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**Modelling African Inflation Rates:
Non-linear Deterministic Terms and
Long-Range Dependence**

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**MODELLING AFRICAN INFLATION RATES:
NON-LINEAR DETERMINISTIC TERMS AND LONG-RANGE DEPENDENCE**

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ABSTRACT

This paper estimates a fractional integration model with non-linear deterministic trends for the inflation rates of five African countries. The results indicate that non-linearities are present in the case of Angola and Lesotho, but not in Botswana, Namibia and South Africa. Moreover, the degrees of differentiation are higher in the latter group of countries.

Keywords: Non-linear models; fractional integration; Africa

JEL Classification: C22, E31

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1. Introduction

This paper estimates a fractional integration model with non-linear deterministic trends for the inflation rates of five African countries. A number of studies have argued that inflation is a fractionally integrated series, with a differencing parameter that is significantly different from zero and unity. For instance, Backus and Zin (1993) found a fractional degree of integration using US monthly data; Hassler (1993) and Delgado and Robinson (1994) provided evidence of long memory in the Swiss and Spanish inflation rates respectively; Baillie, Chung and Tieslau (1996) examined monthly post-World War II CPI inflation in ten countries, and found evidence of long memory with mean-reverting behaviour in all countries except Japan. Similar results were reported by Hassler and Wolters (1995), Baum, Barkoulas and Caglayan (1999) and Boutahar and Jouini (2005).

However, the failure of such studies to take into account possible structural breaks could vitiate their findings (Diebold and Inoue, 2011; Granger and Hyung, 2004; etc.). In particular, Lobato and Savin (1998) showed that the existence of breaks may lead to spurious findings of long-memory properties, and Engle and Smith (1999) proposed a model with a mean shift and fractional integration. In a more general non-linear context, van Dijk et al. (2002) considered a fractional integration smooth transition autoregression time series [FISTAR] model, and Caporale and Gil-Alana (2007) also estimated a model including fractional integration and a non-linear structure.

This paper contributes to the literature on the stochastic properties of inflation by adopting a long-memory model that incorporates non-linear deterministic terms in the form of Chebyshev polynomials. This framework is applied to the inflation rates of five African countries where non-linearities might be present as a result of wars and

conflicts. The structure of the paper is as follows: Section 2 briefly describes the methodology, Section 3 presents the data and the main empirical results, and Section 4 offers some concluding remarks.

2. Methodology

We consider the following model:

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

with m indicating the order of the Chebyshev polynomial, and x_t following an I(d) process of the form

$$(1 - L)^d x_t = u_t, \quad t = 0, \pm 1, \dots, \quad (2)$$

with $x_t = 0$ for $t \leq 0$, and $d > 0$, where L is the lag-operator ($Lx_t = x_{t-1}$) and u_t is I(0).

The Chebyshev polynomials $P_{i,T}(t)$ in (1) are defined as:

$$P_{0,T}(t) = 1, \\ P_{i,T}(t) = \sqrt{2} \cos(i\pi(t-0.5)/T), \quad t = 1, 2, \dots, T; \quad i = 1, 2, \dots \quad (3)$$

(see Hamming (1973) and Smyth (1998) for a detailed description of these polynomials). Bierens (1997) uses them in the context of unit root testing. According to Bierens (1997) and Tomasevic *et al.* (2009), it is possible to approximate highly non-linear trends with rather low degree polynomials. If $m = 0$ the model contains an intercept, if $m = 1$ it also includes a linear trend, and if $m > 1$ it becomes non-linear - the higher m is the less linear the approximated deterministic component becomes.

An issue that immediately arises here is how to determine the optimal value of m . As argued in Cuestas and Gil-Alana (2012), if one combines (1) and (2) in a single equation, standard t -statistics will remain valid with the error term being I(0) by definition. The choice of m will then depend on the significance of the Chebyshev

coefficients. Note that the model combining (1) and (2) becomes linear and d can be parametrically estimated or even tested as in Robinson (1994), Demetrescu, Kuzin and Hassler (2008) and others (see Cuestas and Gil-Alana, 2012).

3. Data and empirical results

The series examined are the monthly inflation rates, from January 2002 to December 2013, in Angola, Botswana, Lesotho, Namibia and South Africa (see Figure 1).

[Insert Figure 1 about here]

Table 1 displays the estimates of d and the corresponding 95% non-rejection intervals in the model given by equations (1) and (2), for the cases of $m = 0, 1, 2$ and 3 and white noise errors. Very similar results were obtained under the assumption of (weakly, e.g., AR) autocorrelated errors. For $m \geq 2$ the model contains non-linear deterministic terms. This is the case for two of the countries examined, Angola and Lesotho, where all the estimated coefficients on the Chebyshev polynomials are statistically significant (see Table 2). For the remaining three countries (Botswana, Namibia and South Africa) the model with an intercept is sufficient to describe the deterministic part of the process.

[Insert Tables 1 and 2 about here]

Concerning the estimates of the differencing parameter, it can be seen that for the two cases of non-linear terms the unit root null hypothesis cannot be rejected; however this hypothesis is decisively rejected in favour of higher degrees of integration ($d > 1$) in the three countries with linear processes.

4. Conclusions

This paper proposes a model that combines fractional integration with non-linear deterministic terms in the form of Chebyshev polynomials for the analysis of inflation rates in five African countries (Angola, Botswana, Lesotho, Namibia and South Africa). The results provide evidence of non-linearities in the cases of Angola and Lesotho only. Moreover, the unit root null hypothesis cannot be rejected for the non-linear processes, while it is decisively rejected in favour of higher degrees of integration for the linear models.

References

- Backus, D. and S. Zin, 1993, Long memory inflation uncertainty. Evidence from the term structure of interest rates, *Journal of Money, Credit and Banking* 25, 681-700.
- Baillie, R.T., C.F. Chung and M.A. Tieslau, 1996, Analyzing inflation by the fractionally integrated ARFIMA-GARCH Model, *Journal of Applied Econometrics* 11, 23-40.
- Baum, C.F., J. Barkoulas and M. Caglayan, 1999, Persistence in the international inflation rates, *Southern Economic Journal* 65, 900-913.
- Bierens, H.J., 1997, Testing the unit root with drift hypothesis against nonlinear trend stationarity with an application to the US price level and interest rate, *Journal of Econometrics* 81, 29-64.
- Boutahar, M. and J. Jouini (2005) A new model for the US inflation rate. Structural change and long memory approaches, Manuscript, GREQAM, Université de la Méditerranée, Marseille, presented at the November 2003 "International Workshop on Models with Breaks in Economics and Finance: Recent Developments" in France.
- Caporale, G.M., and L.A. Gil-Alana. 2007. "Nonlinearities and Fractional Integration in the US Unemployment Rate." *Oxford Bulletin of Economics and Statistics*, 69(4): 521-544.
- Cuestas, J.C. and L.A. Gil-Alana, 2012. A Non-Linear Approach with Long Range Dependence Based on Chebyshev Polynomials, Working Papers 2012-013, The University of Sheffield, Department of Economics.
- Delgado, M. and P.M. Robinson, 1994, New methods for the analysis of long memory time series. Application to Spanish inflation, *Journal of Forecasting* 13, 97-107.
- Demetrescu, M., V. Kuzin, and U. Hassler, 2008, Long Memory Testing in the Time Domain. *Econometric Theory*, Cambridge University Press, vol. 24(01), pages 176-215, February.
- Diebold F.X. and A. Inoue (2001) Long memory and regime switching, *Journal of Econometrics* 105, 131-159.
- Engle, R.F. and A.D. Smith (1999) Stochastic permanent breaks, *Review of Economics and Statistics* 81, 553-574.
- Granger, C.W.J. and N. Hyung, 2004, Occasional structural breaks and long memory with an application to the S&P 500 absolute stock returns, *Journal of Empirical Finance* 11, 399-421.
- Hamming, R. W., 1973, *Numerical Methods for Scientists and Engineers*, Dover
- Hassler, U., 1993, Regression of spectral estimators with fractionally integrated time series, *Journal of Time Series Analysis* 14, 369-380.

Hassler, U. and J. Wolters (1995) Long memory in inflation rates. International evidence, *Journal of Business and Economic Statistics* 13, 37-45.

Lobato, I.N. and N.E. Savin (1998) Real and spurious long memory properties of stock market data, *Journal of Business and Economic Statistics* 16, 261-268.

Robinson, P.M. (1994) Efficient tests of nonstationary hypotheses. *Journal of the American Statistical Association* 89, 1420-1437.

Smyth, G.K., 1998, *Polynomial Approximation*, John Wiley & Sons, Ltd, Chichester, 1998.

Tomasevic, N.M. and T. Stanivuk (2009), Regression Analysis and approximation by means of Chebyshev Polynomial, *Informatologia* 42, 2009., 3, 166-172.

Van Dijk, D.J.C., Franses, P.H. and R. Paap, (2002), "A nonlinear long memory model for US unemployment", *Macroeconomic Dynamics*, 6, 202-241.

Figure 1: Original time series

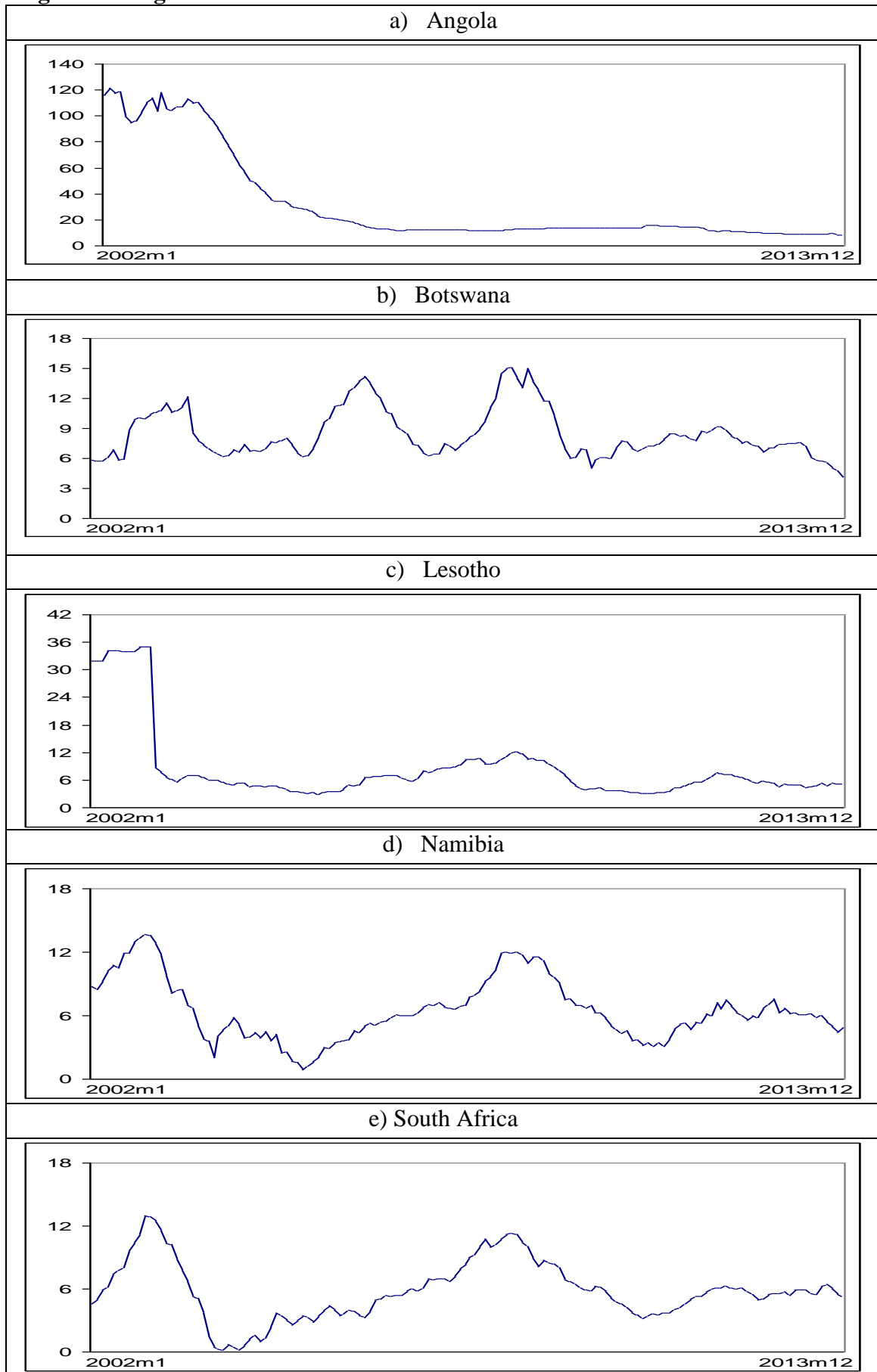


Table 1: Estimates of d in a non-linear set-up based on Chebyshev polynomials

Series	$m = 0$	$m = 1$	$m = 2$	$m = 3$
ANGOLA	1.122 (1.041, 1.212)	1.113 (1.045, 1.203)	1.072 (0.990, 1.172)	0.978 (0.861, 1.109)
BOTSWANA	1.224 (1.101, 1.374)	1.221 (1.101, 1.373)	1.222 (1.110, 1.373)	1.221 (1.110, 1.355)
LESOTHO	1.023 (0.928, 1.178)	1.029 (0.920, 1.167)	1.024 (0.921, 1.167)	1.012 (0.903, 1.164)
NAMIBIA	1.164 (1.065, 1.272)	1.169 (1.065, 1.273)	1.169 (1.065, 1.275)	1.144 (1.042, 1.265)
SOUTH AFRICA	1.413 (1.298, 1.560)	1.411 (1.295, 1.567)	1.410 (1.296, 1.566)	1.397 (1.286, 1.497)

In bold, the significant cases at the 5% level.

Table 2: Estimated coefficients in the selected models

Series	θ_0	θ_1	θ_2	θ_3
ANGOLA	35.179 (2.065)	25.842 (2.553)	18.765 (3.582)	12.647 (3.575)
BOTSWANA	5.766 (7.751)	---	---	---
LESOTHO	19.372 (2.290)	3.261 (1.993)	2.238 (2.503)	3.362 (2.142)
NAMIBIA	8.651 (13.235)	---	---	---
SOUTH AFRICA	4.368 (9.207)	---	---	---

In parentheses, the corresponding t-values.