank exposure to Nigerian banks increased from US$403 million to US$1 billion. European Investment Bank has increased its exposure to Nigerian banks by an additional US$150 million. The International Finance Corporation (IFC) has also increased its exposure to Nigerian banks. Recently, it has announced its intention to inject US$300 million credit into two Nigerian banks. This consists of US$200 million long-term funding to GTbank and US$100 million convertible sub-debt and senior loans to First Bank.

The capital market has also witnessed some stability. The sharp drop in both market capitalization and the NSE ASI noticed between February 2008 and April 2009 has been reversed. As at July 28, 2010 market capitalization (MC) stood at ₦6.33 trillion while ASI was 25,889.98. By November 15, 2010, the ASI had declined marginally to 25,301.34 while MC increased to ₦8.08 trillion. Gross inflows of FDI are expected to improve in 2010 as first quarter 2010 inflows stood at ₦84.78 billion compared to fourth quarter 2009 inflow of ₦102.42 billion. Inflows are toward share equities, banking, telecommunication, manufacturing and oil and gas sectors.

Monetary and credit aggregates have, however, underperformed consistently falling below their long term trends. The decline in broad money (M2) growth witnessed up to July 2009 was reversed and except in January and May 2010, the growth rate has been positive. M2 grew by 4.25 per cent in October 2010 which when annualized represented a growth of 5.10 per cent. Net credit to the economy grew substantially since June 2009 although it has moderated since January 2010. In October 2010, aggregate credit grew by 19.69 per cent which annualizes to 23.63 per cent. Credit to the private sector which grew since July 2009, and declined between January and August, 2010. Since then, it has been rising. By October 2010, credit to private sector, core private sector, and government grew by 3.86, 3.07 and 64.02 per cent, respectively, on annualized basis. It should, however, be noted that the decline in monetary aggregates is not peculiar to Nigeria as other countries faced similar outcomes due to the global financial crisis.

The good news is that the banking system has resumed lending. New credit to the economy increased from ₦ 145,459 million in April 2010 to ₦173, 807 million in May 2010, ₦ 345,998 million in June, 2010 representing increases of 19.49 per cent and 99.1 per cent respectively. It however, declined to ₦322, 275 million in October, 2010, representing decline of 6.85 per cent. Credit by non-intervened banks rose from ₦127,270 in April 2010 to ₦145,885 million in May 2010, and ₦218,904 million in October 2010, representing increases of 14.63 per cent and 50.1 per cent, respectively. Similarly, the intervened banks credit increased from ₦18,189 million to ₦27,922 million and ₦43,371million, also representing 53.51 per cent and 55.33 per cent, respectively. The bulk of the credit went to Oil and Gas, Manufacturing, and Transportation and Storage. Furthermore, the stress test conducted recently on the twenty four banks has shown that the financial soundness of the banks (both intervened and non-intervened) has improved significantly compared to the crisis period.

It is also gratifying to note that of the ₦500 billion approved for power and aviation sectors as well as for the refinancing/restructuring of manufacturer's portfolios with the DMBs, about ₦199 billion had been paid to the Bank of Industry (BOI) for disbursement towards the refinancing/restructuring of manufacturers' exposures to the DMBs. Also, of the other liquidity injections approved by the CBN, ₦80.701 billion had already been disbursed under the Commercial Agricultural Credit Scheme, while ₦368.84 million had been paid by the Bank as its 6.0 per cent interest rebate obligation on 35 large scale agricultural projects under the Agricultural Credit Support Scheme.

5 Reform Challenges

In spite of the achievements so far, a number of challenges have remained. Indeed, economic growth has been robust, but a major challenge is how to sustain and translate this into new employment opportunities. The link between the major growth drivers, particularly agriculture and manufacturing, continue to be weak. Hence, the manufacturing sector remains an insignificant contributor to growth. There is, therefore, urgent need to address all binding constraints to growth. As you all are aware, inadequate or absence of basic economic and social infrastructure remains a major binding constraint on Nigeria's growth and development. There is therefore, an urgent need to fast-track the proposed reforms in some key sectors of the economy, notably power and oil/gas sectors, to attract the much-needed investment and reduce the huge import bills on refined petroleum products. There is absolutely no reason why our refineries should not be functional. There is also the need to deepen the deregulation process in the electricity and transport sector to attract private investment. The allocation of responsibility for infrastructure development among different levels of government need to be reviewed. Resumption of credit to key productive sectors of the economy is key because of the obvious medium-to-long term implications for the real economy. This requires adequate regulatory interventions to develop all sectors of the credit market from microfinance to larger corporations.

While acceleration of credit market reform such as dispute resolution mechanism, credit bureau regulation, and leasing laws are very critical, adequate attention must also be given to development of public-private partnership framework, legal framework for rental markets, etc. A major challenge also lies in reducing the high lending interest rate in the face of low money market rates.

Growing banking system liquidity is still desirable and, hence, the need to quickly bring the banking system reforms to closure. There is urgent need to inject fresh funds into the banks affected by regulatory actions in addition to the removal of the "toxic assets". This is where AMCON is very critical.

A major challenge remains how to strike an appropriate balance between monetary, fiscal and other policies. There is s a limit to what monetary policy can do to deliver economic growth. Other complementary policies must be in place. Banking sector reforms is a necessary but not a sufficient condition for economic growth and development. Complementary reforms in other areas of the economy, particularly in agriculture (in addition to energy sector mentioned above) to curb high import bills on food (rice) and reduce demand pressure in the foreign exchange market, are absolutely necessary.

Equally important is the rising government expenditure and borrowings with the possible crowding-out effects on the private sector. This brings to the fore the need to eliminate unnecessary subsidies that add to government expenditure and debt.

6 Conclusion

Distinguished audience let me reiterate the fact that a sound, efficient and stable financial system is very critical to the development of an economy. The global financial crisis and the post-consolidation weakness in the Nigerian financial system, occasioned by illegal and criminal activities in some of the Nigerian Banks have given rise to a fragile financial system which the CBN has tried to fix in the last seventeen months. The result so far has been quite encouraging. We shall remain focused and committed to this cause. Our goal is to bequeath to this country a stable financial system that will oil the wheels of economic development on a sustainable basis. We count on your support for this noble cause.

Thank you for listening.

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