Inflation and Economic Growth in Nigeria: Detecting the Threshold Level

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This paper re-examines the issue of the existence and the level of inflation threshold in the relationship between inflation and growth in Nigeria, using three different approaches that provide appropriate procedures for estimating the threshold level and inference. While Sarel's (1996) approach provides a threshold point estimate of 9.9 per cent that was not well identified by the data, the technique of Khan and Senhadji (2001) identifies a 10.5 per cent inflation threshold as statistically significant to explain the inflation-growth nexus in Nigeria. Also, the approach of Drukker et al *(2005) suggests a two threshold point model with 11.2 and 12.0 per cent as the appropriate inflation threshold points. These results suggest that the threshold level of inflation above which inflation is inimical to growth is estimated at 10.5 to 12 per cent for Nigeria. Using the estimated two threshold point model, this paper did not find enough reasons to accept the null hypothesis of the super-neutrality of money, and therefore, suggest that there is a threshold level of inflation above which money is not super-neutral.*

Keywords: threshold model, super-neutrality, inflation-growth nexus, inflation threshold points

JEL Classification: E31, O40

1.0 Introduction

High and sustained output growth in conjunction with low inflation is the common objective of macroeconomic policy all over the world. But can they coexist? Could there be a trade-off between lowering inflation and achieving sustained and higher growth? At the operational level, there is recognition that inflation-growth nexus depends on the level of inflation ostensibly because, at some low levels inflation may be positively correlated with output growth, but at higher levels inflation is likely to be inimical to growth. This relationship has been translated into the use of threshold models, which suggest that when inflation exceeds the threshold, higher inflation becomes immediately very

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detrimental to growth, a result that would call for immediate policy changes as soon as inflation exceeds the threshold.

The debate on inflation-growth nexus has remained perennial and has attracted substantial theoretical and empirical efforts. For instance, while the structuralists argue that inflation is crucial for economic growth, the monetarists posit that inflation is harmful to economic growth. The two basic aspects of the debate relate to the presence as well as nature of relationship between inflation and growth and the direction of causality. Commenting on the inconclusive nature of the relationship between inflation and economic growth, Friedman (1973) noted that some countries have experienced inflation with and without development and vice versa.

Wai (1959) argues that there is no relationship between inflation and economic growth noting that growth has been possible without inflation in some countries while in others; there have been inflation without growth. Similarly, Johanson (1967) posits that there is no convincing evidence of any clear association, positive or negative, between the rate of inflation and the rate of economic growth. He argues that it is not inflation that determines economic growth but the application of knowledge, through technical and managerial change and the improvement of human capacities.

Also, in a study on Nigeria, Chimobi (2010) investigates the existence of a relationship between inflation and economic growth using annual data for the period 1970 – 2005. The study finds no co-integrating relationship between the two variables. Using Granger causality test, however, the study established unidirectional causality running from inflation to economic growth.

The studies on the nonlinear relationship between inflation and economic growth argue that at low inflation levels, the relationship between inflation and economic growth is non-existent or positive while at higher levels of inflation, the relationship becomes significant and negative. Fischer (1993) was among the first to identify such a relationship and since then, various researchers have attempted to estimate a threshold beyond which inflation becomes injurious to growth. For instance, Sarel (1996) estimates a threshold of 8 per cent in his cross country study, while Ghosh and Philips (1998) report a lower threshold of 2.5 per cent using a larger sample of countries.

In terms of country specific studies, Mubarik (2005) uses annual data from 1973 to 2000 to investigate the relationship between inflation and growth in Pakistan. He finds a threshold of 9 per cent and concluded that inflation levels beyond the estimated threshold would confer significant output cost on the country. Also, Hussain and Malik (2011) use granger causality test to determine the direction of causality between inflation and economic growth in Pakistan and the error correction model to explore the nature of relationship between the variables. Employing annual data from 1960 to 2006, they find that inflation granger causes growth and not vice versa. In addition, they establish a positive relationship between inflation and economic growth. Similar to the findings of Mubarik (2005), their model detects a threshold of 9 per cent, beyond which inflation begins to lower growth

Mohanty *et al.* (2011) explore possible nonlinear relationship between inflation and growth in India using quarterly series and infer that the inflation rate of 4 to 5.5 per cent may be considered as an inflation threshold. Though their empirical investigation do not find conclusive evidence of the existence of an inflation threshold, they opine that inflation rate less than 5.5 per cent impact positively on Indian economic growth, while the relationship changes once the 5.5 per cent level is exceeded.

Salami and Kelikume (2010) use annual data for the period 1970 to 2008 and 1980 to 2008 to estimate an inflation threshold for Nigeria. For the period 1970 to 2008, an inflation threshold of 8 per cent is detected, while for 1980 to 2008 an insignificant threshold of 7 per cent is established. In a similar study for Nigeria using annual data from 1970 to 2006, Bassey and Onwioduokit (2011) use the framework of Li (2005) to investigate the relationship between inflation and economic growth as well as detect an appropriate threshold. Having established the presence of a negative relationship, they identify a statistically insignificant threshold level of 18 per cent and establish that inflation rates below the threshold are growth propelling. Also, employing the threshold regression model developed by Khan and Senhadji (2001) on a mixture of quasi and actual quarterly data spanning 1981 to 2009, Bawa and Abdullahi (2012) estimate a higher threshold inflation level of 13 per cent when compared with Salami and Kelikume's point estimate, but a lower threshold when compared with the point estimate suggested by Bassey and Onwioduokit.

While the dummy[2] variable specification in Salami and Kelikume may be flawed resulting in the 8 per cent inflation threshold that is not well identified by the data used, the 18 per cent threshold suggested by Bassey and Onwioduokit is not conclusive, as the classical tests for the existence of the threshold at 18 per cent was rejected. Adapting Sarel (1996), Khan and Senhadji (2001) and Drukker et al (2005) methodologies on recent quarterly data spanning 2005Q1 to 2012Q1, this paper re-examines the issue of the existence of the threshold effects of inflation for Nigeria. These methodologies are used in this paper to ensure the robustness of the results and confirm earlier findings.

For ease of exposition, the paper is structured into seven sections; with section one as the introduction. Section two uses recent data to provide some stylized facts on Nigeria's inflation-growth nexus. Section three reviews both the theoretical and empirical literature for the study. While section four discusses the methodology adapted for the study, the optimization and inferential methods of determining the inflation thresholds are presented in section five. Data analysis, results and discussions are contained in section six, while section seven concludes the paper.

2.0 Growth-Inflation Nexus in Nigeria: Some Stylized Facts

The Nigerian economy recorded significant growth in the last two quarters[3] of 2005 with over 8 per cent growth in each of the two quarters. The impressive growth in output recorded in these quarters was attributable to the effective implementation of the economic reform agenda under the auspices of the National Economic and Development Strategy (NEEDS). The main drivers of growth in output during the period were agriculture, general commerce and services (CBN, 2005). Though there were inflationary pressures during the first three quarters of the year, the impressive growth rate in Q4, 2005 was associated with a drastic decline in inflation from almost 24.3 per cent in Q3, 2005 to about 11.3 per cent during the fourth quarter of the year. The initial inflationary pressure in the year was caused by increased food prices

[2] The relationship between threshold k, and log (π) in defining the dummy variable should have been in the form $\log(\pi) > \log(k)$ or $\pi > k$ or $10^{\log(\pi)} > k$, rather than in the form $100 \log(\pi) > k$.

[3] The quarterly GDP compilation, a collaborative effort of the Central Bank of Nigeria (CBN) and National Bureau of Statistics (NBS) commenced in Q1, 2004.

emanating from domestic food supply gap following Nigeria's increased food aid to Niger and Chad during the period. However, improved agricultural harvest and the implementation of sound monetary policies provided some dampening effects towards the end of 2005. Fig 1(a) shows the trend in inflation rate and economic growth in Nigeria between 2005:Q1 and 2012:Q1.

During Q1, 2006, real GDP fell from 8.4 per cent in the preceding quarter to about 7.1 per cent. It fell further to about 5.2 per cent during the second quarter before recovering to higher levels of 5.6 and 6.4 per cent during the third and fourth quarters of the year, respectively. The decline in output growth during the second half of 2006 could be attributable to decline in oil sector contribution to output due to youth restiveness in the Niger-Delta region, and infrastructural inadequacies, especially power. Developments in prices followed a similar pattern as output during the year, except for the Q3, 2006 in which both inflation and growth trended in opposite direction. However, inflationary pressures were effectively curtailed and reduced to a single digit resulting from the implementation of sound macroeconomic policies during the second half of the year, a period of declining growth in real GDP.

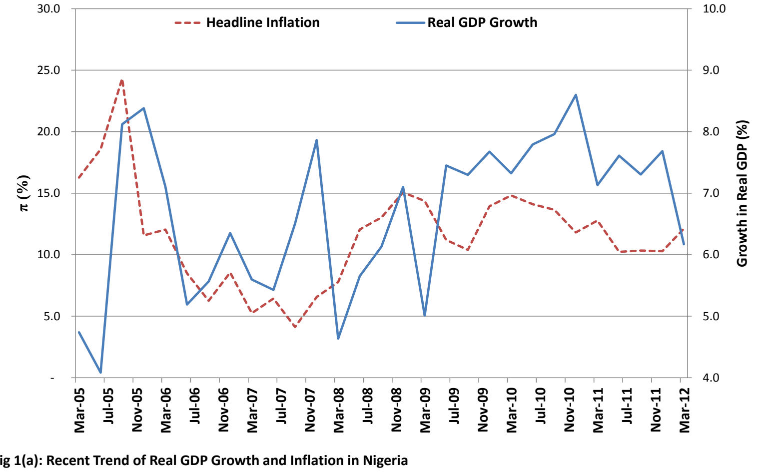

Fig 1(a): Recent Trend of Real GDP Growth and Inflation in Nigeria

In 2007, the continued implementation of sound monetary and fiscal policies further enhanced the growth prospects of the economy in spite of a reduction in real GDP growth rates during the first half of the year. Thus, growth in real GDP revealed impressive performance in the last two quarters of the year as it reached a local high of about 7.9 per cent at end Q4, 2007 before declining drastically to 4.6 per cent in Q1, 2008. There was therefore, an increase in output in 2007 and a decline in inflation rate. The decline in inflation was attributed to good agricultural harvest and sound macroeconomic policies.

Following the decline in output in Q1, 2008, increased growths rates were experienced during the last three quarters of the year partly due to increased availability of funds to the private sector. Other contributory factors to output growth were the stability in the foreign exchange market, sound macroeconomic policies, and clement weather conditions. Similar to the trend in output, prices in 2008 rose significantly and steadily owing to factors such as the global financial crisis, rising liquidity and depreciating exchange rate of the Naira (CBN, 2008).

In 2009, both output growth and inflation rate fell during the first quarter relative to their levels in the preceding quarter. However, the pattern was reversed during Q2, 2009 as output increased to 7.4 per cent, while inflation moderated to 11.2 per cent from 14.4 per cent achieved in Q1, 2009. Again, both output and prices trended downwards in Q3, 2009 and upwards in Q4, 2009. Output growth was driven largely by the non-oil sector and propelled by sound macroeconomic policies, while increases in food prices led to inflationary pressures.

In 2010 a combination of growth enhancing policies led to a steady increase in real GDP relative to its level in the previous year. For instance, the growth rate of real GDP in Q1 and Q4 of the year were 7.3 per cent and 8.6 per cent, respectively. The 8.6 per cent growth in output achieved in Q4, 2010 was the highest during the study period. This output growth was driven largely by agriculture, services, wholesale and retail trade as well as building and construction sectors of the economy. The gradual increase in output during the year was accompanied by a steady decline in prices, due to factors such as improved agricultural harvest and the relative stability in the supply and prices of petroleum products (CBN, 2010).

The first quarter of 2011 witnessed a decline in real GDP relative to the level recorded in Q4, 2010, and a rise in inflation rate. Similarly, the moderate improvement in output achieved in the second quarter was associated with a moderation in inflation rate. For instance, while the output growth rose from from7.1 per cent in Q1, 2011 to 7.6 per cent in Q2, 2011, inflation rate moderated substantially from 12.8 per cent to 10.2 per cent in the same period.

Similar pattern was observed in the remaining two quarters of the year as increased output growth was associated with falling prices. Also, note that the recorded growth in quarterly output of 6.2 per cent in Q1, 2012 was the lowest since Q1, 2009. This deceleration in growth was accompanied by acceleration in inflation rate from 10.2 per cent in Q2, 2011 to 12.1 per cent in the first quarter of 2012.

3.0 Literature Review

The growth theory literature on inflation-growth nexus in the 1950s emphasized the positive impact of inflation on the rate of economic growth (popularly known as the Tobin effect) while the costs of inflation detailed in Fischer and Modigliani (1978) suggested a negative association through the new growth theory mechanisms. Other strands of related literature have also argued that the negative relationship between inflation and growth is not universal (i.e. it appears after certain inflation thresholds) and hence nonlinear.

Paul *et al* (1997) used annual data spanning the period 1960-1989 on 48 developing countries and 22 developed ones to examine the inflation-growth nexus. They found mixed evidences as the relationship was negative in some countries and positive in others. In a study of eleven African economies, CBN (1974) examined the relationship between inflation and output growth and found that in six of the countries (Egypt, Gabon, Ghana, Ivory Coast, Kenya and Sudan) the sign of the price coefficient in the growth regressions was negative. However, for the other five countries (Morocco, Nigeria, Tunisia, Uganda and Zambia) the price coefficient suggested a positive relationship between inflation and growth. The regression coefficients for both the individual countries and the group estimates were not statistically significant and therefore could not provide basis for firm conclusion. This study was however deficient in the sense that the relationships specified assumed that price was the only important variable influencing output, thus, ignoring other crucial control variables.

Barro (1995) used data for 100 countries from 1960 to 1990 to investigate the effects of inflation on economic performance by using the instrumental variable estimation method. He found that a 10 percentage point increase in average inflation per year yielded a reduction in growth rate of real per capita GDP of between 0.2 and 0.3 percentage points. He further noted that the inclusion of high inflation experiences in the growth regressions yielded more statistically significant results and stated that the direction of causation runs from higher inflation to reduced growth. Malla (1997) used a small sample of eleven OECD countries in a pooled time series and cross-section fashion to examine the relationship between inflation and growth. He concluded that the negative effects of inflation on economic growth more than outweigh its positive effects.

Faria and Carneiro (2001) examined the inflation-growth nexus from the perspective of an economy suffering from high and persistent inflation. He studied the case of Brazil and found empirical evidence for a negative effect of inflation on output in the short run. Also, Smyth (1992) confirmed a negative relationship between inflation and growth in the USA and estimated that each one percentage point increase in the USA inflation reduces the country's annual growth rate by 0.223%. In another study on the USA, Smyth (1994) showed that increased inflation impacts growth negatively in the USA and estimated that each one percentage point increase in inflation caused a reduction of 0.158% in America's output growth. In the case of Germany, Smyth (1995) estimated that a 10% increase in the rate of inflation reduces the rate of growth of total factor productivity by 0.025%. Umaru and Zubairu (2012) examined the impact of inflation on economic growth and development in Nigeria between 1970-2010 and found that inflation possessed a positive impact on economic growth through encouraging productivity and output level and on evolution of total factor productivity

Bruno and Easterly (1998) investigated possible relationship between inflation and economic growth using cross country data. They found that inflation has negative effect on medium to long term economic growth and showed that the relationship is influenced by countries with extreme values (either very high or very low inflation). They argued that inflation rates in excess of a critical value of 40 per cent are inimical to growth and went ahead to investigating only cases of discrete high-inflation (40 per cent and above) crises. This yielded very robust empirical result that growth falls sharply during high-inflation episodes and recovers rapidly as inflation falls to moderate levels. Bullard (1995) also provided firm evidence that the negative relationship between inflation and growth only manifests when inflation rates are in excess of some threshold levels.

Examining the non-linear relationship between inflation and economic growth, Burdekin(2000) showed that the effects of inflation on growth reverses substantially as the inflation rate rises. He concluded that the threshold at which inflation first begins to negatively affect growth is around 8 per cent for industrial economies and 3 per cent or less for developing countries. Also, Mallik and Chowdhury (2001) empirically examined the relationship between inflation and GDP growth for four South Asian countries (Bangladesh, India, Pakistan and Sri Lanka) using co-integration and error correction models. They found evidence of a long-run positive relationship between GDP growth and inflation. They also discovered significant feedbacks between inflation and economic growth and concluded that the sensitivity of inflation to changes in growth rates is larger than that of growth to changes in inflation rates. This study puts the countries on a knife edge as they struggle to achieve non-inflationary growth. The challenge for them, therefore, is to find a growth rate that is consistent with a stable inflation rate, rather than beat inflation first to take them to a path of faster economic growth.

Khan and Senhadji (2001) estimated a panel regression with data from 140 countries and spanning about 40 years to investigate the nonlinear relationship between inflation and economic growth. Having established the presence of nonlinearity, they found a threshold range of 1-3 per cent for industrial economies and 11 – 12 per cent for developing economies. The estimated relationships were found to be robust to different estimation procedures, alternative specifications, changes in threshold levels and different data frequency.

Drukker *et al.* (2005) used data from a sample of 138 countries from 1950 to 2000 to investigate the threshold effects in the relationship between inflation and economic growth. The panel regression results revealed that there is one threshold with an estimated value of 19.16 per cent that is well identified by the full sample. For the industrialized sample, the results indicated that there are two threshold points at 2.57 per cent and 12.61 per cent.

Li (2005) used data for 90 developing countries and 28 developed countries over the period 1961 – 2004 and found evidence of a nonlinear relationship between inflation and economic growth. He further showed that the form of nonlinearity in the inflation-growth relationship for developed countries differ from that of the developing ones. While two thresholds were found for the latter, only one threshold was detected for the former. He also studied the transmission channel through which inflation affects economic growth in a nonlinear manner. Based on theory and empirical findings, he identified two major transmission channels, which are the capital accumulation channel and the total factor productivity channel. He noted that inflation has been documented to affect economic growth either directly or via the behavior of the financial intermediaries. He opined that high and unstable prices affect the financial market and developments in the financial markets in turn affect the level and efficiency of investment and ultimately output growth. He concluded, through his empirical work, that for both developing and developed countries, the total factor productivity is the channel through which inflation adversely and nonlinearly affects economic growth.

Motivated by the global inflation episode of 2007/2008 and concern that high level of inflation could undermine growth, Espinoza et al (2010) employed the smooth transition model to examine the rate at which inflation levels in excess of threshold impede economic growth. They used a panel of 165 countries and found an inflation threshold of 10 per cent based on data for the period 1960 – 2007 and suggesting the need for a prompt policy response to inflation at or above the threshold. However, the threshold was found to be much lower for the advanced economies.

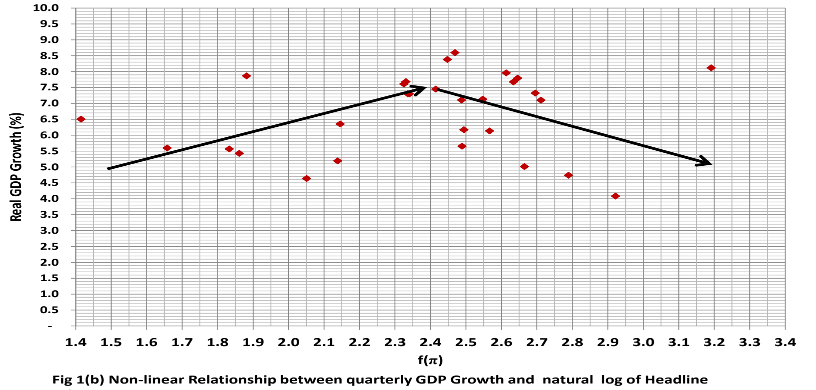

Fig 1(b) Non-linear Relationship between quarterly GDP Growth and natural log of Headline Inflation in Nigeria

4.0 Methodology

It has been established in the literature by numerous authors such as Sarel (1996), Khan and Senhadji (2001), Li (2005), Drukker *et al.* (2005) and Mohanty *et al.* (2011) that inflation exhibits a non-linear relationship with economic growth. It is generally accepted that inflation has a negative effect on growth once it crosses the threshold level, while below the threshold level it is generally expected to have a positive impact on growth. This non-linear relationship between growth and inflation appears to also hold for Nigerian data as depicted in Fig. 1(b).

The list of variables used in the paper for the specifications of the three adapted threshold inflation models of Sarel (1996), Khan and Senhadji (2001) and Drukker *et al.* (2005) are presented in Table 1 below:

Table 1: List of Variables and their definitions

Variable Symbol	Variable Definition
π	Headline CPI inflation, that is Quarter t over Quarter t-4
y	Real Gross Domestic Product Growth, that is Quarter t over Quarter t-4.
w	Real World Gross Domestic Product Growth, that is Quarter t over Quarter t-4.
μ	Autoregressive term
ε	Moving Average term

4.1 Sarel Threshold Model

Sarel (1996) estimates the coefficients β_0 and β_1, which for a given country has the functional form specified in equation (1):

$$y_t = \alpha_o + \beta_o d_t f(\pi_t) + \beta_1(1 - d_t)\{f(\pi_t) - \log(\pi^*)\} + \emptyset' \underline{X} + \epsilon_t \quad (1)$$

where

$$f(\pi_t) = \begin{cases} \log(\pi_t) & if\ \pi_t > 1 \\ \pi_t - 1 & elsewhere \end{cases}$$

and

$$d_t = \begin{cases} 1, & if\ f(\pi_t) \le \log(\pi^*) \\ 0, & elsewhere \end{cases}$$

In equation (1) y_t denotes the real quarterly GDP growth in time t, β_0 is the coefficient of the semi-log transform of inflation $f(\pi_t)$ at time t, β_1 is the coefficient of the extra inflation, and π^* is the expected inflation threshold that should be determined. The vector $\underline{X}$ constitutes other relevant regressor (or control) variables and $\emptyset$ is their coefficient vector. The error or moving average term ε_t is expected to be identically and independently normally distributed with mean zero and constant variance σ^2. With a chosen basic model, equation (1) is iterated with different values of log (π^*) and the structural break occurs at the value of π^* for which the chosen statistical loss function is a minimum. Also, at this value of π^*, the sum of β_0 and β_1 which determines the effect of inflation on output growth, will change sign significantly.

4.2 Khan and Senhadji Threshold Model

Khan and Senhadji (2001) use another econometric method for threshold estimation and inference that were earlier developed by Chan and Tsay (1998) and Hansen (2000) in the context of panel models with threshold effects. For a typical country, the model is specified in equation (2)

$$y_t = \alpha_1 + \gamma_1 d_t\{f(\pi_t) - \log(\pi^*)\, I(\pi_t > 1)\} + \gamma_2(1 - d_t)\{f(\pi_t) - \log(\pi^*)\, I(\pi_t > 1)\} + \emptyset'\,\underline{X} + \epsilon_t \qquad (2)$$

The effect of inflation on GDP growth is captured by γ_1 for periods in which semi-log of inflation is less than or equal to $\log(\pi^*)$ and γ_2 for periods when the semi-log of inflation rates are higher than $\log(\pi^*)$. The indicator function $I(\pi_t > 1)$ equals unity when π_t is greater than one and zero, otherwise. All other parameters are as defined in equation (1). With a basic chosen model, equation (2) can also be iterated with different values of $\log(\pi^*)$ to estimate both the threshold inflation level π^* as well as the model parameters.

4.3 Drukker *et al*. Threshold Model

Drukker *et al*. (2005) apply a new econometric method for estimation and inference in fixed effects panel data models that may contain threshold inflation effects. This model adapted to estimate the coefficients and number of threshold points in a given country is specified in equation (3)

$$y_t = c + \sum_{k=0}^{n} \gamma_k \, d_{tk} f(\pi_t) \; + \; \varphi' X_t \; + \in_t \qquad (3)$$

where n is the number of threshold points, y_t denotes the growth in real GDP at time t, γ_k is the coefficient on the semi-log transformation of inflation $f(\pi_t)$, in threshold region k and X_t is a vector of other regressor variables, φ is a vector of coefficients on X_t and ε_t is as defined in equation (1).

The threshold region indicator variable d_{tk} is defined as:

$$d_{tk} = \begin{cases} 1 & if \;\; \log(\pi_k^*) < \log(\pi_t) \le \log(\pi_{k+1}^*) \\ 0 & elsewhere \end{cases}$$

where $\log(\pi_0^*) = -\infty$, $\log(\pi_{n+1}^*) = +\infty$ are the end-points and (π_k^*) for $k \in \{1, 2, \dots\, n\}$ are the n threshold inflation points. When $n = 0$, equation (3) reduces to the classical linear fixed effects (FE) model

$$y_t = c + \gamma_0 f(\pi_t) \; + \; \varphi' X_t \; + \in_t \qquad (4)$$

and there is no inflation threshold effect. However when $n > 0$, equation (3) is non-linear in the semi-log of inflation. If the true number of threshold points and their values are known, equation (3) would be a linear model and all the standard estimation methods could be used. However, the lack of knowledge of the number of threshold points and their values complicates the estimation and inference. In this case, sequential estimation procedure such as conditional least squares is applied to estimate the thresholds, the number of thresholds and other model parameters.

5.0 Optimization and Inferential Method

In the three models considered in equations (1), (2) and (3), the threshold inflation were unknown and so the models could not be estimated by ordinary least squares method. These models would have to be estimated ideally using the non-linear least squares (NLLS), but as Khan and Senhadji (2001) noted, $f(\pi^*)$ enters the regression in a non-linear and non-differentiable manner. This means that conventional gradient search techniques used in NLLS would not be appropriate, in this case.

Following Khan and Senhadji (2001), the optimization method adopted in this paper is the conditional least squares, which is described as follows. For any given $f(\pi^*)$, the basic chosen model estimated using the Generalized

Autoregressive Conditional Heteroscedasticity (GARCH) methodology generates the statistical loss function as a function of f(π^*) that would be optimize over all possible values of $f(\pi^*)$. The conditional least squares estimate $f({\pi_{opt}}^*)$is found by selecting the value of $f(\pi^*)$ which minimizes the loss function. The statistical loss function we have chosen in this paper is the classical Root Mean Squared Error (RMSE) because of its obvious advantages. That is, for a given $f({\pi_k}^*)$, we obtain RMSE $\{f({\pi_k}^*)\}\ \forall\ k$ ranging from 1 to n, and define our optimal $f(\pi^*)$, denoted $f({\pi_{opt}}^*)$ as:

$$f\left(\pi_{opt}^*\right) = \{ f(\pi_k^*) :\backslash \min_{\forall k}\{RMSE[f(\pi_k^*)]\} \qquad (5)$$

Inverting the semi-log transform produces the level estimate for the inflation threshold π_{opt}^* as:

$$\pi_{opt}^* = \exp\left\{f\left(\pi_{opt}^*\right)\right\}$$

It is also important to determine the statistical significance (or otherwise) of the threshold effect. For the Sarel model we need to test the null hypothesis of no threshold effect, that is, the sum of the estimated parameters $\beta_0 + \beta_1$ is statistically not different from zero. Similarly, for the Drukker et al model we will be interested in testing whether the sum of the γ_k coefficients are statistically not different from zero. In contrast, the Khan and Senhadji model requires us to draw some inferences on whether or not the two coefficients γ_1 and γ_2 are statistically different, by testing the null hypothesis $H_0 : \gamma_1 - \gamma_2 = 0$.

Since the GARCH methodology is used to estimate the parameters of the mean equations (1) to (3), it is assumed that the error terms would be identically and independently normally distributed with mean zero and constant variance. Furthermore, Chan and Tsay (1998) show that in the case of continuous threshold models, the asymptotic distribution of all the estimated parameters, including the threshold level, have a normal distribution. The ARCH Residual LM test and the Jarques–Bera normality test on the residuals will be used to empirically test this assumption. Under the null hypothesis of the estimated parameters, parametric test could be performed.

6.0 Data, Results and Discussions

This paper uses actual real quarterly GDP and inflation data from the National Bureau of Statistics and real world GDP growth sourced from the International Financial Statistics of the IMF. The dataset span the period 2005Q1 to 2012Q1 so as to capture the recent growth – inflation nexus in Nigeria. Because of the changing structure of the Nigerian economy, going back too long in time may not reflect the current realities. We have also adopted the variables used in Mohanty *et al.* (2011) as our regressors to examine the significance of external developments on the Nigeria's domestic growth-inflation nexus. It is also expected that the use of the autoregressive and integrated moving average process would control the impact of domestic factors.

Checking the order of integration of included variables is crucial in any time series modeling. The Augmented Dickey Fuller (ADF) and Philips Perron tests are used to test the stationarity properties of the data. Both tests indicate that the variables y, w and $f(\pi)$ are integrated of order one. The Engle-Granger co-integration test for the three series confirms that these variables are co-integrated, suggesting a long-run relationship between them.

Many studies of inflation-growth nexus estimate the threshold level of inflation using different methodologies. This paper finds the specification of the regressor (or control) variables in Mohanty *et al*. (2011) very appealing. While this paper adopts the same regressors, it also extends the specification of the mean equations (1) through (4) using the Autoregressive and Integrated Moving Average process with an exogenous input (ARIMA-X). Over the years, the GARCH methodology has become quite useful in modeling the mean equation of time series that exhibits some level of volatility. As posited by Engle (1982), this technique allows a conventional regression specification for the mean function with a variance which changes stochastically over the time horizon.

In using the GARCH model, three distinct specifications are required, and these are for the: conditional mean equation, conditional variance equation, and conditional error distribution. The squared residuals of the estimated ARIMA-X mean equations are tested for ARCH effect. The null hypothesis of homoscedasticity in the squared residuals was rejected at the 5 per cent level, implying the presence of ARCH effect, that the mean equations (6) through

(8), using as control variables - the real world GDP growth, AR(3), SAR(4) and MA(4), possess time varying volatilities.

Table 2: ML - ARCH (Marquardt) Coefficients of Non-Linear Regression - Sarel's Method

	$f(\pi^*)$								
Parameters	**2.208274**	**2.230014**	**2.24071**	**2.251292**	**2.261763**	**2.272126**	**2.28238**	**2.29253**	**2.30259**
C	6.662[a]	7.210[a]	7.166[a]	7.285[a]	7.457[a]	7.165[a]	6.497[a]	7.213[a]	6.968[a]
SE(C)	0.098	0.266	0.282	0.270	0.249	0.299	0.300	0.186	0.287
β_0	-0.450[a]	-1.012[a]	-0.981[a]	-0.944[a]	-1.101[a]	-0.827[a]	-0.671[a]	-0.849[a]	-0.683[a]
SE(β_0)	0.061	0.223	0.233	0.250	0.124	0.230	0.249	0.165	0.239
β_1	2.192[a]	-0.562	-0.341	-0.553	-1.435[b]	0.069	0.979	-0.045	0.975
SE(β_1)	0.197	0.799	0.903	0.862	0.674	0.911	1.154	0.683	1.152
θ	0.242[a]	0.228[a]	0.239[a]	0.217[a]	0.167[a]	0.237[a]	0.250[b]	0.229[a]	0.250[b]
SE(θ)	0.019	0.065	0.070	0.064	0.075	0.070	0.105	0.046	0.105
λ	-0.911[a]	-0.295[b]	-0.321[a]	-0.308[c]	-0.255	-0.431[a]	-0.643[a]	-0.415[a]	-0.642[a]
SE(λ)	0.071	0.143	0.124	0.172	0.183	0.127	0.150	0.136	0.150
β	0.734[a]	0.691[a]	0.695[a]	0.724[a]	0.712[a]	0.717[a]	0.726[a]	0.721[a]	0.726[a]
SE(β)	0.016	0.072	0.075	0.088	0.087	0.077	0.061	0.064	0.061
ρ	-1.000[a]	-0.940[a]	-0.942[a]	-0.939[a]	-0.941[a]	-0.952[a]	-0.958[a]	-0.944[a]	-0.958[a]
SE(ρ)	0.003	0.029	0.012	0.035	0.032	0.026	0.018	0.029	0.018
RMSE	0.7104	0.5966	0.5946	0.5937	0.6174	0.5906	0.6100	0.5897	0.6100
DW	1.942	2.054	2.020	1.991	2.100	1.932	1.800	1.912	1.801
ARCH Residual LM Test	0.833	0.050	0.001	0.194	0.723	0.071	0.861	0.314	0.859
P - Values	(0.370)	(0.825)	(0.971)	(0.663)	(0.403)	(0.792)	(0.362)	(0.580)	(0.363)
Jarque Bera Test For White Noise	0.202	0.943	0.740	0.631	0.734	0.156	0.107	0.225	0.104
P - Values	(0.904)	(0.624)	(0.691)	(0.730)	(0.693)	(0.925)	(0.948)	(0.893)	(0.949)
H_0: $\beta_0 + \beta_1 = 0$	**1.742[a]**	**-1.574[c]**	**-1.323**	**-1.497**	**-2.536[a]**	**-0.758**	**0.308**	**-0.894**	**0.292**
SE	**0.206**	**0.830**	**0.933**	**0.898**	**0.685**	**0.939**	**1.181**	**0.702**	**1.176**

a = significance at the 1 per cent level, b = Significance at the 5 per cent level, while c at the 10 per cent level

6.1 Estimation Using Sarel's Model

Following Sarel (1996) methodology, equation (1) is estimated using symmetric GARCH (1,1) to obtain the mean equation:

$$y_t = c + \beta_o d_t f(\pi_t) + \beta_1(1-d_t)\{f(\pi_t) - \log(\pi^*)\} + \theta w_t + \lambda \mu_{t-3} + \beta \mu_{t-4} - \lambda\beta\mu_{t-7} + \rho\epsilon_{t-4} \quad (6)$$

The minimum RMSE is attained when $f(\pi^*_{opt}) = 2.29253$. Inverting the semi-log transform produces the level estimate of 9.9 per cent as the inflation threshold using the Sarel's model. The regression results and diagnostics presented in Table 2 are found to be satisfactory. Using this model, the parameter of interest is the sum of β_0 and β_1 which determines the effect of inflation on output. At 9.8 per cent, the sum of the two coefficients is positive but not significant. In contrast, at the 9.9 per cent threshold in which the global RMSE is attained as shown in Fig. 2, the sum of β_0 and β_1 is negative and also statistically insignificant, indicating that the 9.9 per cent threshold cannot be accepted for Nigeria.

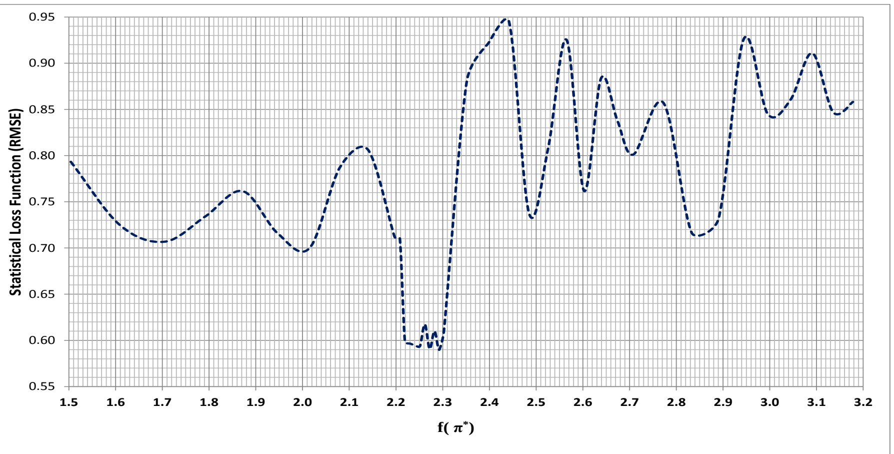

Fig 2: Searching for Inflation Threshold using Sarel's Method

It is however important to note that at $f(\pi^*) = 2.20827$ (or $\pi^* = 9.1$ per cent), $\beta_0 + \beta_1$ is positive and significant indicating that up to 9.1 per cent inflation has positive and significant impact on growth. From 9.2 per cent to 9.6 per cent the impact on growth is negative and in some cases significant. This leads us to suggest a 9.2 to 9.6 per cent as indicative threshold inflation for Nigeria obtained using the Sarel's method, even though the outcome appears inconclusive.

6.2 Estimation Using Khan and Senhadji's Model

Following Khan and Senhadji (2001) methodology, equation (2) is estimated using symmetric GARCH (1,1) to obtain the mean equation:

$$y_t = \alpha_1 + \gamma_1 d_t\{f(\pi_t) - \log(\pi^*)\, I(\pi_t > 1)\} + \gamma_2(1-d_t)\{f(\pi_t) - \log(\pi^*)\, I(\pi_t > 1)\} + \theta w_t + \lambda\mu_{t-3} + \beta\mu_{t-4} - \lambda\beta\mu_{t-7} + \rho\epsilon_{t-4} \quad (7)$$

Table 3: ML - ARCH (Marquardt) Coefficients of Non-Linear Regression Using Kan and Senhadji's Method

Parameters	Estimate	Standard Error
α_1	7.176[a]	0.001
γ_1	3.024[a]	0.631
γ_2	-0.100	0.959
θ	0.241[a]	0.052
λ	-0.453[a]	0.126
β	0.722[a]	0.032
ρ	-0.955[a]	0.024
$f(\pi_{opt}^{*})$	2.35138	-
RMSE	0.6551	-
DW	2.048	-
ARCH Residual LM Test	0.040	-
P - Values	(0.843)	-
Jarque Bera Test For White Noise	1.528	-
P - Values	(0.466)	-
H_0: $\gamma_1 - \gamma_2 = 0$	3.124[a]	1.148

a = significance at the 1 per cent level, b = Significance at the 5 per cent level, while c at the 10 per cent level

The regression results and the diagnostics presented in Table 3 are found to be satisfactory. The diagnostic results suggest that the estimated mean equation (7) did not possess time varying volatility. The results of the optimization method indicate a statistically significant break at $f(\pi^*_{opt}) = 2.35138$ or $\pi^*_{opt} = 10.5$ per cent of inflation as shown in Fig. 3. It is at this level that equation (7) returns a minimum RMSE. The test for the existence of threshold inflation at 10.5 per cent is accepted, since γ_1 and γ_2 are statistically different. Therefore, 10.5 per cent is an inflation threshold for Nigeria using Khan and Senhadji's model. Thus when inflation moves beyond the 10.5 per cent threshold, the positive effect of inflation on growth dies out, considering that the impact of inflation above 10.5 per cent turns unfavorable.

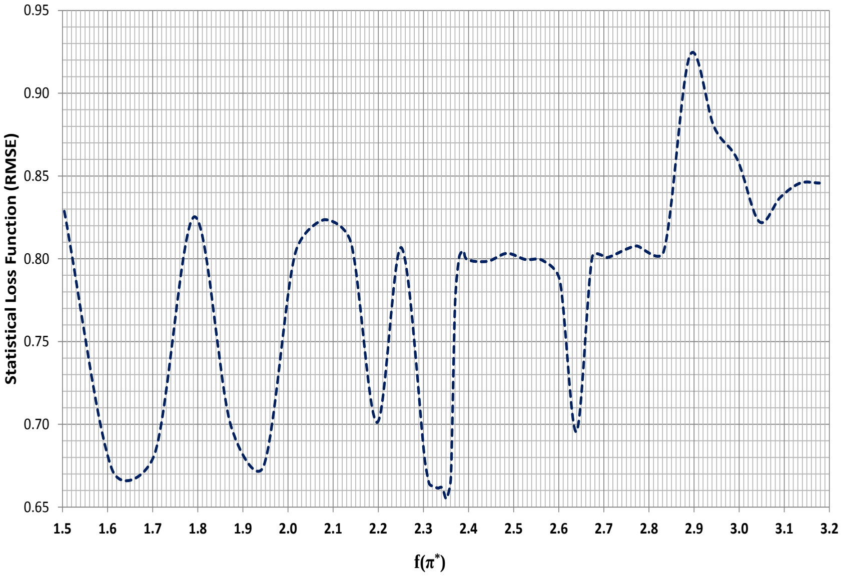

Fig 3: Searching for Inflation Threshold using Khan and SenHadji Method

6.3 Estimation Using Drukker *et al* Model

Following Drukker *et al*. (2005) methodology, equation (3) is estimated using symmetric GARCH (1,1) to obtain the mean equation:

$$y_t = \alpha_1 + \sum_{k=0}^{n} \gamma_k \, d_{tk} f(\pi_t) + \theta w_t + \lambda \mu_{t-3} + \beta \mu_{t-4} - \lambda\beta\mu_{t-7} + \rho \in_{t-4} \quad (8)$$

under the assumption of no threshold effect ($n = 0$), one threshold effect ($n = 1$), two threshold effect ($n = 2$) and three threshold effect ($n = 3$). The diagnostic results are found to be satisfactory at the 5 per cent level of significance. The optimization method selects the estimated model that minimizes the RMSE. From Table 4, it could be seen that the RMSE attained global minimum when n=2 in equation (8), that is at a two threshold point model, suggesting that the two threshold point model with $f(\pi^{*1}_{opt}) =$ 2.41591 and $f(\pi^{*2}_{opt})) =$ 2.48491 is selected to explain the growth-inflation nexus in Nigeria. The fact that the linear fixed effect model ($n = 0$) is not selected present a strong evidence in favor of the presence of at least one threshold point model.

Table 4: Model Selection for Dukker et al Method

No of Thresholds	RMSE	DW	Residual ARCH LM	Jarques Bera Test for White Noise
0	0.6881	1.826	0.185 (0.671)	2.504 (0.286)
1	0.5816	2.416	1.793 (0.192)	2.207 (0.332)
2	0.5759	2.181	4.065 (0.054)	1.913 (0.384)
3	0.6083	2.239	0.192 (0.665)	0.692 (0.707)

p-values are in bracket

Table 5: ML - ARCH (Marquardt) Coefficients of Non-Linear Regression Using Drukker, et al 's Method

Parameters	Estimate	Standard Error
α_1	0.723	1.303
γ_0	2.933[a]	0.517
γ_1	2.619[a]	0.417
γ_2	2.497[a]	0.385
θ	0.245[a]	0.052
λ	-0.559[a]	0.121
β	0.750[a]	0.053
ρ	-0.971[a]	0.021
$f(\pi_{opt}^{*1})$	2.41591	-
$f(\pi_{opt}^{*2})$	2.48491	-
$H_0: \Sigma_i \gamma_i = 0$	8.050[a]	0.768

a = significance at the 1 per cent level, b = Significance at the 5 per cent level, while c at the 10 per cent level

Inverting the semi-log transform produces the level threshold inflation estimates of 11.2 per cent and 12.0 per cent for the two threshold-point model.

The estimated parameters of this model are presented in Table 5. All the estimated parameters of equation (8) with $n = 2$, except the constant are statistically significant. Drukker *et al*. (2005) noted that although the thresholds and the semi-log transform of inflation complicates the computation of the marginal effect of inflation on long-run growth, the monetary theory literature generates at least an interesting hypothesis about the γ_k coefficients. The null hypothesis that money is super-neutral can be investigated by testing whether all the γ_k are zero, which is equivalent to testing that their sum add up to zero. From Table 5, it is clear that this hypothesis of the super- neutrality of money is rejected, suggesting that there is a threshold level of inflation above which money is not super-neutral.

Table 6: Threshold Estimates using Dukker et al Method

No of Thresholds	$f(\pi_{opt}^{*1})$	$f(\pi_{opt}^{*2})$	$f(\pi_{opt}^{*3})$	γ_0	γ_1	γ_2	γ_3
0	-	-	-	1.434[a] (0.365)	-	-	-
1	2.41591	-	-	3.112[a] (0.432)	2.646[a] (0.320)	-	-
2	2.41591	2.48491	-	2.933[a] (0.517)	2.619[a] (0.417)	2.497[a] (0.385)	-
3	2.41591	2.48491	2.56495	2.987[a] (0.281)	2.502[a] (0.237)	2.355[a] (0.195)	2.646[a] (0.199)

Parameter standard errors are in bracket
Superscript a = significance at 1 per cent level

Table 6 presents the estimates of the inflation thresholds and the γ_k $(k = 0, 1,2 \text{ } and \text{ } 3)$ coefficients for all the different models. The estimated coefficients are statistically different and decreasing in k, except γ_3 in the three threshold point model.

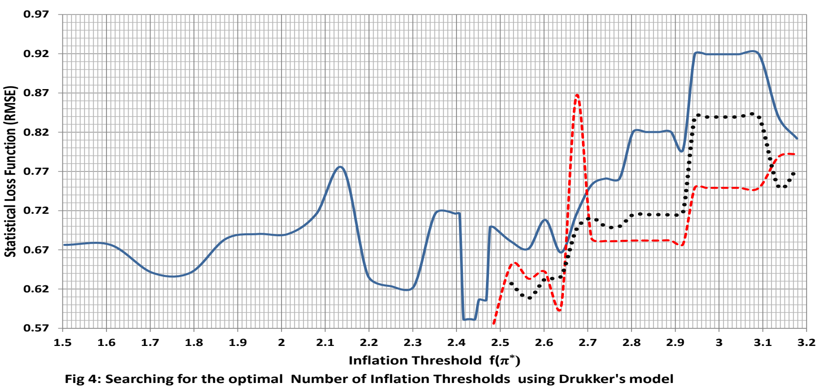

Fig 4: Searching for the optimal Number of Inflation Thresholds using Drukker's model

Fig 4 presents graphically the result of the optimization effort, under the assumption of one threshold effect (n=1), two threshold effect (n=2) and three threshold effect (n=3). It is very clear from the graph that the global RMSE minimum is achieved with the two threshold point model

7.0 Summary and Conclusion

This paper re-examines the issue of the inflation-growth nexus and empirically investigate the existence of any threshold level of inflation in Nigeria. Based on recent quarterly data spanning the period Q1:2005 to Q1:2012, the paper used three different models to ensure the robustness of the results. While studies of inflation-growth nexus estimate the threshold level of inflation using different control variables, this paper extends the specification of the models using the Autoregressive and Integrated Moving Average process with the quarterly growth in real world output as exogenous input. Because this specification exhibits some level of volatility, the GARCH methodology is used in estimating the parameters of the models.

With the use of the GARCH methodology to estimate the parameters of the models, it is assumed that the residuals would be identically and independently normally distributed with mean zero and constant variance. This supports earlier findings in the literature that the asymptotic distribution of all the estimated parameters has a normal distribution. The ARCH Residual LM test and the Jarques–Bera normality test on the residuals empirically confirmed this assumption. Under the various null hypothesis on the estimated parameters, parametric test were performed.

Salami and Kelikume (2010) estimated 8 per cent threshold point for Nigeria is not well identified by the data used. Though the two estimated parameters of the inflation and extra inflation were significant at the 1 and 10 per cent levels, respectively, the classical test for the existence of a threshold model, based on the sum of the two coefficients did not appear to be statistically significant. Bassey and Onwioduokit (2011) identified 18 per cent as a threshold point for Nigeria even though the threshold was not well identified by the data used. More recently Bawa and Abdullahi (2012) identified 13 per cent as an inflation threshold that is well identified by the data. The three threshold point model estimated in this paper establishes 13 per cent as the third threshold point model, but is outperformed by the chosen two threshold point model.

Although the empirical results presented in this paper identifies 9.9 per cent as a probable inflation threshold that is not fully identified by the data, the paper strongly suggests the existence of a one threshold point of 10.5 per cent that is well identified by the data. The results also suggest a two threshold-point model for Nigeria, with the two threshold points at 11.2 and 12 per cent beyond which inflation exerts a negative effect on growth. Also, the two threshold-point model suggests that there is a threshold level of inflation above which money is not super-neutral.

It should be noted that the concept of inflation threshold and inflation target are quite distinct. Inflation targeting is a monetary policy construct in which a central bank announces a target and then directs its policy tools in achieving the set target. Inflation threshold on the other hand, is a point of inflexion for the inflation-growth trade-off, where at some low levels, inflation may be positively correlated with growth, but at higher levels inflation is likely to be inimical to growth. While recommending that inflation threshold need not be necessarily the inflation target, the inflation objective for monetary policy should be set lower than the inflation threshold.

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