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IS THERE AN ASYMMETRIC BEHAVIOUR IN AFRICAN INFLATION? A NON-LINEAR APPROACH

Juan C. Cuestas
Sheffield University, Sheffield, UK

Luis A. Gil-Alana
University of Navarra, Pamplona, Spain

and

Estefania Mourelle
Universidad da Coruña, A Coruña, Spain

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ABSTRACT

In this paper we test the inflation persistence hypothesis as well as model the long run behaviour of inflation rates in a pool of African countries, using a non-linear framework. In order to do so, we rely on unit root tests applied to non-linear models and fractional integration. The results show that the hypothesis of inflation persistence does not hold empirically for most of the countries. In addition, the estimated models (logistic smooth transition autoregression, LSTAR) are stable in the sense that the variable tends to remain in the regime (low inflation or high inflation) once reached and changes between regimes are only achieved after a shock. The results also indicate that the effects of the shocks on inflation tend to die out; exogenous factors, i.e. supply shocks and inertia may be causing this outcome, as they play a substantial role in the determination of the inflation rates for our selected African countries.

JEL Classification: C32, E31, F15.
Key words: Inflation, persistence, unit roots, nonlinearities, STAR.

Corresponding author: Luis A. Gil-Alana
University of Navarra
Navarra Center for International Development
E-31080 Pamplona, Spain

Email: alana@unav.es

1. Introduction

Modelling the dynamics of inflation has become a hot topic during the last decades, in particular for industrialised countries. This is not surprising, given that price stability has become the main objective of the monetary authorities for a number of countries. Accordingly, the analysis of whether the inflation has a unit root, i.e. persistence hypothesis, or is stationary (i.e. with transitory shocks) has several implications. From a theoretical viewpoint this is important provided that stationarity is assumed in a number of theoretical models (Dornbusch, 1976; Taylor, 1979, 1980; Calvo, 1983; etc.). In addition, it is important for policy purposes, given that monetary authorities assume that inflation is stationary, as is the growth of the monetary base -the main instrument of monetary policy, when taking policy decisions (Taylor, 1985; McCallum, 1988). However, although the empirical literature on inflation persistence is quite vast for developed countries (see Baum et al., 1999; and Kumar and Okimoto, 2007, for a literature review), the topic has been less researched in developing economies.

Regarding the relationship between economic growth and inflation persistence, the effect may be, a priori, negative. There are two possible channels, through welfare (Briault, 1995) and through the direct impact of inflation on economic growth (Faria and Carneiro, 2001). In the former, there is a distributive effect of wealth from creditors to debtors. Further, inflation persistence may lead to higher inflation and uncertainty, which could affect consumption, saving/borrowing/investment decisions, and distortions on price formation (Friedman, 1977). In addition, De Gregorio (1993) claims that, capital flights, pessimism in the decision-taking process and delays in investment, are the main fundamental links between inflation and economic growth, through capital accumulation. The direct effect of inflation on economic growth, may have important economic and policy implications; provided that inflation may potentially affect economic performance negatively, then monetary authorities should implement an inflation target.

In this paper we aim to investigate the inflation persistence hypothesis in a group of African countries, including Burkina Faso, Cameroon, Egypt, Ethiopia, Gambia, Ghana, Ivory Coast, Kenya, Madagascar, Mauritius, Morocco, Niger, Nigeria, Senegal, Seychelles, South Africa, Sudan and Swaziland[1]. The reason for choosing African countries is two-fold. First, the literature on the inflation persistence in Africa is quite

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[1] From our pool of countries, only South Africa and Ghana have established an inflation target. The former started pursuing a 3-6% inflation target in 2000, whereas the latter only set a 0-10% in 2007.

scarce, in particular using non-linear techniques;[2] and second, the results we obtain could help policy makers on the design of the inflation policy to promote economic growth.

For this purpose we employ unit root methods along with other techniques based on fractional integration. On the other hand, we look for evidence of asymmetries in the evolution of these inflation rates and, in the affirmative, we model non-linear components. As aforementioned, an assessment of the dynamic properties of inflation could be of further help when aiming at promoting economic growth.

In recent contributions, such as Arango and González (2001), Gregoriou and Kontonikas (2009) and Byers and Peel (2000) among others, non-linear models for the inflation dynamics have gained some popularity. There are several reasons why non-linear modelling may be superior to linear models to understand the behaviour of inflation rates. First, it might be sensible to think that the speed of adjustment towards the equilibrium after a shock is asymmetric. That is, the further the inflation rate deviates from the equilibrium or inflation target, the higher will be the efforts of the government to control it and, therefore, the speed of reversion of the variable (Gregoriou and Kontonikas, 2006). This implies the existence of a threshold for the inflation rate within which the monetary authority may not apply any particular policy, not only when inflation targets are set in terms of a threshold of values, but also when the costs of applying monetary policy offset the benefits of its application (see Orphanides and Wieland's, 2000, model). Second, according to the seminal paper of Sargent and Wallace (1973) among others, inflation may behave as a non-linear process with multiple equilibria[3].

The above mentioned sources of non-linearities can be captured through smooth transition autoregressive (STAR) models (Byers and Peel, 2000). In general, smooth transitions are preferred to other alternatives because, among other reasons, their flexibility captures a wide range of non-linear behaviours; they allow for the variable to smoothly vary between regimes; there exists a well-defined modelling cycle in the literature; and standard non-linear inference techniques can be used. Granger and Teräsvirta (1993), Teräsvirta (1994, 1998) and van Dijk et al. (2002) discuss these models at length.

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[2] In a recent contribution, Coleman (2008a), by means of fractional integration tests, finds evidence of inflation persistence in the franc zone countries

[3] Arango and Melo (2006) also justify the use of STAR models for macroeconomic variables based upon the assumption of asymmetries in business cycles.

Furthermore, ample evidence on the good performance of STARs reflecting asymmetric behaviour can be found in the empirical literature; see, for instance, the works on several aggregate macroeconomic variables (Teräsvirta and Anderson, 1992; Skalin and Teräsvirta, 1999, 2002; and Öcal and Osborn, 2000), exchange rates (Taylor and Peel, 2000; and Cuestas and Mourelle, 2010) or inflation with strong fluctuations (Arango and González, 2001).

The paper is organised as follows. The next section summarises the tests that have been applied to test the inflation persistence hypothesis. Section 3 explains the estimation procedure in order to model inflation in the selected countries. Section 4 presents the results. The main conclusions are drawn in the last section.

2. Testing for the inflation persistence hypothesis

In order to test for the persistence in inflation in our pool of African countries, we apply two types of unit root tests, i.e. Ng and Perron (2001) and Kapetanios et al. (2003). Fractionally integrated or I(d) methods will also be employed.

According to Ng and Perron (2001), traditional unit root techniques based on linear models might suffer from two issues. First, they may tend to over accept the null hypothesis -have power problems- when the autoregressive parameter is near to unity and, second, when the errors of a moving average process are close to -1, information criteria tend to select a lag length not high enough to avoid power problems. In order to avoid these problems, Ng and Perron (2001) propose a Modified Information Criterion (MIC) that controls for the sample size. Further, Ng and Perron (2001) propose a Generalised Least Squares (GLS) detrending method to overcome the power problem associated with the traditional unit root tests. Thus, Ng and Perron (2001) obtain the following unit root tests: MZ_α and MZ_t that are the modified versions of the Phillips (1987) and Phillips and Perron (1988) Z_α and Z_t tests; the MSB that is related to the Bhargava's (1986) R_1 test; and, finally, the MP_T test that is a modified version of the Elliot et al. (1996) point optimal test.

On the other hand, the unit root tests just described are all based on autoregresssive alternatives. That is, in its simplest form we can consider the AR(1) specification,

$$y_t = \mu + \rho y_{t-1} + \varepsilon_t, \qquad (1)$$

and the unit root corresponds to the null:

$$H_o : \rho = 1. \tag{2}$$

Alternatively, we can consider a fractional setting,

$$(1 - L)^d y_t = \mu + \varepsilon_t, \tag{3}$$

and the unit root null is now described by:

$$H_o : d = 1. \tag{4}$$

AR and fractional departures from (2) and (4) have very different long run implications. In (3), y_t is nonstationary but non-explosive for all $d \geq 0.5$ and through 1, y_t can be viewed as becoming “more nonstationary”, but it does so gradually, unlike in case of (1) around (2). The dramatic long run change in (1) around $\rho = 1$ has the attractive implication that rejection of (2) can be interpreted as evidence of either stationarity or explosivity. However, rejection of the null does not necessarily warrant acceptance of any particular alternative. On the other hand, fractional tests against (4) can be regarded as a useful diagnostic tool to supplement tests directed against AR alternatives.

In the empirical application carried out in Section 4 we implement a testing procedure developed by Robinson (1994) for testing unit roots and other fractionally integrated hypotheses of form as in (3). Alternatively we could have employed the well known semiparametric method of Geweke and Porter-Hudak (1983). This approach, however, has been found to have very low power if the process displays short run (ARMA) dynamics, and, though there exist recent improvements of this approach (see, Robinson, 1995; Velasco, 1999; Shimotsu and Phillips, 2002, Kim and Phillips, 2006, etc.) these methods require the choice of the bandwidth number along with other user-chosen parameters and the results are usually very sensitive to these parameters. The same happens with the non-parametric approaches (Lo, 1991, Giraitis et al., 2003; etc.) where the estimates are extremely sensitive to the choice of the bandwidth numbers.

In addition, many economic variables, and in particular inflation rates, may present asymmetric speed of mean reversion. This implies the existence of two regimes, i.e. in the inner regime the variable behaves as a unit root process, whereas in the outer regime the variable reverts to the equilibrium value. Controlling for this source of non-linearity is interesting when dealing with the inflation rate, since policy makers may decide not to react when the inflation is within range of certain values, given that the costs of any policy decision may overwhelm the benefits. However, when the inflation rate is outside a given threshold, the monetary authority might intervene in the markets in order to return the inflation rate to a more sensible value.

Non-linearites and the order of integration of inflation rates become, therefore, a key point to understand the degree of persistence of inflation.[4] Thus, Henry and Shields (2004) applied the Caner and Hansen's (2001) unit root test, which takes into account the analysis of the order of integration of the variables in the threshold autoregression (TAR) framework, for the US, Japanese and UK inflation. Their results are supportive of the partial unit root hypothesis, implying that shocks have permanent effect in one regime, but have finite lives in the other one. However, the Caner and Hansen's (2001) unit root test assumes that the shifts between regimes are sudden instead of smooth.

Kapetanios et al. (2003) develop a unit root test in order to take into account non-linear adjustment of variables towards equilibrium, assuming that the transition between regimes is smooth rather than sudden. According to the authors, the reason for applying the latter is that linear unit root tests might suffer from lack of power in the presence of non-linearities in the dynamics of the variables and, hence, may not be able to distinguish between a unit root and a non-linear I(0) process. Accordingly, this test analyses nonstationarity under the null hypothesis against non-linear but globally stationary exponential smooth transition autoregressive (ESTAR hereafter) processes under the alternative, i.e.

$$y_t = \beta y_{t-1} + \phi y_{t-1} F(\theta; y_{t-1}) + \varepsilon_t, \qquad (5)$$

where $\varepsilon_t : iid(0, \sigma^2)$ and $F(\theta; y_{t-1})$ is the transition function, which is assumed to be exponential,

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[4] On the other hand, fractional integration and non-linearities are issues which are intimately related (see, e.g., Diebold and Inoue, 2001; Davidson and Teräsvirta, 2002; Shao and Wu, 2007; Caporale and Gil-Alana, 2008; etc.).

$$F(\theta; y_{t-1}) = 1 - \exp\{-\theta y_{t-1}^2\}, \qquad \theta > 0 \quad (6)$$

In practice, it is common to reparameterise equation (5) as

$$\Delta y_t = \alpha y_{t-1} + \gamma y_{t-1}\left(1 - \exp\{-\theta y_{t-1}^2\}\right) + \varepsilon_t \quad (7)$$

in order to apply the test. The idea behind this technique is to test whether the variable is a unit root process in the outer regime, assuming that it is a unit root in the inner regime by imposing $\alpha = 0$. However, the issue with equation (7) is that in order to test the null hypothesis $H_0 : \theta = 0$ against $H_1 : \theta > 0$ in the outer regime[5], the coefficient γ cannot be identified under H_0. In order to overcome this problem, KSS propose a Taylor approximation of the ESTAR model, i.e.

$$\Delta y_t = \delta y_{t-1}^3 + error\ term \quad (8)$$

Now, it is possible to apply a standard t-statistic[6] to test whether y_t is a I(1) process, $H_0 : \delta = 0$, or is a stationary process, $H_1 : \delta < 0$. Note that equation (8) may include lags of the dependent variables to control for autocorrelation, whose selection can be done using standard procedures.

In recent contributions, Cuestas and Harrison (2010), and Gregoriou and Kontonikas (2006) find evidence of stationarity of inflation rates applying Kapetanios et al. (2003) unit root test for a number of countries, which highlights the importance of taking into account the possibility of asymmetric speed of adjustment towards the equilibrium when testing for the order of integration of inflation.

3. Modelling non-linearities

3.1 The STAR model

Smooth transition (ST) models are a special class of state-dependent, non-linear time series models, where the variable is assumed to vary between two extreme regimes and

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[5] Note that the process is globally stationary provided that $-2 < \phi < 0$.

[6] The test does not follow the t-Student distribution. Kapetanios et al. (2003) provides critical values, obtained by Monte Carlo simulations.

the smoothness of the transition is estimated from the data. The dependent variable is given by a linear combination of predetermined variables plus a random disturbance, where each coefficient is a function of a state variable. Such a parameterisation permits a variety of dynamic behaviour; at the same time, once the state is given, the model is locally linear.

This paper focusses on the basic univariate version of ST models, the smooth transition autoregression (STAR), where all predetermined variables are lags of the dependent variable and regimes are endogenously determined. Let y_t a stationary, ergodic process. The STAR model of order *p* is defined as:

$$y_t = \pi_0 + \sum_{i=1}^{p} \pi_i y_{t-i} + F(y_{t-s}) \left[\theta_0 + \sum_{i=1}^{p} \theta_i y_{t-i} \right] + u_t \qquad (9)$$

where $F(y_{t-s})$ is a transition function that satisfies $0 \leq F \leq 1$, *s* is the transition lag and u_t is an error process, $u_t \rightarrow Niid\left(0, \sigma^2\right)$. STARs are usually interpreted as consisting of two extreme regimes, corresponding to F=0 (with π_i coefficients, i=1,...,p) and F=1 (with $\pi_i + \theta_i$ coefficients, i=1,...,p), and a continuum of intermediate situations.

The transition from one regime to the other is smooth over time, meaning that the parameters in (9) gradually change with the state variable. The transition variable, y_{t-s}, and the associated value of $F(y_{t-s})$ determine the regime at each t. The features of the transition function are a key issue for understanding non-linearities, especially the fact of having an even or odd $F(y_{t-s})$. The logistic function usually represents the odd case:

$$F(y_{t-s}) = \frac{1}{1 + \exp\left[-\gamma\left(y_{t-s} - c\right)\right]} \quad , \qquad \gamma > 0 . \qquad (10)$$

The resulting model is the logistic STAR (LSTAR), where $F(-\infty) = 0$ and $F(\infty) = 1$. The slope parameter determines the smoothness of the transition from one extreme regime to the other, so that the higher it is, the more rapid the change; in case $\gamma = 0$, the STAR specification nests the linear model. The location parameter *c* indicates the threshold between the two regimes; in the logistic case, $F(c) = 0.5$, so the regimes are associated with low and high values of y_{t-s} relative to *c*.

The exponential function is employed for the even case

$$F(y_{t-s}) = 1 - \exp\left[-\gamma(y_{t-s} - c)^2\right] \quad , \qquad (11)$$

and provides the exponential STAR or ESTAR model. This specification implies F(c)=0 and F(±∞)=1 for some finite *c*, defining the inner and the outer regime, respectively. In addition, should $\gamma \rightarrow 0$ or $\gamma \rightarrow \infty$, the ESTAR model collapses into the linear autoregression.

The type of (regime-switching) behaviour is quite different depending on the specification considered. In the logistic model the two extreme regimes correspond to y_{t-s} values far above or below *c*, where dynamics may be different; the exponential model suggests rather similar dynamics in the extreme regimes, related to low and high y_{t-s} absolute values, while it can be different in the transition period.

3.2 Modelling approach

Traditionally, the STAR modelling cycle has relied on developing the iterative methodology proposed by Teräsvirta (1994). It is based on that of Box and Jenkins (1970) and involves three stages; search for specification, estimation and evaluation of the model. There exists a well-established STAR modelling procedure in the literature (see Granger and Teräsvirta, 1993; and Teräsvirta, 1994).

The starting point consists of finding out the linear model that characterises the behaviour of the series under study. Once this specification is obtained, it is tested whether the data display the kind of behaviour generated by STARs. This stage is centred on the selection of the appropriate transition lag and the form of the transition function. In the next step, the parameters of the ST autoregression are estimated by non-linear least squares.

However, most recent empirical works do not follow this strategy in such a strict manner. It is argued that it is possible to develop valid non-linear formulations that improve the fit of the linear ones without having to do the previous tests. This is done by means of an extensive search of STAR models through a grid for the combination (γ, c, s) and by paying more attention to their evaluation; any possible inadequacy of the models is expected to be unveiled at the validation stage (see Potter, 1999; Öcal and Osborn, 2000; van Dijk et al., 2002; Skalin and Teräsvirta, 1999; and Sensier et al., 2002, among others).

After estimating the STAR model, it is necessary to evaluate its properties in order to verify if it satisfactorily explains the behaviour of the variable. Most tests commonly used in dynamic models are valid in STAR models. Besides, Eitrheim and Teräsvirta (1996) have especially derived three evaluation tests for smooth transitions.

Finally, we develop a structural analysis of the non-linear model; it is based on computing the roots of the characteristic polynomials associated to the STAR model, which provide with information to understand its dynamic properties. Unit and explosive roots deserve special attention, as the model may be globally stationary but locally unstable (see Teräsvirta and Anderson, 1992; Skalin and Teräsvirta, 1999; and Öcal and Osborn, 2000). Specifically, in a logistic specification the model is nonstationary if it contains a positive real root with modulus equal or greater than one; the reason is that positive real roots lead to monotonic behaviour, whereas negative real and complex ones generate oscillations and the series as a whole can be stationary if the oscillations are important enough to drive the series out of the nonstationary state.

4. Empirical results

4.1 The data

The data for this empirical analysis consists of monthly inter-annual CPI-based inflation rates for a number of African countries: Burkina Faso, Cameroon, Egypt, Ethiopia, Gambia, Ghana, Ivory Coast, Kenya, Madagascar, Mauritius, Morocco, Niger, Nigeria, Senegal, Seychelles, South Africa, Sudan and Swaziland, from 1969m1 until 2008m2, except for Seychelles whose sample starts in 1976m6 and Gambia and Swaziland whose series ends in 2006m9 and 2007m4, respectively. The data have been obtained from the *International Financial Statistics* database of the *International Monetary Fund*.

Figure 1 displays the graphs of the series of inflation. The first feature to highlight about the inflation rates of these countries is that most of these countries have suffered from high inflation periods. Also, Figure 1 shows that inflation rates undergo continuous oscillations, moving from situations of huge inflation to more moderate ones and vice versa. However, these high inflation periods can be considered as moderate compared with some Latin American countries. Secondly, the path of the inflation rates of these countries is somewhat volatile. This may be due to the frequent socio-political turmoils at which most of these countries have been subject to, as well as interventions in the markets.

The sources of inflation may vary depending on the country. For instance, the Central Bank of West African countries devaluated Burkina Faso, Ivory Coast, Niger, Senegal's currencies in 1994 against the French Franc. Likewise, the currency of Cameroon was devalued at the end of 1993. These measures could increase quite considerably the prices of imported products, raising hence, the inflation rates in those periods. Further, Jeong et al. (2002) provide evidence that domestic inflation in a number of African countries is attributable to inflation shocks originating in neighbouring countries. This explains the apparent high degree of correlation among the inflation rates of these countries. Furthermore, Coleman (2008b) finds certain degree of real exchange rate undervaluation, which might have pushed up the inflation rates. Finally, two recent contributions, Barnichon and Peiris (2007) and Jumah and Kunst (2007), provide evidence of the strong and positive relationship between inflation and money gap and output gap in Sub-Saharan countries, in the former, and cocoa prices in West African countries, in the latter. All these events may generate non-linear behaviour in the inflation rates of these countries, which should be taken into account when modelling the dynamics of the variable.

4.2 Unit root testing

In Table 1 we display the results of the Ng and Perron (2001) and KSS unit root tests. It is worth noticing that in most cases these two tests provide similar conclusions. However, there are a few exceptions, such as those of Egypt, Seychelles and Sudan, where we cannot reject the null hypothesis with the Ng and Perron (2001) test, but we do reject it with the KSS, and for Morocco, where the opposite applies, i.e. we cannot reject the null hypothesis of unit root with the KSS test, but we do reject it with the Ng and Perron (2001) test. To sum up, it is possible to reject the null hypothesis in favour of stationarity in all the cases except for Kenya and South Africa. In the latter, although an inflation target was set from 2000 onwards, the inflation rate appears to be nonstationary for the whole period. This latter result is compatible with Rangasamy (2009) result on South Africa’s measurement of inflation persistence, since this author finds a high degree of persistence.

[Table 1 near here]

The unit root tests results have important implications about the behaviour of inflation rates, as stated in the introduction. Accordingly, our results point to lack of inflation persistence for most of the countries.

However, the above methodology focuses exclusively on the I(0)/I(1) specifications, and do not consider fractional differencing as an alternative plausible way to describe the time dependence in the data. Thus, in what follows we consider the following model,

$$y_t \;=\; \mu \;+\; \beta t \;+\; x_t; \qquad (1 - L)^d x_t \;=\; u_t, \qquad\qquad (12)$$

where u_t is supposed to be I(0) described as a white noise or as a weakly autocorrelated (e.g. ARMA) process.

In Table 2 we estimate the fractional differencing parameter *d* in equation (12) under the assumption that the error term is white noise. We use the Whittle function in the frequency domain (Dahlhaus, 1989), also presenting the 95% confidence band of the non-rejection values of d using Robinson's (1994) parametric approach. We consider the three standard cases examined in the literature, i.e., the case of no regressors (i.e., $\alpha = \beta = 0$ a priori in (12)), an intercept (i.e., α unknown and $\beta = 0$ a priori), and an intercept with a linear time trend (α and β unknown). The first thing we observe in this table is that the estimates of *d* are very similar for the three specifications of the deterministic terms, though they substantially vary from one series to another. Thus, we observe five series with estimates below 1 and with the unit root null hypothesis being rejected in favour of mean reversion (i.e., $d < 1$). These series are those corresponding to Swaziland, Egypt, Burkina Faso, Seychelles and Ivory Coast. There is another group of five countries where the unit root cannot be rejected at the 5% level: Niger, Sudan, Senegal, South Africa and Ethiopia. For the remaining eight countries (Cameroon, Gambia, Ghana, Kenya, Madagascar, Mauritius, Morocco and Nigeria), the estimated values of *d* are found to be strictly higher than 1 in all cases.

[Tables 2 and 3 near here]

However, the significance of the above results might be due in large part to unaccounted-for I(0) autocorrelation in u_t. Thus, in Table 3, we display the estimates of *d* under the assumption of weak autocorrelation for the error term. Here, we employ a non-parametric approach due to Bloomfield (1973). This method produces autocorrelations decaying exponentially as in the ARMA case. In this approach, the spectral density function is given by:

$$f(\lambda;\tau) \;=\; \frac{\sigma^2}{2\pi}\; \exp\left(2\sum_{r=1}^{m}\tau_r\cos(\lambda r)\right), \qquad (13)$$

where *m* is the number of parameters required to describe the short run dynamics of the series. Bloomfield (1973) showed that the logarithm of an estimated spectral density function is often found to be a fairly well-behaved function and can thus be approximated by a truncated Fourier series. He showed that the spectral density of an ARMA process can be well approximated by (13). Moreover, this model is stationary across all values of τ, and the model accommodates extremely well in the context of fractionally integrated models.[7] Using this model, the results are displayed in Table 3.

The values are generally smaller than in the previous case of white noise disturbances. We observe six series that display mean reversion ($d < 1$): Burkina Faso, Ivory Coast, Egypt, Morocco, Niger and Swaziland. There are eight countries which present values of *d* below 1 but where the unit root cannot be rejected (Cameroon, Ethiopia, Gambia, Madagascar, Mauritius, Senegal, Seychelles and Sudan). Finally, for South Africa, Kenya, Ghana and Nigeria, the unit root is rejected in favour of higher orders of integration.

The results in this section indicate that the series are highly persistent in most of the cases, with values close to or in the unit circle in many cases. This apparent contradiction with respect to the unit root tests previously computed suggest that non-linear structures may be present in the data.

4.3 Estimated STAR models

The first step in detecting non-linearities in the evolution of African inflation rates is to determine the linear specifications for the eighteen countries under study. An ordinary least squares estimation is carried out, where the number of lags is selected in the usual manner in the non-linear literature, using the Akaike information criterion (AIC) (see Granger and Teräsvirta, 1993; Teräsvirta, 1994; Öcal and Osborn, 2000; van Dijk et al., 2002, for example). The lag order *p* ranges from 1 to 12.[8]

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[7] The model of Bloomfield has been used in the context of fractional integration by Velasco and Robinson (2000), Gil-Alana (2004) among many others.

[8] To save space, these models are not reported but they are available from the authors upon request.

Although several authors demonstrate that conclusions from linearity tests are not a tool for guiding the modelling process, it is commonplace to compute such tests; in doing so, we follow the so-called unconditional approach. This strategy assumes that the transition variable is the linear combination $\sum_{i=1}^{p} \upsilon_i z_{t-i}$, where $\upsilon'=(0 \ldots 1 \ldots 0)'$ is a selection vector with the only unit element corresponding to the unknown transition lag (Teräsvirta, 1998). The tests for a linear characterisation of inflation rates against LSTAR and ESTAR representations have been computed for the value of *p* selected with AIC and *d* varying from 1 to *p*. Table 4 displays a summary of p-values of the linearity tests in their F version. The figures indicate that the hypothesis of a linear behaviour of inflation rates against a LSTAR specification is rejected in all countries at a 5% significance level except for Morocco and Nigeria, where we can reject the null at a 10% significance level; regarding the exponential alternative, the null hypothesis is always rejected.

[Tables 4 and 5 near here]

The next step is to specify and estimate STARs for the eighteen inflation series. Following the traditional methodology (Teräsvirta and Anderson, 1992; Granger and Teräsvirta, 1993; Teräsvirta, 1994), we determine the delay parameter *s* and choose the most appropriate model type, logistic or exponential. To select *s*, we vary it ranging from 1 to *p,* and the value minimizing the p-value of his linearity test is chosen; at times, the value of *s* chosen under the LSTAR alternative is different from the one under the ESTAR, so that the final value is determined when selecting the model type. After this stage, the choice between logistic and exponential STAR models is based on a sequence of three ordinary F tests. For shake of brevity, we only indicate the decision rule for selecting the model and refer the reader to Teräsvirta (1994) for further details on this procedure. Should the p-value of the F-statistic of the second test be the lowest, the model to choose is the ESTAR; otherwise, the selected model is logistic.

Table 5 reports the results of the previous tests. It is observed that in most countries the selected function is logistic; in some cases the ESTAR model is chosen by slight margin. This is an extremely sensible result given our series. The LSTAR model assumes that shocks may have asymmetric effects on the variable, i.e. the effects of negative shocks may be different from the effects of positive ones on the variable; the economic interpretation is that a LSTAR specification can generate two regimes with different dynamics for the inflation rates, one for their high values and another for the low ones.

The ESTAR model would be adequate if local dynamics were similar at both the large and small values of the transition variable, and different in the middle, which is not the case of inflation rates. In addition, according to Lütkepohl and Krätzig (2004), the ESTAR specification has the drawback of mimicing a linear one when the slope parameter γ is high and the extreme values of the variable are rather separated; *a priori*, these circumstances seem quite feasible in our series, given their continuous oscillations.

In short, both the specific statistical procedures and the intrinsic features of the series point to the logistic model as the most appropriate for reflecting the potential non-linear evolution of African inflation rates. Hence, we only consider the logistic alternative in the estimation stage. It is appreciated that the role of the specification techniques in our paper is more that of being a tool to guide the research than strictly apply their results.

As it was previously argued, the estimation process follows the most recent empirical literature. Model building is based on an extensive grid search; all the combinations of p and s are defined, trying for different values of γ and considering a value for c close to the sample mean of the transition variable. This strategy necessarily generates a great number of LSTAR specifications.

LSTAR models are estimated by non-linear least squares. Following the recommendations of Teräsvirta (1994), the argument of the logistic transition function is scaled by dividing it by the standard deviation of the dependent variable, in order to overcome some usual problems in the estimation. In those countries where parameter convergence is attained[9], the models presenting the best statistical properties are selected for further refinement. First, non-significant coefficients are dropped to conserve degrees of freedom and then, we simplify this first set of estimations through cross-parameter restrictions so as to increase efficiency; the limit t-value for these coefficients is 1.6.

Table 6 reports the final selected models in full detail. Following the results of the Ng and Perron (2001) and KSS unit root tests, all processes are I(0) except for

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[9] It is not possible to obtain adequate LSTARs that describe the evolution of the inflation rates in Senegal, Sudan and Egypt; this is due to either convergence problems in the estimation or to getting unsatisfactory models.

Kenya and South Africa, so in these two countries the variable is the inflation rate growth (inflation in first differences). Inflation rates (and their growth) display remarkable dependence on their own history in most African countries. Strictly speaking, this dependence refers to concrete and repeated periods in time. The estimated location parameter defines the two extreme regimes; as it is close to the sample means of the inflation rates in most countries (where it is not, *c* is greater than the mean, except for Cameroon), the lower regime is given by negative or low to moderate inflation rates and the upper regime, by high inflation values (three digits in some countries).

[Table 6 about here]

The values of γ indicate rapid transitions between the extreme regimes in almost all countries; the change is even abrupt in some of them, so that the corresponding STAR model mimics a threshold (SETAR) model. These results are the expected ones, according to the already discussed evolution of African inflation rates. Exogenous factors may play a more important role than domestic demand in determining inflation, leading to the observed sudden changes in its values.

LSTAR models are validated by means of misspecification tests and by paying particular attention to the features of their transition functions. Regarding the former, we consider the test of no autoregressive conditional heteroskedasticity (ARCH) with one lag and the three tests proposed by Eitrheim and Teräsvirta (1996): the test of residual serial independence against processes of different orders, although just the corresponding to order 8 is shown (AUTO); the test of no remaining non-linearity in the residuals, computed for several values of the transition lag under the alternative but only the one minimizing the p-value of the tests is displayed (NL); the test of parameter constancy that allows for monotonically changing parameters under the alternative (PC). The following diagnostic statistics are also reported: the residual standard error (s), the adjusted determination coefficient ($\bar{R}^2$) and the variance ratio of the residuals from the non-linear model and the best linear specification (s^2/s^2_L).

The estimated models present no evidence of misspecification in general. In few countries, some tests do not offer satisfactory results, like the ARCH one or one of the Eitrheim and Teräsvirta's (1996) tests. However, the evaluation procedure as a whole points to the expected behaviour of the estimated models. As a result, LSTAR models seem adequate to describe the evolution of African inflation rates (and their growth).

Two points are highlighted. First, according to the variance ratio, the estimated non-linear models explain 3%-22% of the residual variance of the best linear autoregression in all fifteen countries. Second, in order to describe the behaviour of the LSTAR models more in depth, the validation stage is completed with the examination of the estimated residuals. The results are not reported to save space, but they are available from the authors upon request; the conclusion is that LSTAR models globally lessen the largest residuals of the linear specifications. The key point is that these divergences between residuals are particularly striking in outstanding phases of the African economies along the sample, i.e., the devaluation process carried out by the Central Bank of West African countries in 1994, severe droughts (Ethiopia 1984, 1991; Kenya 1992; or Ghana 1982-1983, for example), the coffee boom in 1993 in Kenya, or the drop in uranium revenues in 1981 in Niger (the last two are country-specific sources of inflation). In short, we count on a sign of better behaviour of the non-linear models, a fact that is supported by the variance ratios.

In order to better characterise the variable within each country and possibly find common facts, we study the local dynamic properties of the LSTAR models. Conditional on the regime, the models are locally linear and the dynamics can be interpreted through the roots of the characteristic polynomials. To summarise local dynamics, we consider the two extreme values of the transition function, $F = 0$ and $F = 1$, and compute the roots of the resulting polynomial. Table 7 reports the main results; to save space, only the dominant root is shown, that is, the root with the highest modulus that determines the long-run behaviour of the series within each regime.

[Table 7 near here]

In almost all countries the estimated LSTAR models are always stable. As long as the inflation rate (and its growth) remains within the lower or the upper regime, the variable tends to remain there. In our sample, the lower regime spans negative to moderate values of inflation, while the upper regime corresponds to high inflation rates or hyperinflation phases. An exogenous shock is needed to push the inflation from one extreme regime to the other. Cameroon, Niger, Nigeria, Kenya and South Africa are the only countries presenting locally unstable but globally stationary models.

Cameroon presents an explosive root in the lower regime, so that inflation evolves quickly towards the upper regime (rates greater than 0.44%), where it tends to remain unless an exogenous shock occurred. The opposite situation takes place in the remaining countries; stability is found in the lower regime, but inflation will not remain indefinitely in this state. For Niger and Nigeria, once the transition variable is above 30.69% and 53.96%, respectively, the model becomes locally unstable and is dominated by an explosive root that sends inflation back to moderate rate. In the cases of Kenya and South Africa, variations in inflation rates exceeding 2.73% and 0.84%, respectively, involve local instability.

4.4 Economic implications

The above statistical results point out to several important economic insights. First, the extreme regimes are very well defined in the vast majority of the countries, in the sense that they contain a large number of observations; in other words, these countries can be in a low as well as in a high inflation phase, where they remain for a given period of time. However, in those countries with few observations in one of the extreme regimes, e.g. Cameroon, Niger, Nigeria and South Africa (in the first case there is almost no lower regime strictly speaking), the model shows local instability and inflation would take low to moderate values.[10]

Therefore, we appreciate how African countries coexist, in an intermittent way, with low and large inflation stages, passing abruptly from one to the other. Our results also suggest that countries where extreme values for inflation are seldom observed do not stay in this phase for long and go back to the other regime. The underlying explanation to this behaviour may be that African inflation is especially affected by exogenous shocks, which cause a sudden impact on it, as the ability of the internal forces of the economy to control prices is quite limited (Jeong et al., 2002). Second, in the literature, demand pressures (output gap) and monetary and fiscal policies have been suggested as major factors in determining inflation in African countries (see Barnichon and Peiris, 2007; and Jumah and Kunst, 2007), but we pinpoint the role that supply shocks (movements in exchange rates, variations in oil prices in international markets, social and political conflicts, droughts, etcetera) and inertia play in the evolution of domestic prices, as a differential fact from what is usual in developed countries.

In addition, exchange rate variations of African currencies come out as a relevant source of inflation. The oscillating evolution of the exchange rate in these countries, even containing structural changes, will steadily push up or down domestic prices. Domestic inflation in Africa is also influenced by innovations coming from other countries or international events (for instance, the oil crisis in the seventies, see figure

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[10] As pointed put by one anonymous referee, differences in this analysis on a country by country basis, are mainly related to different economic structures, different degree of development, and, most importantly, different degrees of political stability, which conditionates the evolution of their inflation rates.

1), but geographical proximity does not seem to be a deciding transmission factor of inflation. The case of Ivory Coast is an exception for being one of the leader inflation producers in Africa; its effects are clearly observed in neighbouring countries like Ghana, Cameroon or Senegal.

Finally, expectations are usually not well-anchored in these countries, so there might be uncertainty in the way economic agents incorporate the new prices after a shock; the results we have obtained confirm this point. This inertia is mainly due to poor credibility on central banks and politics. It is worth mentioning that price stability has become the main objective for some African central banks, like those of South Africa and Ghana, which have recently adopted an inflation-targeting framework.

5. Conclusions

Inflation is still a source of severe problems in many developing countries and high levels of inflation disrupt steady growth and lead to missallocation of resources through distortions in relative prices. Aimed at contributing to the empirical literature on inflation persistence in developing economies, this paper analyses the evolution of inflation in a group of African countries, by means of non-linear (regime-dependent) models.

The persistence analysis points to lack of persistence patterns in most of the countries under study, implying that shocks tend to dissipate their effects along time, i.e. shocks only have temporary effects. In addition, the inflation rate tends to remain in its current regime (low or high inflation) as long as no exogenous shocks occurred. This conclusion has important insights; monetary policy decisions to reduce inflation might have the desired effect if they are applied with the correct magnitude and as the variable is globally stationary, the effects should last until another shock pushes inflation to the upper (high inflation) regime. These models could then be used as a means to forecast the future behaviour of the inflation rates of these countries, so monetary authorities may be able to anticipate changes in regime, and apply policy decisions to keep inflation rates under control. Hence, although we are providing with univariate models, they could serve, jointly with other indicators.

As further research, we propose to include exogenous macroeconomic indicators which might help us to better explain the future behaviour of African inflation rates, such as exchange rates, external deficit, GDP, etc., on account of not being within the scope of the present paper to apply multivariate analysis.

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Table 1: Ng-Perron and KSS unit root test results

Country	MZ_a	MZ_t	MSB	MP_T	$\hat{t}_{NL}$	$\hat{t}_{NLD}$
B. Faso	-37.6768**	-4.34028**	0.11520**	0.65038**	-2.89679*	-2.83387*
Cameron	-8.10112**	-1.99369**	0.24610**	3.09837**	-2.46385**	-2.40880
Egypt	-3.70277	-1.29645	0.35013	6.65062	-2.14086*	-3.00063*
Ethiopia	-9.66018**	-2.03173**	0.21032**	3.18293**	-3.33837**	-3.50028**
Gambia	-9.56014**	-2.16786**	0.22676**	2.63713**	-2.43822**	-2.75373**
Ghana	-6.31252*	-1.77621*	0.28138	3.88248*	-4.07465**	-5.06459**
Ivory Coast	-14.9918**	-2.70834**	0.18066**	1.74900**	-1.96605**	-1.99264
Kenya	-3.85244	-1.26919	0.32945	6.46202	-1.99522*	-1.86977
Madagascar	-6.93430*	-1.85832*	0.26799*	3.54691*	-1.99754*	-1.91247
Mauritius	-7.81919*	-1.95802*	0.25041*	3.20795*	-3.54197*	-3.94045*
Morocco	-7.36445*	-1.91737*	0.26035*	3.33267*	-1.61313	-2.15850
Niger	-18.9213**	-3.06796**	0.16214**	1.32388**	-2.82085**	-2.99555**
Nigeria	-8.59416*	-2.0729 *	0.24120*	2.85088*	-2.05404*	-2.40386
Senegal	-20.6729*	-3.21503*	0.15552*	1.18513**	-2.60929**	-2.72865*
Seychelles	-4.02173	-1.02293	0.25435	6.52005	-3.87539**	-4.09288**
South Africa	-1.16415	-0.67769	0.58213	18.0789	-1.22845	-1.63503
Sudan	-4.01824	-1.41541	0.35225	6.09973	-2.75137**	-3.55871**
Swatziland	-11.7627**	-2.41301**	0.20514**	2.13181**	-3.62084**	-5.86949**

Note: The order of lag to compute the tests has been chosen using the modified AIC (MAIC) suggested by Ng and Perron (2001). The Ng-Perron tests include an intercept, whereas the KSS test has been applied to the raw data, $\hat{t}_{NL}$ say, and to the demeaned data, $\hat{t}_{NLD}$ say. The symbols * and ** mean rejection of the null hypothesis of unit root at the 10% and 5% respectively. The critical values for the Ng-Perron tests have been taken from Ng and Perron (ngperron01), whereas those for the KSS have been obtained by Monte Carlo simulations with 50,000 replications:

Sig. level	MZ_{α}	MZ_t	MSB	MP_T	$\hat{t}_{NL}$	$\hat{t}_{NLD}$
5%	-8.100	-1.980	0.233	3.170	-2.210	-2.921
10%	-5.700	-1.620	0.275	4.450	-1.917	-2.648

Table 2: Estimates of d based on white noise disturbances****

Country	No regressors	Constant	Constan and trend
B. Faso	0.799 (0.730, 0.878)	0.794 (0.725, 0.874)	0.794 (0.725, 0.874)
Cameroon	1.073 (1.004, 1.156)	1.073 (1.004, 1.156)	1.073 (1.004, 1.156)
Coast Ivory	0.898 (0.833, 0.975)	0.902 (0.836, 0.980)	0.902 (0.836, 0.980)
Egypt	0.788 (0.726, 0.862)	0.781 (0.720, 0.856)	0.782 (0.721, 0.857)
Ethiopia	1.049 (0.983, 1.126)	1.050 (0.984, 1.128)	1.050 (0.984, 1.128)
Gambia	1.099 (1.033, 1.177)	1.102 (1.036, 1.180)	1.102 (1.036, 1.180)
Ghana	1.396 (1.316, 1.488)	1.397 (1.317, 1.489)	1.397 (1.317, 1.489)
Kenya	1.123 (1.061, 1.195)	1.123 (1.061, 1.195)	1.123 (1.061, 1.195)
Madagascar	1.170 (1.096, 1.261)	1.170 (1.096, 1.261)	1.170 (1.096, 1.261)
Mauritania	1.220 (1.147, 1.316)	1.229 (1.147, 1.317)	1.229 (1.147, 1.317)
Morocco	1.166 (1.077, 1.288)	1.170 (1.080, 1.299)	1.169 (1.080, 1.299)
Nigeria	1.189 (1.130, 1.262)	1.190 (1.129, 1.261)	1.190 (1.129, 1.261)
Niger	0.925 (0.850, 1.006)	0.919 (0.845, 1.001)	0.919 (0.845, 1.001)
South Africa	1.041 (0.969, 1.111)	1.034 (0.966, 1.106)	1.034 (0.966, 1.106)
Senegal	0.968 (0.903, 1.046)	0.969 (0.903, 1.047)	0.969 (0.903, 1.047)
Seychelles	0.801 (0.743, 0.869)	0.799 (0.736, 0.872)	0.801 (0.738, 0.873)
Sudan	0.948 (0.890, 1.022)	0.947 (0.889, 1.020)	0.947 (0.889, 1.020)
Swatziland	0.723 (0.664, 0.794)	0.719 (0.659, 0.791)	0.720 (0.660, 0.791)

Note: 95% cofidence intervals are reported in parenthesis

Table 3: Estimates of d based on Bloomfield-Type disturbances

Country	No regressors	Constant	Constant and trend
B. Faso	0.759 (0.597 0.954)	0.746 (0.584, 0.933)	0.746 (0.583, 0.933)
Cameroon	0.967 (0.820, 1.145)	0.967 (0.820, 1.145)	0.967 (0.820, 1.145)
Coast Ivory	0.839 (0.707, 0.981)	0.821 (0.702, 0.978)	0.821 (0.702, 0.978)
Egypt	0.759 (0.657, 0.910)	0.760 (0.649, 0.904)	0.761 (0.652, 0.905)
Ethiopia	0.996 (0.849, 1.158)	0.997 (0.850, 1.158)	0.997 (0.851, 1.158)
Gambia	1.062 (0.916, 1.238)	1.064 (0.919, 1.241)	1.064 (0.919, 1.241)
Ghana	1.223 (1.033, 1.458)	1.224 (1.034, 1.459)	1.224 (1.034, 1.459)
Kenya	1.203 (1.047, 1.376)	1.203 (1.048, 1.377)	1.203 (1.048, 1.376)
Madagascar	0.898 (0.787, 1.034)	0.898 (0.788, 1.034)	0.898 (0.788, 1.034)
Mauritania	0.990 (0.863, 1.145)	0.991 (0.864, 1.148)	0.991 (0.864, 1.148)
Morocco	0.748 (0.650, 0.874)	0.746 (0.640, 0.874)	0.746 (0.638, 0.874)
Nigeria	1.241 (1.097, 1.400)	1.241 (1.097, 1.400)	1.241 (1.097, 1.400)
Niger	0.816 (0.704, 0.948)	0.815 (0.702, 0.954)	0.815 (0.702, 0.955)
South Africa	1.062 (0.944, 1.214)	1.049 (0.915, 1.210)	1.049 (0.923, 1.210)
Senegal	0.968 (0.831, 1.146)	0.969 (0.831, 1.148)	0.969 (0.831, 1.148)
Seychelles	0.903 (0.765, 1.066)	0.907 (0.760, 1.073)	0.908 (0.760, 1.073)
Sudan	0.970 (0.851, 1.131)	0.969 (0.850, 1.128)	0.969 (0.850, 1.128)
Swatziland	0.723 (0.601, 0.876)	0.719 (0.596, 0.873)	0.720 (0.598, 0.873)

Note: 95% confidence intervals are reported in parenthesis

Table 4: Linearity tests against smooth transition autoregressions (p-values)

Country \ Alternative	Logistic	Exponential
Burkina Faso	0.00000	0.00000
Cameroon	0.00000	0.00000
Egypt	0.00000	0.00000
Ethiopia	0.01995	0.00020
Gambia	0.00000	0.00000
Ghana	0.00000	0.00000
Ivory Coast	0.00000	0.00000
Kenya	0.00000	0.00000
Madagascar	0.00000	0.00000
Mauritius	0.00000	0.00000
Morocco	0.06982	0.00014
Niger	0.00015	0.00000
Nigeria	0.05386	0.01007
Senegal	0.00000	0.00000
Seychelles	0.00000	0.00000
South Africa	0.00005	0.00000
Sudan	0.00000	0.00000
Swaziland	0.02094	0.00000

Table 5: Selection of the STAR model (p-values)

Country \ Test		Test 1	Test 2	Test 3	Type of model
	Selected s				
Burkina Faso	3	0.00014505	0.00006674	0.00000015	LSTAR
	2	0.00856581	0.00000000	0.00000049	ESTAR
Cameroon	1	0.00352293	0.00007813	0.00000000	LSTAR
	10	0.00000325	0.00000009	0.00000000	LSTAR
Ethiopia	12	0.65479162	0.17931616	0.00942136	LSTAR
	9	0.02073356	0.02266712	0.02272209	LSTAR
Gambia	1	0.03613561	0.00001923	0.00000000	LSTAR
	4	0.00966759	0.00000000	0.00000026	ESTAR
Ghana	12	0.02384183	0.00031748	0.00000609	LSTAR
	1	0.00041027	0.00000000	0.01093720	ESTAR
Ivory Coast	1	0.00415542	0.11194982	0.00003049	LSTAR
	8	0.00189104	0.00000274	0.00058170	ESTAR
Kenya	4	0.02277378	0.00031378	0.00000001	LSTAR
	12	0.31319892	0.00000311	0.00000022	LSTAR
Madagascar	1	0.42865518	0.03829365	0.00007182	LSTAR
Morocco	1	0.75829481	0.00056089	0.00014238	LSTAR
Mauritius	12	0.00053740	0.00000001	0.00000000	LSTAR
Niger	1	0.33441889	0.00000330	0.00000373	ESTAR
	4	0.48195009	0.00000000	0.00091150	ESTAR
Nigeria	6	0.04564419	0.54952453	0.03373846	LSTAR
	4	0.00774914	0.17767220	0.05515887	LSTAR
Seychelles	12	0.06053522	0.00033123	0.00997878	ESTAR
	1	0.00419251	0.00000005	0.21993916	ESTAR
South Africa	1	0.14967000	0.00176815	0.00308283	ESTAR
	11	0.11553637	0.00000083	0.64843927	ESTAR
Swaziland	12	0.00016282	0.02351455	0.00094747	LSTAR
	1	0.36877410	0.00000001	0.10756692	ESTAR

Note: Regarding the selection of *s*, we do not present the p-values corresponding to all the linearity tests carried out for each potential value of *s* in order to save space and to focus the attention on the determination of the model type; the detailed results are available from the authors upon request. When two values of *s* are reported, the first one corresponds to the linearity test against the logistic alternative and the second one, to the exponential specification.

Table 6: Estimated LSTAR models for inflation rates

BURKINA FASO

$$\begin{aligned}
&y_t = \underset{(0.29)}{0.63} + \underset{(0.05)}{0.92} y_{t-1} + \underset{(0.05)}{0.10} y_{t-2} - \underset{(0.05)}{0.08} y_{t-4} + \underset{(0.05)}{0.23} y_{t-5} - \underset{(0.09)}{0.32} y_{t-6} - \underset{(0.08)}{0.11} y_{t-7} + \\
&\underset{(0.06)}{0.26} y_{t-9} - \underset{(0.03)}{0.18} y_{t-10} + \Big(\underset{(1.00)}{1.88} - \underset{(0.06)}{0.31} y_{t-1} + \underset{(0.10)}{0.29} y_{t-6} + \underset{(0.08)}{0.11} y_{t-7} - \underset{(0.06)}{0.26} y_{t-9}\Big) \times \\
&\Big[1 + exp\Big\{-\underset{(24.14)}{17.36} \times 0.11 \Big(y_{t-6} - \underset{(0.74)}{7.63}\Big)\Big\}\Big]^{-1} + u_t
\end{aligned}$$

s=4.33; $\bar{R}^2 = 0.76$; $s^2/s_L^2 = 0.92$; ARCH=64.88 (0.00); AUTO=1.59 (0.13); NL=1.59 (0.08); PC=0.74 (0.80)

CAMEROON

$$\begin{aligned}
&y_t = -\underset{(3.13)}{3.39} + \underset{(0.21)}{1.50} y_{t-1} - \underset{(0.38)}{0.85} y_{t-2} + \underset{(0.39)}{0.62} y_{t-3} - \underset{(0.33)}{0.54} y_{t-4} + \underset{(0.28)}{0.62} y_{t-5} - \underset{(0.04)}{0.05} y_{t-7} - \\
&\underset{(0.32)}{0.54} y_{t-9} + \underset{(0.43)}{0.66} y_{t-10} - \underset{(0.77)}{1.64} y_{t-11} + \Big(\underset{(3.78)}{7.31} - \underset{(0.22)}{0.67} y_{t-1} + \underset{(0.38)}{0.85} y_{t-2} - \underset{(0.39)}{0.62} y_{t-3} + \\
&\underset{(0.33)}{0.54} y_{t-4} - \underset{(0.28)}{0.62} y_{t-5} + \underset{(0.34)}{0.70} y_{t-9} - \underset{(0.46)}{0.79} y_{t-10} + \underset{(0.77)}{1.53} y_{t-11}\Big) \times \Big[1 + exp\Big\{-\underset{(0.70)}{2.43} \times \\
&0.13 \Big(y_{t-11} - \underset{(2.38)}{0.44}\Big)\Big\}\Big]^{-1} + u_t
\end{aligned}$$

s=2.11; $\bar{R}^2 = 0.92$; $s^2/s_L^2 = 0.81$; ARCH=27.50 (0.00); AUTO=1.03 (0.41); NL=1.19 (0.28); PC=1.17 (0.26)

ETHIOPIA

$$\begin{aligned}
&y_t = \underset{(0.21)}{0.89} + \underset{(0.03)}{0.95} y_{t-1} + \underset{(0.05)}{0.10} y_{t-4} - \underset{(0.05)}{0.07} y_{t-5} - \underset{(0.05)}{0.12} y_{t-8} + \underset{(0.07)}{0.25} y_{t-9} - \underset{(0.07)}{0.13} y_{t-10} - \\
&\underset{(0.05)}{0.12} y_{t-11} + \Big(\underset{(1.60)}{1.94} - \underset{(0.09)}{0.11} y_{t-1} + \underset{(0.13)}{0.36} y_{t-3} - \underset{(0.18)}{0.76} y_{t-4} + \underset{(0.18)}{0.24} y_{t-5} - \underset{(0.17)}{0.20} y_{t-6} + \\
&\underset{(0.14)}{0.33} y_{t-7} - \underset{(0.07)}{0.25} y_{t-9} + \underset{(0.07)}{0.13} y_{t-10} + \underset{(0.05)}{0.12} y_{t-11}\Big) \times \Big[1 + exp\Big\{-\underset{(96.41)}{30.15} \times 0.10 \Big(y_{t-10} - \\
&\underset{(0.49)}{22.09}\Big)\Big\}\Big]^{-1} + u_t
\end{aligned}$$

s=3.15; $\bar{R}^2 = 0.90$; $s^2/s_L^2 = 0.91$; ARCH=6.21 (0.01); AUTO=2.06 (0.04); NL=1.18 (0.28); PC=0.73 (0.82)

GAMBIA

$$\begin{aligned}
&y_t = \underset{(0.29)}{0.45} + \underset{(0.05)}{0.89} y_{t-1} + \underset{(0.06)}{0.13} y_{t-3} - \underset{(0.14)}{0.22} y_{t-5} + \underset{(0.10)}{0.10} y_{t-6} + \Big(\underset{(0.90)}{1.57} + \underset{(0.09)}{0.33} y_{t-1} - \\
&\underset{(0.10)}{0.22} y_{t-2} - \underset{(0.09)}{0.37} y_{t-4} + \underset{(0.18)}{0.75} y_{t-5} - \underset{(0.13)}{0.48} y_{t-6}\Big) \times \Big[1 + exp\Big\{-\underset{(2.11)}{3.62} \times 0.09 \Big(y_{t-5} - \\
&\underset{(2.16)}{12.95}\Big)\Big\}\Big]^{-1} + u_t
\end{aligned}$$

s=2.60; $\bar{R}^2 = 0.94$; $s^2/s_L^2 = 0.94$; ARCH=9.74 (0.00); AUTO=1.04 (0.40); NL=2.38 (0.02); PC=1.07 (0.38)

GHANA

$$\begin{gathered}y_t = \underset{(0.69)}{2.04} + \underset{(0.11)}{0.51} y_{t-1} + \underset{(0.10)}{0.25} y_{t-2} + \underset{(0.07)}{0.14} y_{t-4} + \underset{(0.05)}{0.11} y_{t-5} - \underset{(0.03)}{0.08} y_{t-10} + \Big(-\underset{(0.94)}{0.28} + \\ \underset{(0.13)}{1.01} y_{t-1} - \underset{(0.14)}{0.62} y_{t-2} - \underset{(0.09)}{0.15} y_{t-3} - \underset{(0.09)}{0.26} y_{t-4} + \underset{(0.02)}{0.05} y_{t-12} \Big) \times \Big[1 + exp \Big\{ -\underset{(171.22)}{103.98} \times \\ 0.03 \left(y_{t-11} - \underset{(0.44)}{14.87} \right) \Big\} \Big]^{-1} + u_t\end{gathered}$$

s=5.63; $\bar{R}^2 = 0.97$; $s^2/s_L^2 = 0.78$; ARCH=41.26 (0.00); AUTO=0.55 (0.82); NL=1.58 (0.06); PC=1.52 (0.05)

IVORY COAST

$$\begin{gathered}y_t = \underset{(0.27)}{0.34} + \underset{(0.05)}{0.90} y_{t-1} - \underset{(0.11)}{0.20} y_{t-2} + \underset{(0.12)}{0.24} y_{t-3} - \underset{(0.10)}{0.25} y_{t-4} + \underset{(0.09)}{0.09} y_{t-6} + \underset{(0.07)}{0.12} y_{t-8} + \\ \Big(\underset{(0.47)}{0.39} + \underset{(0.11)}{0.28} y_{t-2} - \underset{(0.12)}{0.24} y_{t-3} + \underset{(0.11)}{0.25} y_{t-4} - \underset{(0.09)}{0.09} y_{t-6} - \underset{(0.08)}{0.19} y_{t-8} \Big) \times \\ \Big[1 + exp \Big\{ -\underset{(153.08)}{58.38} \times 0.13 \left(y_{t-1} - \underset{(0.45)}{4.74} \right) \Big\} \Big]^{-1} + u_t\end{gathered}$$

s=2.66; $\bar{R}^2 = 0.87$; $s^2/s_L^2 = 0.97$; ARCH=4.86 (0.03); AUTO=1.35 (0.22); NL=1.62 (0.10); PC=1.21 (0.25)

KENYA

$$\begin{gathered}\Delta y_t = \underset{(0.10)}{0.13} + \underset{(0.04)}{0.05} \Delta y_{t-1} + \underset{(0.04)}{0.19} \Delta y_{t-2} - \underset{(0.04)}{0.13} \Delta y_{t-4} + \underset{(0.04)}{0.11} \Delta y_{t-6} + \underset{(0.05)}{0.10} \Delta y_{t-8} + \\ \underset{(0.04)}{0.07} \Delta y_{t-10} + \underset{(0.04)}{0.10} \Delta y_{t-11} - \underset{(0.04)}{0.51} \Delta y_{t-12} - \Big(-\underset{(1.14)}{2.95} + \underset{(0.15)}{0.37} \Delta y_{t-1} + \underset{(0.13)}{0.33} \Delta y_{t-3} + \\ \underset{(0.04)}{0.13} \Delta y_{t-4} - \underset{(0.13)}{0.38} \Delta y_{t-5} - \underset{(0.04)}{0.11} \Delta y_{t-6} + \underset{(0.19)}{0.51} \Delta y_{t-8} - \underset{(0.14)}{0.20} \Delta y_{t-9} - \underset{(0.18)}{0.48} \Delta y_{t-10} \Big) \times \\ \Big[1 + exp \Big\{ -\underset{(8.18)}{9.74} \times 0.43 \left(\Delta y_{t-8} - \underset{(0.26)}{2.73} \right) \Big\} \Big]^{-1} + u_t\end{gathered}$$

s=1.84; $\bar{R}^2 = 0.38$; $s^2/s_L^2 = 0.86$; ARCH=0.15 (0.70); AUTO=0.31 (0.96); NL=1.63 (0.06); PC=1.57 (0.04)

MADAGASCAR

$$\begin{gathered}y_t = \underset{(0.24)}{1.03} + \underset{(0.05)}{1.27} y_{t-1} - \underset{(0.07)}{0.39} y_{t-2} + \underset{(0.06)}{0.14} y_{t-3} - \underset{(0.04)}{0.06} y_{t-5} - \underset{(0.02)}{0.04} y_{t-10} + \\ \Big(-\underset{(2.96)}{1.01} - \underset{(0.09)}{0.42} y_{t-1} + \underset{(0.10)}{0.37} y_{t-3} + \underset{(0.08)}{0.13} y_{t-6} + \underset{(0.08)}{0.12} y_{t-8} + \underset{(0.11)}{0.22} y_{t-10} - \underset{(0.09)}{0.43} y_{t-11} \Big) \times \\ \Big[1 + exp \Big\{ -\underset{(73.14)}{63.40} \times 0.09 \left(y_{t-9} - \underset{(0.24)}{35.81} \right) \Big\} \Big]^{-1} + u_t\end{gathered}$$

s=2.63; $\bar{R}^2 = 0.95$; $s^2/s_L^2 = 0.92$; ARCH=5.97 (0.01); AUTO=1.17 (0.32); NL=1.17 (0.28); PC=1.45 (0.08)

MAURITIUS

$$\begin{gathered}y_t = \underset{(0.19)}{0.37} + \underset{(0.05)}{1.31} y_{t-1} - \underset{(0.05)}{0.27} y_{t-2} - \underset{(0.02)}{0.09} y_{t-8} + \Big(\underset{(1.70)}{3.21} - \underset{(0.05)}{0.25} y_{t-1} + \underset{(0.09)}{0.21} y_{t-4} - \\ \underset{(0.10)}{0.17} y_{t-5} + \underset{(0.08)}{0.17} y_{t-7} - \underset{(0.02)}{0.09} y_{t-8} \Big) \times \Big[1 + exp \Big\{ -\underset{(1.86)}{2.63} \times 0.12 \left(y_{t-7} - \underset{(3.16)}{19.41} \right) \Big\} \Big]^{-1} + u_t\end{gathered}$$

s=1.81; $\bar{R}^2 = 0.95$; $s^2/s_L^2 = 0.97$; ARCH=3.76 (0.05); AUTO=2.76 (0.00); NL=1.55 (0.09); PC=1.62 (0.05)

MOROCCO

$$y_t = \underset{(0.12)}{0.26} + \underset{(0.05)}{1.24}y_{t-1} - \underset{(0.07)}{0.49}y_{t-2} + \underset{(0.09)}{0.24}y_{t-3} - \underset{(0.10)}{0.20}y_{t-4} + \underset{(0.10)}{0.17}y_{t-5} - \underset{(0.07)}{0.08}y_{t-6} + \underset{(0.03)}{0.04}y_{t-9} + \Big(\underset{(0.41)}{1.47} + \underset{(0.06)}{0.09}y_{t-1} - \underset{(0.12)}{0.40}y_{t-3} + \underset{(0.17)}{0.63}y_{t-4} - \underset{(0.16)}{0.53}y_{t-5} + \underset{(0.11)}{0.30}y_{t-6} - \underset{(0.05)}{0.19}y_{t-9}\Big) \times \left[1 + exp\left\{-\underset{(9.91)}{11.78} \times 0.23\left(y_{t-3} - \underset{(0.36)}{7.01}\right)\right\}\right]^{-1} + u_t$$

s=1.00; $\bar{R}^2 = 0.95$; $s^2/s_L^2 = 0.95$; ARCH=0.06 (0.80); AUTO=0.91 (0.50); NL=0.84 (0.59); PC=1.63 (0.04)

NIGER

$$y_t = \underset{(0.19)}{0.41} + \underset{(0.05)}{0.97}y_{t-1} - \underset{(0.06)}{0.10}y_{t-2} + \underset{(0.05)}{0.16}y_{t-4} - \underset{(0.06)}{0.11}y_{t-5} + \underset{(0.05)}{0.09}y_{t-6} - \underset{(0.05)}{0.09}y_{t-8} + \underset{(0.06)}{0.14}y_{t-9} - \underset{(0.04)}{0.14}y_{t-10} - \Big(\underset{(10.81)}{22.43} - \underset{(0.18)}{1.02}y_{t-1} + \underset{(0.47)}{1.06}y_{t-2} - \underset{(0.24)}{0.85}y_{t-3} + \underset{(0.14)}{0.45}y_{t-5} - \underset{(0.22)}{0.43}y_{t-7} + \underset{(0.21)}{0.46}y_{t-8} - \underset{(0.12)}{0.83}y_{t-11}\Big) \times \left[1 + exp\left\{-\underset{(7.60)}{8.28} \times 0.10\left(y_{t-2} - \underset{(1.20)}{30.69}\right)\right\}\right]^{-1} + u_t$$

s=3.42; $\bar{R}^2 = 0.88$; $s^2/s_L^2 = 0.87$; ARCH=23.46 (0.00); AUTO=1.37 (0.20); NL=1.46 (0.12); PC=2.75 (0.00)

NIGERIA

$$y_t = \underset{(0.31)}{1.16} + \underset{(0.02)}{1.05}y_{t-1} + \underset{(0.05)}{0.06}y_{t-5} - \underset{(0.07)}{0.20}y_{t-6} + \underset{(0.06)}{0.08}y_{t-7} - \underset{(0.02)}{0.05}y_{t-11} + \Big(\underset{(5.28)}{4.21} + \underset{(0.15)}{0.40}y_{t-1} - \underset{(0.20)}{0.62}y_{t-3} + \underset{(0.31)}{0.65}y_{t-6} - \underset{(0.41)}{0.78}y_{t-7} + \underset{(0.31)}{0.33}y_{t-8} + \underset{(0.30)}{0.41}y_{t-9} - \underset{(0.40)}{0.97}y_{t-10} + \underset{(0.25)}{0.56}y_{t-11}\Big) \times \left[1 + exp\left\{-\underset{(3.81)}{5.59} \times 0.06\left(y_{t-9} - \underset{(3.26)}{53.96}\right)\right\}\right]^{-1} + u_t$$

s=3.29; $\bar{R}^2 = 0.97$; $s^2/s_L^2 = 0.92$; ARCH=4.62 (0.03); AUTO=1.44 (0.18); NL=1.23 (0.23); PC=1.39 (0.11)

SEYCHELLES

$$y_t = \underset{(0.22)}{0.41} + \underset{(0.08)}{1.00}y_{t-1} - \underset{(0.10)}{0.10}y_{t-2} + \underset{(0.10)}{0.15}y_{t-4} - \underset{(0.09)}{0.10}y_{t-5} - \underset{(0.03)}{0.09}y_{t-9} + \Big(\underset{(1.29)}{3.51} - \underset{(0.10)}{0.41}y_{t-1} + \underset{(0.12)}{0.29}y_{t-2} + \underset{(0.07)}{0.18}y_{t-3} - \underset{(0.12)}{0.37}y_{t-4} + \underset{(0.12)}{0.18}y_{t-5} + \underset{(0.07)}{0.09}y_{t-6} - \underset{(0.07)}{0.07}y_{t-7}\Big) \times \left[1 + exp\left\{-\underset{(12.55)}{11.26} \times 0.11\left(y_{t-7} - \underset{(1.00)}{10.09}\right)\right\}\right]^{-1} + u_t$$

s=3.38; $\bar{R}^2 = 0.85$; $s^2/s_L^2 = 0.96$; ARCH=2.98 (0.08); AUTO=1.77 (0.08); NL=0.87 (0.58); PC=0.76 (0.76)

SOUTH AFRICA

$$\Delta y_t = \underset{(0.08)}{0.09} + \underset{(0.04)}{0.06}\Delta y_{t-2} + \underset{(0.04)}{0.08}\Delta y_{t-3} - \underset{(0.06)}{0.07}\Delta y_{t-4} + \underset{(0.06)}{0.07}\Delta y_{t-5} - \underset{(0.06)}{0.06}\Delta y_{t-6} + \underset{(0.04)}{0.11}\Delta y_{t-9} - \underset{(0.04)}{0.49}\Delta y_{t-12} + \left(-\underset{(0.48)}{0.72} + \underset{(0.15)}{0.23}\Delta y_{t-1} + \underset{(0.17)}{0.26}\Delta y_{t-4} - \underset{(0.21)}{0.28}\Delta y_{t-5} + \underset{(0.20)}{0.28}\Delta y_{t-6} + \underset{(0.15)}{0.17}\Delta y_{t-7} + \underset{(0.25)}{0.41}\Delta y_{t-8} + \underset{(0.16)}{0.16}\Delta y_{t-11}\right) \times \left[1 + exp\left\{-\underset{(1.39)}{2.03} \times 1.22\left(\Delta y_{t-8} - \underset{(0.49)}{0.84}\right)\right\}\right]^{-1} + u_t$$

s=0.73; $\bar{R}^2 = 0.23$; $s^2/s_L^2 = 0.96$; ARCH=22.82 (0.00); AUTO=0.76 (0.64); NL=1.31 (0.18); PC=1.12 (0.31)

SWAZILAND

$$y_t = \underset{(0.44)}{1.12} + \underset{(0.06)}{0.55}y_{t-1} + \underset{(0.08)}{0.17}y_{t-2} + \underset{(0.05)}{0.18}y_{t-3} + \left(\underset{(1.43)}{2.70} + \underset{(0.10)}{0.35}y_{t-1} - \underset{(0.11)}{0.30}y_{t-2} - \underset{(0.09)}{0.27}y_{t-4} + \underset{(0.08)}{0.24}y_{t-5} - \underset{(0.08)}{0.14}y_{t-9} + \underset{(0.10)}{0.22}y_{t-10} - \underset{(0.08)}{0.29}y_{t-11}\right) \times \left[1 + exp\left\{-\underset{(30.64)}{22.00} \times 0.15\left(y_{t-2} - \underset{(0.49)}{12.72}\right)\right\}\right]^{-1} + u_t$$

s=3.18; $\bar{R}^2 = 0.76$; $s^2/s_L^2 = 0.97$; ARCH=4.41 (0.04); AUTO=0.37 (0.94); NL=1.54 (0.07); PC=1.38 (0.11)

Notes: y_t denotes the inflation rate. Values under regression coefficients are standard errors of the estimates; s is the residual standard error; $\bar{R}^2$ is the adjusted determination coefficient; s^2/s_L^2 is the variance ratio of the residuals from the nonlinear model and the best linear AR selected with AIC; ARCH is the statistic of no ARCH based on one lag; AUTO is the test for residual autocorrelation of order 8; NL is the test for no remaining nonlinearity; PC is a parameter constancy test. Numbers in parentheses after values of ARCH, AUTO, NL and PC are p-values.

Table 7: Local dynamics: dominant roots in each regime

Country	Regime (value of F)	Root	Modulus
Burkina Faso	Lower (F=0)	$0.9441 \pm 0.2040i$	0.96
	Upper (F=1)	$0.9281 \pm 0.1682i$	0.94
Cameroon	Lower (F=0)	$1.1827 \pm 0.2103i$	1.20
	Upper (F=1)	$0.9294 \pm 0.1926i$	0.95
Ethiopia	Lower (F=0)	$0.9677 \pm 0.1356i$	0.98
	Upper (F=1)	$-0.6810 \pm 0.5355i$	0.87
Gambia	Lower (F=0)	0.8900	0.89
	Upper (F=1)	$0.9323 \pm 0.1664i$	0.95
Ghana	Lower (F=0)	0.9423	0.94
	Upper (F=1)	$0.8938 \pm 0.2027i$	0.92
Ivory Coast	Lower (F=0)	0.9568	0.96
	Upper (F=1)	$0.8779 \pm 0.1051i$	0.88
Kenya	Lower (F=0)	$-0.6931 \pm 0.6894i$	0.98
	Upper (F=1)	$1.0154 \pm 0.2187i$	1.04
Madagascar	Lower (F=0)	$0.9276 \pm 0.1331i$	0.94
	Upper (F=1)	$0.9734 \pm 0.0819i$	0.98
Mauritius	Lower (F=0)	$0.9618 \pm 0.1212i$	0.97
	Upper (F=1)	$0.8695 \pm 0.1739i$	0.89
Morocco	Lower (F=0)	0.9251	0.92
	Upper (F=1)	$0.9320 \pm 0.1890i$	0.95
Niger	Lower (F=0)	$0.9064 \pm 0.0689i$	0.91
	Upper (F=1)	-1.3449	1.34
Nigeria	Lower (F=0)	$0.9496 \pm 0.1096i$	0.95
	Upper (F=1)	$0.9942 \pm 0.2285i$	1.02
Seychelles	Lower (F=0)	$0.9230 \pm 0.1596i$	0.94
	Upper (F=1)	$0.8741 \pm 0.1747i$	0.89
South Africa	Lower (F=0)	$-0.6729 \pm 0.6711i$	0.95
	Upper (F=1)	$0.7311 \pm 0.6871i$	1.00
Swaziland	Lower (F=0)	0.9361	0.94
	Upper (F=1)	$0.9621 \pm 0.1811i$	0.98

Figure 1: Inflation rates

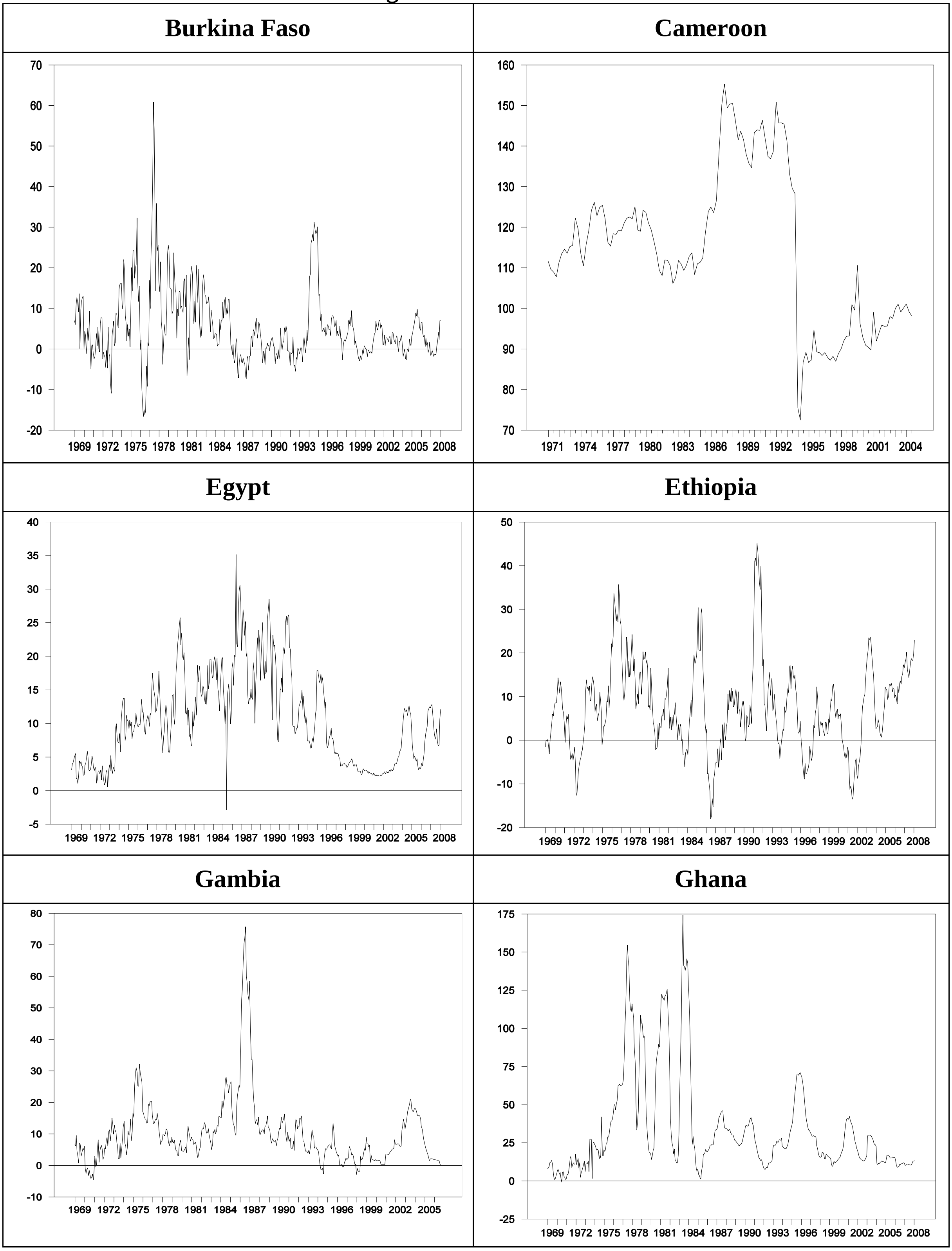
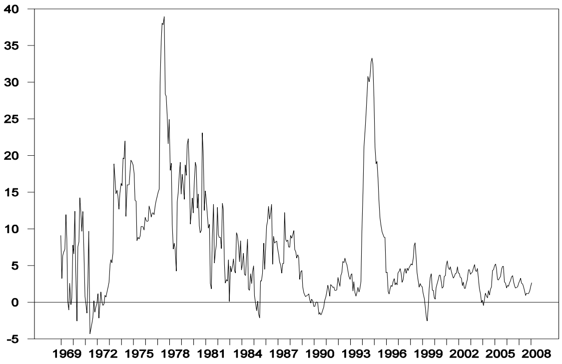
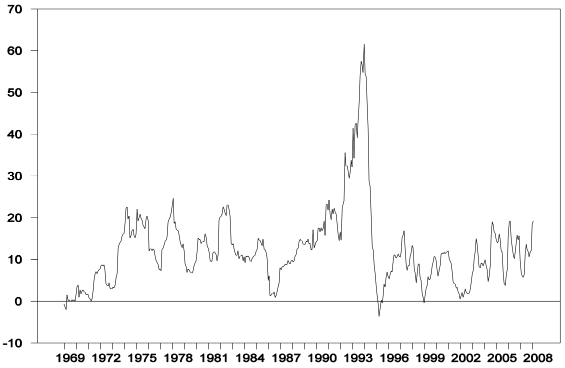


Figure 1: Inflation rates (cont.)

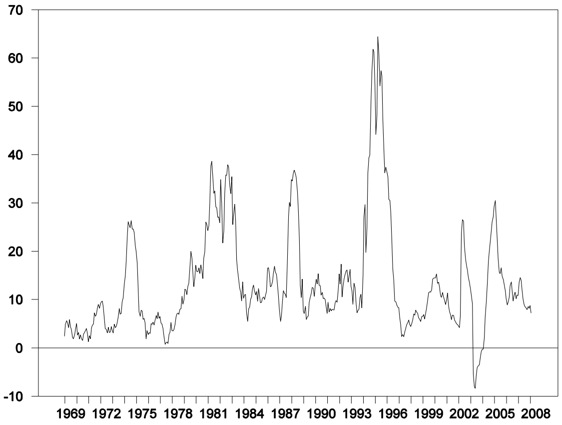
Ivory Coast



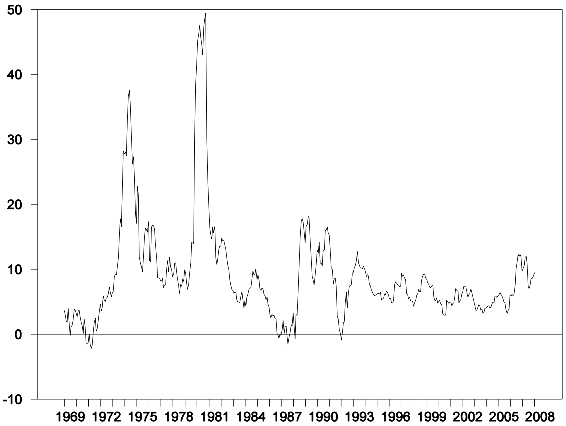
Kenya



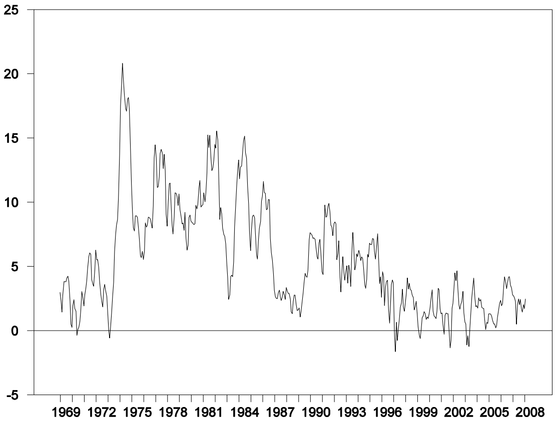
Madagascar



Mauritius



Morocco



Niger

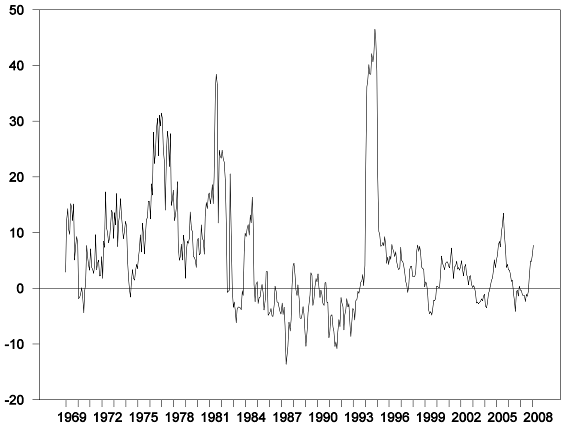
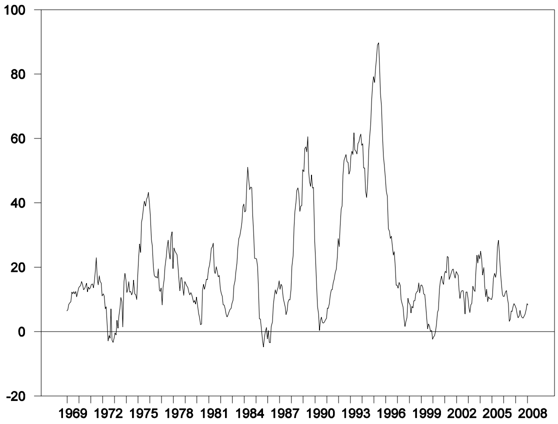
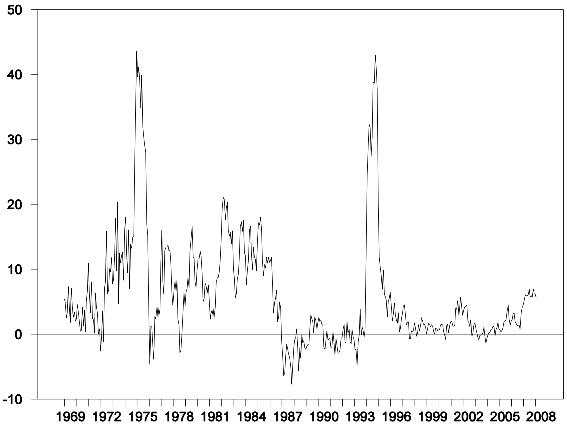


Figure 1: Inflation rates (cont.)

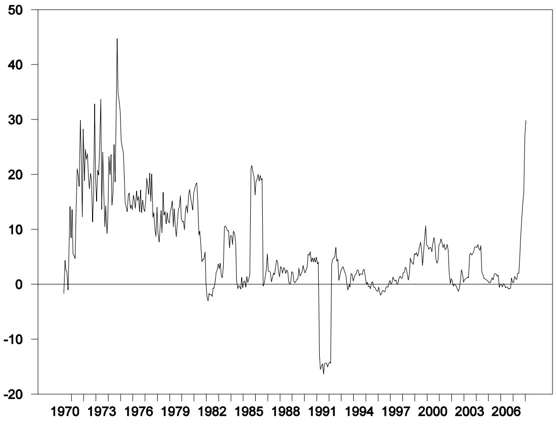
Nigeria



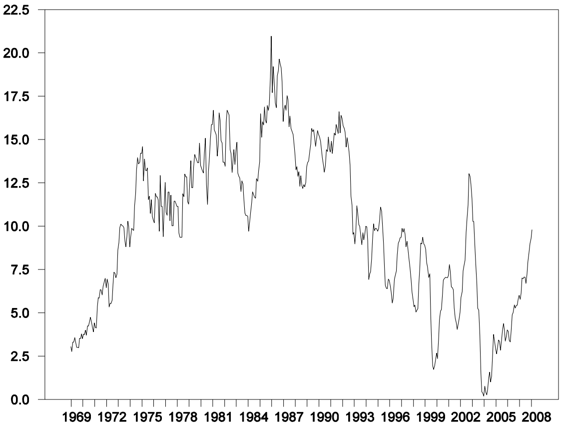
Senegal



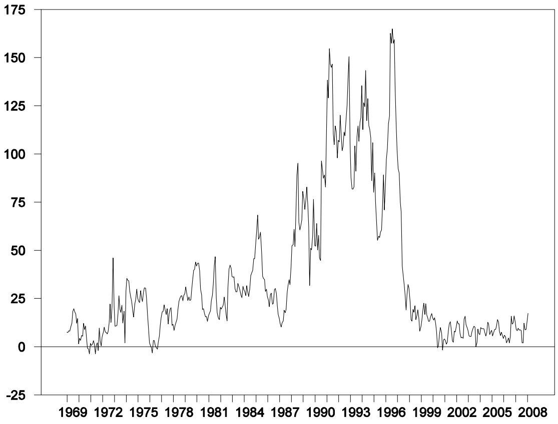
Seychelles



South Africa



Sudan



Swaziland