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NON-LINEARITIES, STRUCTURAL BREAKS AND FRACTIONAL INTEGRATION IN THE ANALYSIS OF THE GHANAIAN AND THE SOUTH AFRICAN CPI INFLATION RATES

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ABSTRACT

Keeping a low steady rate of inflation is one of the government's most important responsibilities. Inflation is an important determinant of economic growth. Consequently, it has been one of the most examined areas in economics, from both theoretical and empirical perspectives. Indeed, economists have shown continued interest in this essential economic variable. The most important question related to inflation is: Does non-linearity exist in inflation? The answer to this question, which has important policy implications, can support or endanger the validity of several important economic models. Hence, a clear understanding of the changing aspects of inflation is crucial to any economy because it is regarded as a significant variable in a number of economic models, whose legitimacy critically relies on whether or not this variable is stationary. In practice, many economic time series models rely on linearity. Nonetheless, it has often been found that simple linear time series models regularly leave certain aspects of economic and financial data inexplicable. This paper proposes a model that combines fractional integration with non-linear deterministic terms based on the Chebyshev polynomials in time for the analysis of CPI inflation rates of Ghana and South Africa in Sub-Saharan Africa. Firstly, we tested for non-linear deterministic terms in the context of fractional integration. The estimates of the differencing parameter, *d*, were found to be 1.11 and 1.32, respectively for the Ghanaian and the South African inflation rates, but the non-linear trends were found to be statistically insignificant in the two series. A linear model was then investigated and the results indicated that the order of integration for the Ghanaian inflation series was slightly above 1. However, for the case of South Africa, a cyclical $I(d)$ process was found to be more appropriate, with an order of integration below 1, thus showing mean reversion and a cyclical structure of approximately 80 periods (months) per cycle. The implication of these findings could assist in a decision-making process regarding adjusting monetary policy instruments such as inflation targeting (IT) or adopting different monetary policies, to achieve the desired target.

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Keywords: CPI inflation, Fractional integration, Chebyshev polynomial, Non-linear trends
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INTRODUCTION

Inflation is regarded as a significant variable in a number of economic models whose legitimacy critically relies on whether or not it is stationary. Therefore, an in-depth understanding of the changing aspects of inflation is crucial for the economy. Most economic time series models rely on linearity. However, it has often been found that simple linear time series models regularly leave certain aspects of economic and financial data inexplicable.

Non-linearity in inflation may reflect different speed of adjustment toward equilibrium or the level designated by policymakers. That is, as the deviation of the inflation rate from equilibrium or selected value increases, so does the speed of adjustment. For countries whose central banks tend to keep inflation within a target range, non-linearity in inflation may come from the response of monetary policy to inflation. As has been pointed out in Orphanides and Wieland (2000), when there are more objectives than just inflation stabilisation, central banks may concentrate on other objectives such as output stabilisation or low unemployment, as inflation may be near or within the target range.

This paper seeks to make a contribution to the existing literature on inflation studies by proposing a model with potential non-linear trends and structural breaks, where the errors are assumed to be fractionally integrated, $I(d)$. Most of the previous methods used in analysing non-linearities were based on the assumption of $I(0)$ of the error terms. Therefore, in this paper, the point of departure does not only lie in estimating non-linearities using the recently developed methodology by Cuestas and Gil-Alana (2016), but also on the assumption of the error term being fractionally integrated $I(d)$. This framework is applied to two Sub-Saharan African countries: Ghana and South Africa, which are countries with an Inflation Targeting (IT) policy.

The structure of the paper is as follows: Section 2 provides a review of the literature on non-linearity issues in the context of testing, modelling and estimation with $I(d)$ errors. Section 3 focuses on the materials, validation and application of the proposed research methodology in the framework of inflation. Discussion of the empirical results for Ghana and South Africa is presented in Section 4, while some concluding remarks and policy implications are presented in Section 5.

LITERATURE REVIEW

The properties of inflation rates have been extensively explored in the literature. A common feature that runs through most of the related research is the issue of the degree of persistence of shocks, which is related to the unending debate about the possible existence of unit roots in inflation. For instance, Ericsson and Irons (1994), Evans and Lewis (1995), Crowder and Hoffman (1996), Ericsson et al. (1998), Crowder and Wohar (1999), Hendry (2000), Rapach and Weber (2004), Lee (2005), and Russell and Banerjee (2008) have presented an argument that inflation contains a unit root, meaning that shocks to inflation are completely persistent. On the other hand, other researchers such as Rose (1988), Culver and Papell (1997), Papell and Prodan (2004), and Noriega and Ramos-Francia (2013) argue that inflation is a stationary variable, and therefore, suggest that the impact of shocks on such a variable is transitory.

A number of studies have also claimed that inflation is a fractionally integrated process, with a differencing parameter that is significantly different from zero and unity. For example, Backus and Zin (1993), found the US monthly inflation data to be fractionally integrated; Hassler (1993), and Delgado and Robinson (1994) provided evidence of long memory in the Swiss and Spanish inflation, in that order. Hassler and Wolters (1995), Baillie et al. (1996), and Baum et al. (1999) have also found inflation to be fractionally integrated. Nonetheless, the failure of such studies to consider the issue of structural breaks could impair their findings (Diebold and Inoue, 2001; Granger and Hyung, 2004). In recent times, non-linearities have also attracted interest among economic researchers. However, research in this area has provided contradicting or mixed results, depending on the methodology employed (see Granger and Teräsvirta, 1993; Potter, 1999; van Dijk et al., 2002).

To the best of our knowledge, this study is one of the few attempts to address the issue of non-linearities, structural breaks and fractional integration in the Ghanaian inflation rates. Nonetheless, in South Africa, Caporale et al. (2015) estimated a fractional integrated model with non-linear deterministic trends for the inflation rates in five countries including South Africa. Using a 2002-2013 inflation data span, their results indicated that non-linearities are present in the case of Angola and Lesotho, but not in Botswana, Namibia and South Africa. Currently, there has been an increase in research concerning the estimation of inflation persistence or long-range dependence in South Africa. Rangasamy (2009) employed the eminent univariate autoregressive (AR) equation to measure inflation persistence at an aggregate and disaggregate levels. The method is heavily dependent on the estimation of the AR terms where inflation is the dependent variable, set out in a regression equation which includes a constant term. The sum of the AR terms ρ, where, $\rho \in (0,1)$, determines the extent of persistence, so that if $\rho \geq 1$, then inflation contains unit root and is volatile. However if $\rho < 1$, then inflation is mean reverting. The researcher's results revealed a decline in inflation persistence after the adoption of IT policy in 2000, with respective estimates for before and after adoption of IT being 0.98 and 0.83, in that order.

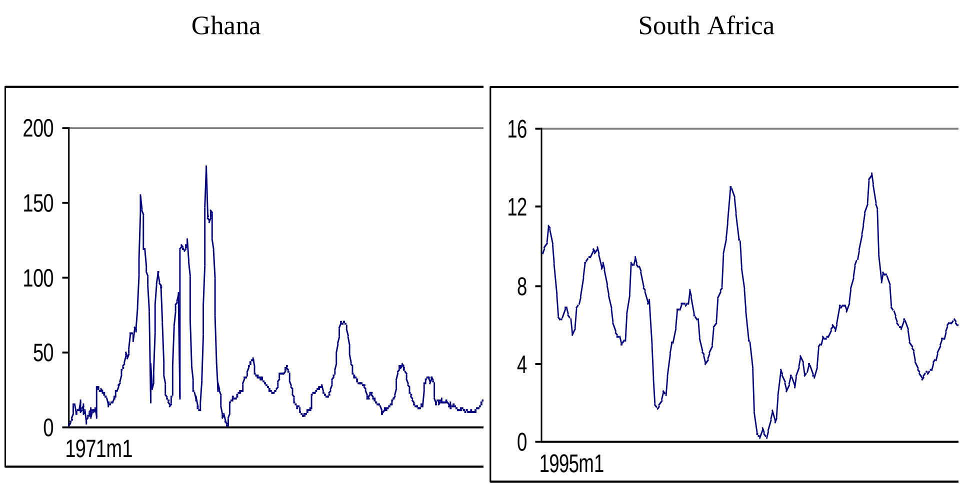
Balcilar et al. (2016) used a fractionally integrated model in the context of regime switching setup to investigate inflation persistence. The fractionally integrated model permits inflation persistence to be very long. In fact, the Markov-switching model estimates inflation persistence from a higher regime characterised by high inflation rates, to a lower regime characterised by low inflation rates. They concluded that inflation persistence is much stronger in high inflation episodes compared to low inflation episodes, while controlling for high inflation volatile rates. The results are similar to those of Rangasamy (2009). In another study, Burger and Marinkov (2008) obtained recursive estimates for inflation persistence before and after IT in South Africa. They demonstrated that inflation persistence has not decreased since IT (though mean reverting), but expressed concern about the South African Reserve Bank (SARB)'s ability to decrease inflation persistence at all with the new monetary policy regime. Nonetheless, they concluded that the SARB is able to anchor expectations.

In Ghana, not much has been done as far as estimation of inflation persistence is concerned. However, Boateng et al. (2016) examined the CPI inflation rates of Ghana from a different perspective, allowing for fractional degrees of differentiation using fractional integration and employing techniques based on Whittle parametric and semi-parametric methods and autoregressive fractionally integrated moving average (ARFIMA) models together with standard I(0)/I(1) methods. Their findings indicated the presence of long memory or persistence in CPI inflation rate of Ghana. Alagidede et al. (2014) examined the crucial issue of inflation persistence in Ghana in order to gain a better understanding regarding welfare and policy implications. Specifically, their study investigated the existence of persistence at both aggregate (national) and regional levels. Moreover, the study included investigation of persistence across 13 sectors, covering both core and headline inflation rates. Employing fractional integration methods, their study provided some important additions to the literature. Their results showed evidence suggesting i) asymmetries in the degrees of inflation persistence both regionally and sectorally; and ii) high potential for significantly different conclusions about inflation persistence, depending on whether month-on-month inflation or year-on-year inflation was being assessed.

MATERIALS AND METHODS

The series we considered in this section characterises the monthly Consumer Price Index (CPI) inflation rate of Ghana and South Africa, covering the period from January 1971 to October 2014 and from January 1995 to December 2014, respectively. The data were obtained from the Bank of Ghana and Statistics South Africa, for Ghana and South Africa, respectively.

FIGURE 1. THE BEHAVIOUR OF CPI INFLATION RATES OF GHANA AND SOUTH AFRICA



Source: Diagram produced from Gauss statistical software
Note: The data is obtained from Bank of Ghana and Statistics South Africa

We will start the empirical section by conducting a test for the potential presence of non-linearities in the context of fractional integration. In particular, we will assume a non-linear trend model based on the Chebyshev polynomials in time, where the errors are assumed to be $I(d)$.The specific model is

$$y_t = \sum_{i=0}^{m} \theta_i P_{iT}(t) + x_t, \qquad t = 1, 2, 3, \dots \quad (1)$$

where
y_t denotes the observed time series, m indicates the order of the Chebyshev polynomial. Suppose x_t is $I(d)$, such that:

$$(1-L)^d x_t = \mu_t \quad t = 1,2,3, \ldots \quad (2)$$

with $I(0)$, μ_t, which is a covariance stationary process with a spectral density function that is positive and finite at the long run or zero frequency, then the Chebyshev polynomials $\theta_i P_{iT}(t)$ in (1) are defined by:

$$P_{0,T}(t) = 1$$
$$P_{iT}(t) = \sqrt{2}\cos\left(\frac{i\pi(t-0.5)}{T}\right), \; T = 1,2, \ldots, T; I = 1,2, \ldots \quad (3)$$

(see Hamming, 1973; and Smyth, 1998, for a detailed description of these polynomials). If $m = 0$, the model contains an intercept; if $m = 1$, a linear trend is also included; and if $m > 1$, the model becomes non-linear. The higher the value of m, the less linear the approximated deterministic model (Caporale et al., 2015). Cuestas and Gil-Alana (2016) recommended a simple method that is basically a slight modification of Robinson (1994). They considered a setup in (1) and (2) testing the null hypothesis:

$$H_0: d = d_0 \quad (4)$$

for any real value d_0. Under H_0, and employing the two equations (1) and (2), we obtain:

$$y_t^* = \sum_{i=0}^{m} \theta_i P_{iT}^*(t) + x_t, \qquad t = 1,2, \ldots \quad (5)$$

where

$$y_t^* = (1-L)^{d_0} y_t P_{iT}^*(t) = (1-L)^{d_0} P_{iT}(t)$$

Given the linear structure of the relationship and the $I(0)$ nature of the error term x_t, the coefficients in (5) can be estimated by standard least square methods (OLS/GLS). For testing H_0 in equation (4), Cuestas and Gil-Alana (2016) proposed a Lagrange Multiplier (LM) in equations (1) and (2) that are asymptotically standard $N(0,1)$ distributed.

In the case of rejection of the non-linear hypothesis, linear methods will be adopted. Here we will consider a model of the form:

$$y_t = \beta_0 + \beta_1 t + x_t, \quad (1-L)^d x_t = \mu_t, \; t = 1,2, \ldots \quad (6)$$

where y_t refers to the inflation rate, β_0 and β_1 are the coefficients on the intercept and a linear trend respectively, and x_t is assumed to be an $I(d)$ process. Thus, μ_t is $I(0)$, and given the parametric nature of this method, its functional form must be specified. We consider two cases: uncorrelated errors (white noise) and autocorrelated ones. In the latter case we use the exponential spectral model of Bloomfield (1973).

Finally, based on the fact that the periodogram of the South African inflation rate displays its highest value at a non-zero frequency, we also consider an alternative long memory approach based on the model,

$$(1 - 2\cos w_r L + L^2)^d x_t = \mu_t, \; t = 1,2, \ldots \quad (7)$$

where w_r and d are real values, and μ_t is $I(0)$.

For practical purposes we define $w_r = \frac{2\pi r}{T}$, with $r = \frac{T}{c}$, where c indicates the number of time periods per cycle, while r stands for the frequency with a pole or singularity in the spectrum of x_t. Note that if $r = 0$, (or $c = 0$), the fractional polynomial in equation (7) becomes $(1 - L)^{2d}x_t$, which is the polynomial associated with the common case of fractional integration at the long run or zero frequency presented in equation (2) or equation (6).

DATA AND EMPIRICAL RESULTS

In this section, we firstly conducted the test proposed in Cuestas and Gil-Alana (2016) to test for fractional integration in the context of non-linear deterministic trends. The results are displayed in Table 1. We observe that the estimated values of d are 1.11 and 1.32, respectively for Ghanaian and South African inflation rates. Next, we focus on the estimated coefficients for the deterministic terms, and observe that they all remain statistically insignificant, leading to the rejection of the hypothesis of non-linearities in the two series examined. As a result, in Table 2, we assume a linear model given by equation (6).

TABLE 1. ESTIMATES OF d IN THE CONTEXT OF NON-LINEAR TRENDS

Est	d	θ_0	θ_1	θ_2	θ_3
Ghana	1.11 (1.04, 1.19)	-14.322 (-0.07)	16.431 (0.13)	-1.912 (-0.03)	-3.460 (-0.10)
South Africa	1.32 (1.21, 1.42)	9.087 (0.47)	-0.140 (-0.01)	4.423 (1.01)	-7.380 (-0.90)

Note: The values in parenthesis in the second column refer to the 95% confidence band. In the remaining columns they are t-values.

TABLE 2. ESTIMATES OF d WITH A LINEAR MODEL

Series/Cases	No regressors	An intercept	A linear time trend
	i) White noise errors		
Ghana	1,11 (1.05, 1.19)	1,11 (1.05, 1.19)	1,11 (1.05, 1.19)
South Africa	1,21 (1.11, 1.33)	1,45 (1.34, 1.59)	1,45 (1.34, 1.59)
	ii) Autocorrelated (Bloomfield) errors		
Ghana	1,22 (1.01, 1.45)	1,22 (1.01, 1.45)	1,22 (1.01, 1.45)
South Africa	1,10 (0.89, 1.40)	1,18 (0.96, 1.46)	1,18 (0.96, 1.46)

Note: The values in parenthesis refer to the 95% confidence bands.

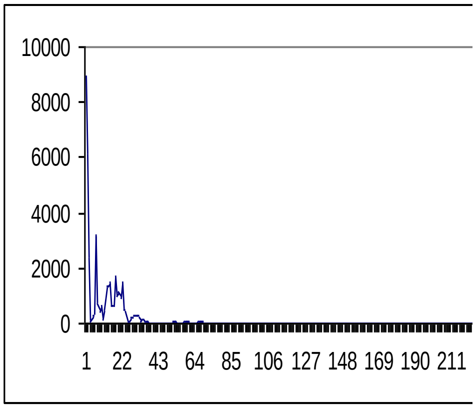
Table 2 displays the estimates of d in (6) for the three cases of (i) no regressors (i.e., $\beta_0 = \beta_1 = 0$ in (6)), (ii) an intercept ($\beta_0 = 0$ and β_1 unknown), and (iii) an intercept with a linear time trend (β_0 and $\beta_1$unknown). The three cases were considered under both uncorrelated (white noise) and autocorrelated (Bloomfield) errors (as shown in Table 2). The results indicate that the intercept is sufficient to describe the deterministic terms[2], and the estimated values of d are 1.11 and 1.45 for the Ghanaian and the South African inflation rates under white noise errors, and 1.22 and 1.18 respectively, under autocorrelated errors. In fact, the unit root hypothesis (i.e., $d = 1$) is rejected in favour of a higher order of integration for the Ghanaian inflation rate, while this hypothesis cannot be rejected for the South African inflation rate with the model of Bloomfield (1973).

[2]This is based on the t-values on the coefficients in the d −differenced processes (unreported).

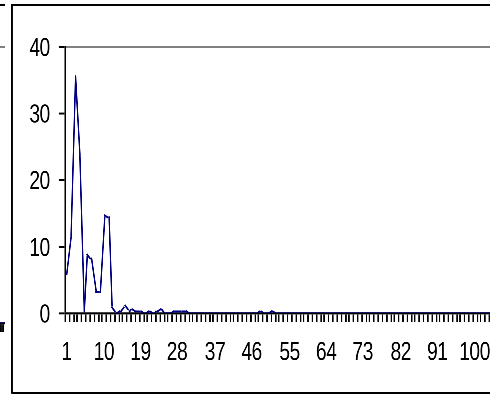
FIGURE 2. PERIODOGRAMS OF THE INFLATION RATES

All frequencies

Ghana

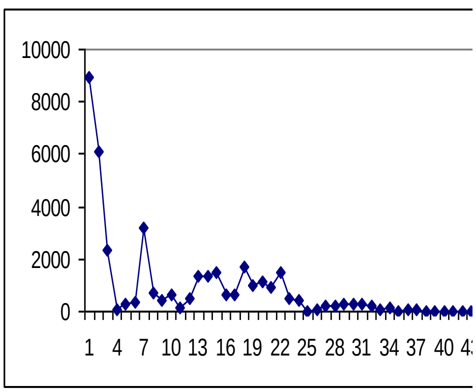


South Africa

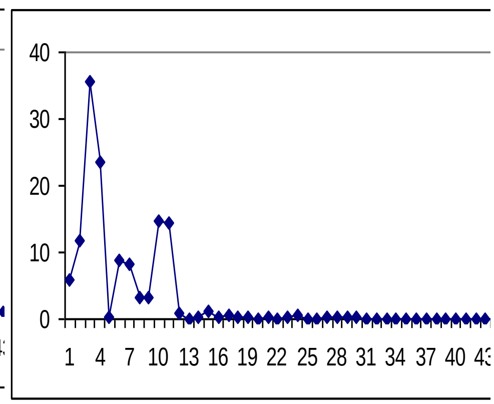


First 50 frequencies

Ghana



South Africa



Source: Diagram produced from Gauss statistical software
Note: The data is obtained from Bank of Ghana and Statistics South Africa

Figure 2 displays the periodogram of the two series. The periodogram is an asymptotically unbiased estimate of the spectral density function. Under the fractionally integrated specification in equation (2), we should expect the periodogram to display the highest value at the smallest (zero) frequency. This is precisely what we observe for the periodogram of the inflation rate of Ghana in Figure 2. However, for the South African rate, the highest value corresponds to a non-zero frequency, which is, in fact, the third frequency, corresponding to cycles of length $T/3$ which is 80 periods (months).

TABLE 3. ESTIMATE OF d IN THE CONTEXT OF CYCLICAL FRACTIONAL INTEGRATION

	r	Constant	d
SOUTH AFRICA	80	6.244 (17.65)	0.71 (0.64, 0.81)

Note: *The value in parenthesis in the third column is a t-value, while in the fourth it is the 95% confidence band.*

We, thus, try a non-zero cyclical fractional representation for this series, using the model in equation (6), but replacing the second part by equation (7). The results are reported in Table 3. As before, only an intercept is required to describe the deterministic part; r = 80 (as suggested by the periodogram) and the differencing parameter is found to be 0.71, implying non-stationarity, but mean reverting behaviour.

CONCLUSIONS

This paper explores and compares the persistency of inflation series of Ghana and South Africa, the only two countries in sub-Saharan Africa with Inflation Targeting (IT) policy. Persistency of inflation is defined as the time that it takes for an inflation shock to dispel. It is very imperative that central banks, which are responsible for stabilising inflation at low levels, fully appreciate the nature of this process. We proposed a fractional integration approach combined with linear and non-linear structures. We started by adopting the method suggested by Cuestas and Gil-Alana (2016) that allows for non-linear deterministic terms in the context of fractional integration. The results indicated that the two inflation series are highly persistent, with orders of integration which are above 1 in both series. However, the non-linear trends were found to be statistically insignificant in the two cases. Using a linear deterministic approach, both series seem to be well-described by means of an intercept, although for the South African inflation rate, a cyclical $I(d)$ model seems to be more adequate.

An economic substantiation for the existence of fractionally integrated behaviour in the data, coupled with a solid pragmatic evidence supporting this hypothesis, is provided. In agreement with previous research, there is evidence of a high persistence and non-mean reversion behaviour of the Ghanaian inflation series, hence shocks will, in general, have a permanent effect. The implication of this is that, monetary policymakers and government may consider enacting a new monetary policy or tightening the existing IT monetary policy, in order to steer inflation stability. Nonetheless, a mean reversion behaviour was found in the South African inflation series, but it was cyclical, taking about 80 periods (months) to revert to stability. This means that, overall, shocks will not have a permanent effect. Monetary authorities and governments may consider tightening the existing IT policy and also guard against creating uncertainties, especially from the political fronts, since the consequences of these will affect the behaviour of inflation rate, and the economy at large, negatively. Indeed, our measures of persistence allow us to establish cross-country comparisons, and it is deduced that significant differences arising between these two countries, may be related to the different monetary institutions governing each of them. These results, therefore, imply that the inflation structure of these two countries are different, being very persistent and non-mean reverting in the case of Ghana, and being highly cyclical and mean reverting in the case of South Africa. Further research should be conducted to confirm these results.

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