A Nonlinear Approach to Tunisian Inflation Rate

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In this study, we investigated the properties and the macroeconomic performance of the nonlinearity of the Inflation Rate Set in Tunisia. We developed an inference asymptotic theory for an unrestricted two-regime threshold autoregressive (TAR) model with an autoregressive unit root. We proposed two types of tests namely asymptotic and bootstrap-based. These tests as well as the distribution theory allow a joint consideration of nonlinear thresholds and non-stationary unit roots.

Our empirical results reveal a strong evidence of a threshold effect. This makes clear the possibility of non stationary and nonlinear of the Monthly Inflation Rate in Tunisia for the 1994.01-2011.06 period. While the Perron test found a unit root, our TAR unit root tests are arguably significant. Then, the evidence is quite strong that the inflation rate is not a unit root process.

Keywords: TAR models; Thresholds; nonlinear time series; nonstationary; Inflation Rate.

JEL Classifications: C01, C22, C24, E00, E31, E52

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1. Introduction

Most of the economic and financial time series show non linear dynamics. That is why taking into account the existence of a regime-changing phenomenon tends to deeply modify the applied econometric approaches to macroeconomics and finance. This makes it impossible to analyse the changing time series relying on the usual linear autoregressive models of the ARMA or VAR types. Aiming at reproducing these non-linear dynamics, it has become a need to resort to processes that are adapted to non-linearity.

There are several time series, like inflation rate, which do not exhibit a linear behaviour. This can be explained by the fact that several factors may account for the non-linearity of these series such as the world economic and financial crises, the increase of energy prices and the raw materials costs, the corruption and so on. Such factors have important implications on the inflation rate adjustment process so as to reach a targeted value. In this case, it would be difficult to empirically analyse the inflation rate dynamics while retaining the standard linear models. Therefore, threshold models seem to be particularly interesting as they allow considering such phenomena as asymmetry or highly important ruptures. In this case, the most commonly used models are TAR, STAR and SETAR since the regime change in these models is regulated with a threshold.

Inspired by the analysis proposed by Caner and Hansen (2001), this research work tries to provide a methodology to study the non stationarity and non-linearity of the inflation rate in Tunisia during the period 1994.01 - 2011.09. Specifically, checking the unit root, our study was an attempt to find out whether a possible threshold could exist within the data. Therefore, in a first step, we applied the Perron (1989) unit root tests to our time series. In a second step, we followed the analysis proposed by Caner and Hansen (2001).

Through the above analysis, it can be clearly remarked that no previous study was achieved to demonstrate the non linearity of the inflation rate in the developing countries. We may even dare say that it was limited to developing ones. We thought that it could be an appealing challenge to carry out such a study in a developing country – Tunisia, and pave the way for further potential future research in the field. Thus, the added value of this study could stem from its being pioneer in such a field.

In this paper, therefore, it would not be surprising to investigate the existence of a non linearity of the inflation rate without seeking its causes. This study examines, then, the stationarity and the possible non linearity of the series applying a TAR model. Within this model, Wald tests and Wald and *t* tests were studied for a threshold effect for nonlinearity and for unit roots for non-stationarity, respectively. We tried to determine the general autoregressive orders without artificially restricting the coefficients across regimes.

This paper was organized as follows. Section 2 presented a brief literature review. Section 3 described the TAR model classes. Section 4 displayed the data. A new set of asymptotic tools that are useful for the study of threshold processes with possible unit roots was introduced before detailing Caner and Hansen estimation model in section 5. Our empirical results were discussed in section 6 before drawing our major conclusion in the last section.

2. Literature review

There are several time series which do not exhibit a linear behaviour in the fields of economics and finance. This non linear behaviour cannot be well fitted by the common and popular ARMA models.

Bacon and Watts (1971) were the first authors to introduce the term "smooth transition". Chan and Tong (1986), then, generalized this modeling to the abrupt transition threshold models (TAR models) enabling the transition between regimes to be smooth which led them to introduce the STAR process. Following the work of Teräsvirta and Anderson (1992) and Teräsvirta (1994), Van Dijk, Teräsvirta and Franses (2002) developed the processes that describe external systems between which the transition is supposed to be smooth and a set of continuum intermediate states.

Hansen (1999b) illustrates the self-exciting threshold autoregressive (SETAR) models with two applications: annual sunspot for the time period 1700-1988 and the U.S. monthly industrial production for the period 1960.01 through 1998.09. He presents three different SETAR models: one-regime, two-regime, and three-regime. The tests led to the conclusion that annual sunspots and monthly U.S. industrial production are SETAR (2) processes.

However, Gishani (2010) fits three empirical datasets, two River flow time series and one Blowfly data set. He applied the TAR and the GARCH models to the simulated and the real data and evaluated the findings. Specifically, he sought possible thresholds that might be present in the data. The author showed significant non-linear effects for the three empirical time series.

Applying this method to the real exchange rate, Tjostheim and Yin (2011) analysed their estimation in a class of new nonlinear threshold autoregressive models with both stationary and unit root regimes. The authors treated these models by examining the British pound/American dollar real exchange rate logarithm, where y_t, is defined as $\log(e_t) + \log(p_t^{UK}) - \log(p_t^{USA})$, where e_t is the nominal exchange rate monthly average, and p_t^i denotes the consumption price index of country i during the period January 1988 - February 2011. The authors proved the threshold effect in their example.

Recently, Nattahi (2013) has highlighted the superiority of the regime change in models, and questioned the efficiency of the French stock market.

In the context of other applications, Zhao and Wu (2015) analyzed the evolution of pork price in China using the threshold autoregression model (TAR). They showed that the pork price series is a unit root process in each regime, and that the heteroskedasticity in the TAR model greatly affects the results of the linearity test. Nevertheless, they found that the changing process of pork prices has two regimes: a mild regime and an expansion one.

Michis (2016) examined the effect of the market structure on the use of nonlinear pricing tactics by banks. Using a panel dataset of seven European countries, the author suggested that nonlinear pricing is associated with an increasing monopoly power in the European banking systems.

3. The Non-linear model: TAR model classes

We would start by providing a brief description of the TAR model introduced by Tong (1983). The movements between the regimes, in this class, are controlled by a variable called a threshold. Then, a two regimes TAR model can be represented by equation (1)

$$Y_t = I_t\left[\alpha_{10} + \sum_{i=1}^{p}\alpha_{1i}Y_{t-i}\right] + (1 - I_t)\left[\alpha_{20} + \sum_{i=1}^{p}\alpha_{2i}Y_{t-i}\right] + e_t \qquad (1)$$

The error term in equation (1) is a white noise process and I_t is an indicator function such as,

$$I_t = 1 \text{ if } Y_{t-1} > \gamma \quad \text{and} \quad I_t = 0 \text{ if } Y_{t-1} \leq \gamma$$

where γ is the threshold variable that separates the two regimes.

Nevertheless, to estimate a time series with an assumed TAR model behaviour it is essential to know the value of the threshold parameter in the series. Then, if the value of the threshold parameter is known, the estimation of the TAR model is readily available.

Hansen (1996) described the asymptotic distribution of the likelihood ratio test for a threshold. In other studies, Hansen (1997b, 2000) developed an alternative approximation to the asymptotic distribution. Hansen (1999), however, used the Self-exciting Threshold Autoregressive method to test the problem of linearity and to redeem the number of regimes for two applications; annual sunspot means (1700-1988) and monthly U.S. industrial production (1960.01-1998.06). The non-linear autoregressive method was also used in many economic applications such as the industrial production (Terasvirta and Anderson, 1992), unemployment (Rothman, 1991 and Hansen, 1997). Therefore, the Self-exciting Threshold Autoregressive provided a particularly innovative approach which is adequate to reproduce the inherent non-linearity on the observed data.

Yet, in all of the above listed papers, the important maintained assumption is that the data are stationary, ergodic, and have no unit roots. This makes it impossible to discriminate nonstationarity from nonlinearity. Contrary to previous research, this study provided the first rigorous treatment of statistical tests that simultaneously allow for both effects in order to analyse the possibly of non-stationary and/or nonlinear time series.

In what follows, we examined a two-regime TAR with an autoregressive unit root. Within this model, we investigated the Wald tests for a threshold effect for nonlinearity and the Wald and *t* tests for unit roots for non-stationarity.

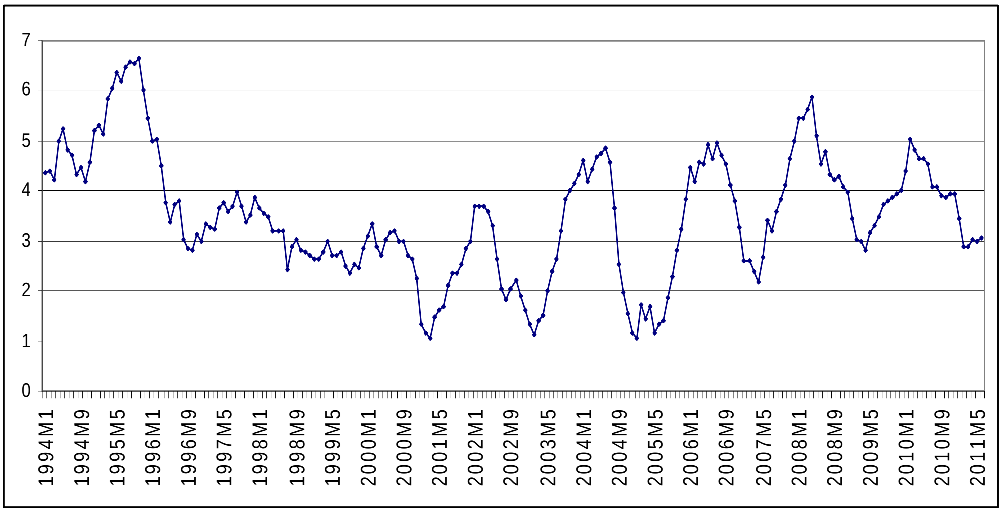
4. Data presentation

This study is designed to examine the possibility of the non-linearity and the number of regimes of statistic series of inflation rate in Tunisia. The applied methodology is the Threshold Autoregressive (TAR).

We estimated a baseline TAR (2) with $p=12$ for the period 1994.01-2011.06. This suggested that $p=12$ is enough to reduce the errors to white noise. We transformed the series to approximate stationarity by taking growth rates setting $\pi_t = 100 \times (LnCPI_t - LnCPI_{t-12})$, where CPI_t denotes the monthly consumer price index. The transformed series (π_t) was represented in figure 1 and noted by monthly inflation rate.

Figure 1

Monthly inflation rate, 1994.01-2011.06



Following its evolution over time (figure 1), we refer to Perron test (1989) to determine the differentiation order of the inflation rate (π_t).

Nevertheless, Perron test (1989) is used when the macro-economic series show break points; i.e., a change in the level or in the slope, which means that the fluctuations are not transitory. In fact, for the inflation rate, we remarked, according to their aspects (see Figure 1), that their evolutions over time show intercept shifts. This leads us to introduce one dummy variable which indicates the intercept shift:

$$RT_t \quad with \quad \begin{cases} RT_t = 0 \ \text{if} \quad t \le T_B \\ RT_t = 0 \ \text{if} \quad t > T_B \end{cases}$$

where T_B presents a break date.

The estimating equation of the inflation rate is written as follows:

$$\pi_t = \varphi \pi_{t-1} + \alpha t + \beta + \sum_{i=1}^{p} \theta_i (\pi_{t-i} - \pi_{t-1-i}) + \delta_1 + \varepsilon_t \qquad (2)$$

The results of the calculations are summarised in Table 1. This table leads to the standard conclusion that the inflation rate has a unit root. In fact, $t_{\hat{\theta}_i} = 5.60 > 1.60$ leads us to consider p = 1 and $t_{\hat{\varphi}} = -7.50 < t_c = -4.30$, which implies that the series are not stationary in level.

Table 1

Perron test results

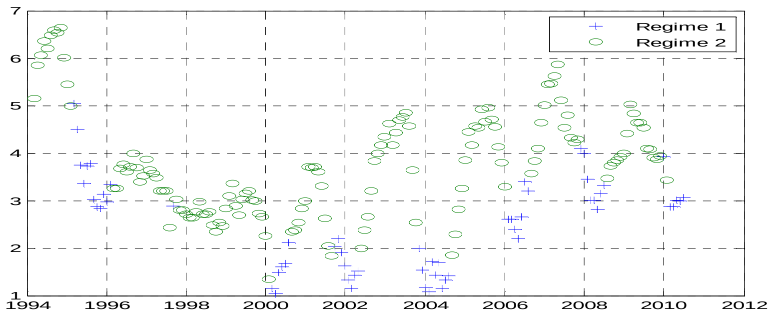
Dependent variable $D\pi_t$			Dependent variable $D^2\pi_t$		
Variables	Coefficients	t-statistics	Variables	Coefficients	t-statistics
Intercept	0.46	3.71	*Intercept*	0.09	1.09
π_{t-1}	-0.076	-3.90	$D\pi_{t-1}$	-0.60	-7.50
Trend	0.0004	1.15	*Trend*	0.0003	-2.22
RT_t	-0.27	-2.77	RT_t	-0.13	-1.40
$D\pi_{t-1}$	0.359	5.60	$D^2\pi_{t-1}$	-0.09	-1.34
T_B=1995.08	λ=0.1			α=1%	t_c=-4.30

Notes: D: is the first difference operator and D^2 is the second difference operator

According to the previous stationarity analysis, we conclude that the retained series is nonstationary in level and integrated at first order. A plot is given in Figure 2. Hence, we can use the estimation method suggested by Caner and Hansen (2001).

Figure 2

Monthly inflation rate, classified by a threshold regime



5. Caner and Hansen (2001) estimation model

The threshold autoregression model (TAR) is presented by the following equation:

$$\Delta y_t = \theta_1' x_{t-1} I_{\{Z_{t-1}<\gamma\}} + \theta_2' x_{t-1} I_{\{Z_{t-1}\geq\gamma\}} + e_t \qquad (3)$$

with $t = 1,\dots,T$, where $x_{t-1} = \left(y_{t-1}\ r_t'\ \Delta y_{t-1} \cdots \Delta y_{t-k}\right)'$, $I_{\{\ \}}$ is the indicator function, e_t is an *iid* error, $Z_t = y_t - y_{t-m}$ for some $m \geq 1$ and r_t is a vector of deterministic components including an intercept and possibly a linear time trend. The threshold γ is unknown. It belongs to the interval $[\gamma_1, \gamma_2]$ so that $P(Z_t \leq \gamma_1) = \pi_1 > 0$ and $P(Z_t \leq \gamma_2) = \pi_2 < 1$ with $\pi_2 = 1 - \pi_1$. This imposes the restriction that no "regime" has less than π_1% of the total sample.

Generally, what is necessary for the results in Caner and Hansen (2001) estimation model is that Z_{t-1} be predetermined, strictly stationary and ergodic with a continuous distribution function.

In addition, the choice $Z_t = y_t - y_{t-m}$ is convenient because it is ensured to be stationary under the alternative assumptions that Y_t is I(1) or I(0).

Caner and Hansen (2001) separate the discussion of the components of θ_1 and θ_2. These vectors are written as:

$$\theta_1 = \begin{pmatrix} \rho_1 \\ \beta_1 \\ \alpha_1 \end{pmatrix}, \quad \theta_2 = \begin{pmatrix} \rho_2 \\ \beta_2 \\ \alpha_2 \end{pmatrix}$$

where ρ_1 and ρ_2 are scalar, β_1 and β_2 have the same dimension as r_t, and α_1 and α_2 are *k*-vectors. Thus (ρ_1, ρ_2) are the slope coefficients on y_{t-1}, (β_1, β_2) are the slopes on the deterministic components, and (α_1, α_2) are the slope coefficients on $(\Delta y_{t-1}, \cdots, \Delta y_{t-k})$ in the two regimes (see Caner and Hansen, 2001).

The estimated TAR model (2) by ordinary least squares (OLS) is written as follows:

$$\Delta y_t = \hat{\theta}_1(\gamma) x_{t-1} I_{\{Z_{t-1}<\gamma\}} + \hat{\theta}_2(\gamma) x_{t-1} I_{\{Z_{t-1}\geq\gamma\}} + \hat{e}_t(\gamma) \quad (4)$$

Let $\hat{\sigma}^2(\gamma) = T^{-1}\sum_1^T \hat{e}_t(\gamma)^2$ be the OLS estimate of σ^2 for fixed γ. The least squares estimate of the threshold γ is found by minimizing $\hat{\sigma}^2(\gamma)$

$$\hat{\gamma} = \underset{\gamma\in[\gamma_1,\gamma_2]}{\arg\min}\ \hat{\sigma}^2(\gamma)$$

The estimated model is, then, presented as follows:

$$\Delta y_t = \hat{\theta}_1 x_{t-1} I_{\{Z_{t-1}<\gamma\}} + \hat{\theta}_2 x_{t-1} I_{\{Z_{t-1}\geq\gamma\}} + \hat{e}_t \quad (5)$$

The estimates (5) can be used to conduct inference concerning the parameters of (3) using standard Wald and *t* statistics (see Caner and Hansen, 2001).

6. Empirical results

Our results show the standard conclusion that the linear representation for the monthly inflation rate has a unit root. At this level, we apply the Wald test (W_T) to show a threshold model. The Wald tests (W_T), 5% bootstrap critical values, and bootstrap *p*-values for threshold are presented in table 2.

In fact, we transform the series by taking $Ln\pi_t$ which denotes the log of the inflation rate in one side. Moreover, in second side we transform the series by taking the Logistic inflation rate. We also report the variables of the form $Z_t = Ln\pi_t - Ln\pi_{t-m}$ for delay parameters *m* from 1 to 12.

In first time, we consider the log of the inflation rate. We can make $\hat{m} = 2$ that is the value that minimizes the residual variance. This is equivalent to selecting *m* as the value that maximizes W_T. This estimate corresponds to the threshold test statistic of $W_T = 54.43$.

Each statistics is highly significant and easily rejects the null hypothesis of linearity in favour of the threshold model. Since the W_T test rejects the null of no threshold for practically any choice of *m*, it seems certain that we can accept the TAR model (table 2).

Through our results, we can conclude that there is very strong evidence for a TAR model.

Table 2

Threshold and unit root tests unconstrained model

				Unit Root Tests, p-Values					
	Bootstrap Threshold Test			R_{1T}		t_1		t_2	
m	W_T	5% C.V	p-Value	Asym.	Boot	Asym.	Boot	Asym.	Boot
1	47.59	36.41	0.005	0.011	0.013	0.658	0.303	0.014	0.010
2	55.19	36.62	0.001	0.041	0.035	0.029	0.017	0.853	0.498
3	48.05	36.64	0.005	0.127	0.086	0.218	0.091	0.518	0.225
4	48.75	36.64	0.004	0.505	0.320	0.451	0.193	0.827	0.463
5	34.19	36.60	0.075	0.714	0.492	0.592	0.279	0.896	0.567
6	38.04	36.65	0.035	0.809	0.585	0.695	0.344	0.902	0.580
7	49.77	36.63	0.004	0.874	0.655	0.709	0.348	0.949	0.710
8	44.49	36.39	0.011	0.476	0.308	0.285	0.123	0.960	0.799
9	54.38	36.50	0.001	0.557	0.371	0.349	0.155	0.948	0.886
10	47.16	36.52	0.005	0.811	0.593	0.603	0.295	0.960	0.793
11	51.11	36.32	0.001	0.990	0.916	0.961	0.797	0.927	0.640
12	44.60	36.28	0.007	0.989	0.909	0.948	0.709	0.938	0.666

While the LS point estimate for the delay parameter is $\hat{m}=12$, the choice $\hat{m}=8$ yields a near-identical value for the residual sum-of-squares and hence test statistic W_T, (see table 2). This means that $\hat{m}=8$ is an equivalently good statistical choice. Therefore, we prefer models with smaller delay parameters, leading us to take $\hat{m}=8$ as our preferred model specification.

The same methodology is applied with the logistic inflation rate. The results reveal that there is very strong evidence for a TAR model (see table 3).

Table 3

Threshold and unit root tests unconstrained model

	Bootstrap Threshold Test			Unit Root Tests, p-Values					
				R_{1T}		t_1		t_2	
m	W_T	5% C.V	p-Value	Asym.	Boot	Asym.	Boot	Asym.	Boot
1	46.53	36.74	0.007	0.014	0.015	0.662	0.310	0.017	0.011
2	54.42	36.67	0.001	0.039	0.034	0.028	0.018	0.839	0.480
3	45.79	36.76	0.008	0.176	0.114	0.144	0.068	0.820	0.456
4	48.10	36.53	0.005	0.506	0.321	0.455	0.202	0.822	0.460
5	33.74	32.84	0.086	0.710	0.497	0.588	0.277	0.896	0.566
6	37.63	36.69	0.041	0.806	0.589	0.690	0.350	0.903	0.572
7	49.11	36.33	0.003	0.871	0.667	0.704	0.362	0.949	0.705
8	43.90	36.29	0.011	0.467	0.318	0.278	0.126	0.960	0.787
9	53.55	36.50	0.002	0.540	0.367	0.335	0.150	0.949	0.873
10	46.48	36.49	0.007	0.968	0.867	0.932	0.651	0.900	0.571
11	50.24	36.34	0.007	0.990	0.915	0.960	0.790	0.925	0.622
12	43.82	36.40	0.011	0.987	0.899	0.944	0.686	0.935	0.651

We present the LS parameter estimates of the log of the monthly inflation rate in Table 4 with the preferred specification of $\hat{m}=8$. The point estimate of the threshold is $\gamma=-0.29$. Thus the TAR splits the regression function depending on whether the variable $Z_t = Ln\pi_t - Ln\pi_{t-12}$ lies above or below -0.29. The first regime is when $Z_{t-1} < -0.29$, occurring when the inflation rate has fallen, remained constant, or has risen by less than -0.29 points over an eight-month period. Approximately 70.6% of the observations rise in this regime.

Table 4

Least Squares Estimates Unconstrained Threshold Model

	Estimates $\hat{m}=8,\ \gamma=-0.29$				Tests for Equality of Individual Coefficient	
	$Z_{t-1}<-0.29$		$Z_{t-1}>-0.29$		Wald Statistics	Bootstrap p. Value
	Estimate	s.e.	Estimate	s.e.		
Constant	0.158	0.097	-0.009	0.046	2.426	0.354
π_{t-1}	-0.137	0.057	-0.002	0.036	3.918	0.171
$\Delta\pi_{t-1}$	0.118	0.114	0.332	0.108	1.828	0.310
$\Delta\pi_{t-2}$	0.397	0.128	0.123	0.101	2.796	0.210
$\Delta\pi_{t-3}$	-0.158	0.127	0.116	0.089	3.104	0.181
Δy_{t-4}	-0.020	0.148	0.020	0.085	0.056	0.854
$\Delta\pi_{t-5}$	0.195	0.149	-0.119	0.082	3.413	0.166
$\Delta\pi_{t-6}$	-0.230	0.196	0.117	0.076	2.744	0.212
$\Delta\pi_{t-7}$	-0.048	0.202	0.025	0.072	0.117	0.807
$\Delta\pi_{t-8}$	0.581	0.198	-0.111	0.070	10.82	0.011
$\Delta\pi_{t-9}$	-0.092	0.195	-0.001	0.069	0.194	0.750
$\Delta\pi_{t-10}$	-0.060	0.192	0.024	0.068	0.173	0.768
$\Delta\pi_{t-11}$	-0.158	0.214	-0.067	0.068	0.161	0.768
$\Delta\pi_{t-12}$	-0.051	0.215	-0.315	0.068	10.562	0.012

The tests for the pair wise equality of individual coefficients, and bootstrap *p*-values based on the null hypothesis of no threshold are represented in table 4, too. The point estimates and test results show that the coefficients on $\Delta\pi_{t-1}$ and $\Delta\pi_{t-2}$ are driving the threshold model, with the other coefficients either less important or invariant across regimes. The same results are shown to logistic inflation rate (see table 5).

Table 5

Least Squares Estimates Unconstrained Threshold Model

	Estimates $\hat{m}=8,\ \gamma=-0.29$				Tests for Equality of Individual Coefficient	
	$Z_{t-1}<-0.29$		$Z_{t-1}>-0.29$		Wald Statistics	Bootstrap p. Value
	Estimate	s.e.	Estimate	s.e.		
Constant	-0.462	0.172	-0.021	0.119	4.396	0.199
π_{t-1}	-0.135	0.056	-0.002	0.035	3.944	0.162
$\Delta\pi_{t-1}$	0.117	0.113	0.325	0.107	1.783	0.325
$\Delta\pi_{t-2}$	0.391	0.127	0.121	0.100	2.753	0.220
$\Delta\pi_{t-3}$	-0.157	0.126	0.118	0.089	3.152	0.172
$\Delta\pi_{t-4}$	-0.018	0.147	0.023	0.085	0.060	0.858
$\Delta\pi_{t-5}$	0.188	0.148	-0.119	0.082	3.278	0.176
$\Delta\pi_{t-6}$	-0.233	0.193	0.116	0.076	2.809	0.222
$\Delta\pi_{t-7}$	-0.053	0.199	0.024	0.072	0.133	0.779
$\Delta\pi_{t-8}$	0.569	0.194	-0.110	0.070	10.80	0.010
$\Delta\pi_{t-9}$	-0.082	0.191	-0.001	0.069	0.158	0.780
$\Delta\pi_{t-10}$	-0.061	0.188	0.024	0.068	0.182	0.754
$\Delta\pi_{t-11}$	-0.159	0.210	-0.067	0.068	0.171	0.761
$\Delta\pi_{t-12}$	-1.028	0.211	-0.321	0.068	10.082	0.015

Note: Δ is the first difference operator

In addition, to assess robustness with respect to subsamples, the constrained TAR model with m = 8 was re-estimated on the two subsamples obtained by splitting the sample at its midpoint. They appear to be remarkably stable across the two regimes. We also report the bootstrap *p*-values for the threshold test W_T and the unit root test R_{1T}. On each subsample, the threshold test W_T easily rejects the null hypothesis of linearity in favour of threshold nonlinearity. The unit root tests are split, with the first subsample failure to reject the null hypothesis, while the null hypothesis of a unit root is rejected in the second subsample.

Conclusion

This paper developed a new asymptotic theory for threshold autoregressive models with a possible unit root with an application to the Tunisian inflation rate following caner and Hansen (2001). Our empirical application revealed a very strong evidence to support the hypothesis that the process is a non-stationary non-linear threshold autoregression. It would be useful to generalize our analysis on macroeconomic several series to show the importance of non-stationarity and/or nonlinearity for different studies.

Nevertheless, this paper is concerned with the time series properties of the Monthly inflation rate which dynamic structure has important implications for modelling, testing, and forecasting a macroeconomic policy. Indeed, structural change has a pervasive in economic time series relationships and in this condition; recommendations can be misleading or worse. Furthermore, goods and services market efficiency implies that prices respond quickly and accurately to relevant information.

Further discussion is also left for future research because the smooth transition autoregressive (STAR) models are extensively used in econometrics.

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