The Economic Research Guardian – Vol. 10(2)2020
Semi-annual Online Journal, www.ecrg.ro
ISSN: 2247-8531, ISSN-L: 2247-8531
Econ Res Guard 10(2): 122-143

Inflation Dynamics in Tunisia: a Smooth Transition Autoregressive Approach

Wissem Boukraine
University of Tunis El Manar, Faculty of Economic Science and Management of Tunis, Tunis, Tunisia
E-mail: boukrainewissem@gmail.com

Abstract
The aim of this paper is to assess the effectiveness of the Tunisian monetary reforms. We use a smooth transition autoregressive model STAR in order to analyze inflation dynamics in Tunisia, based on the evolutions of its persistence and its volatility, on monthly data from 1990 to 2020. We distinguish three sub-periods based on two monetary reforms: the declaration of price stability as the central bank first priority in 2006 and the adoption of a proactive monetary policy aimed at anticipating inflation in 2011. The main findings suggest that the ESTAR specification describes better the behavior of inflation, it also show changes in the persistence and important shifts in volatility reinforcing the effectiveness of the monetary reforms despites political instability and the democratic transition in Tunisia. But still, more reforms are required for a fully commitment to a specific inflation target, as it will reinforce the Tunisian central bank credibility.

Keywords: Inflation, persistence, volatility, Smooth Transition Autoregressive, Tunisia

JEL classification: C24, E31

Received: 26 July 2020; Received in revised form: 25 October 2020; Accepted: 29 October 2020

1. Introduction

The global economy witnessed a significant fall in inflation since the seventies as central banks adopted several reforms in order to stabilize prices. High inflation levels weakens investor confidence, discourage saving and slows economic growth, while extremely low inflation limit the central bank ability to stimulate demand. But one thing is certain inflation deteriorates the purchasing power which feeds social tension. The latter is an important fact for the Tunisian economy cradle of the Arab spring revolutions, since it still suffers from its main drivers; high unemployment rates and low real wages. In addition, the fact that inflation is still on the rise, despite measures undertaken by the Tunisian central bank, prompts questions as to whether or not inflation dynamics has changed, exhibiting higher levels of persistence and volatility. Analyzing inflation dynamic has important implications for the design of economic policies in general and the conduct of monetary policy in particular.

During the last decade, inflation blurred the line between lower and middle class in Tunisia and keeps threatening the success of the democratic transition as social tensions rises with each painful restrictive monetary policy. In this context, understanding inflation's dynamics through the evolution of its persistence and volatility becomes interesting, especially in light of monetary reforms undertaken by the Tunisian's central bank. Indeed, until 2005 the central bank of Tunisia perused several objectives at once in a discretionary way and adopted price stability as its main goal only in 2006. But it didn't really pursue a proactive monetary policy aimed at anticipating inflation until 2011, with the establishment of a corridor to its main interest rate. In the same year political turbulence hit the country; the Tunisian economy experienced an inflation that kept rising to unprecedented levels in the last two decades.

In this paper we use a Smooth Transition Autoregressive approach STAR, we test for nonlinearity to analyze the evolution of the Tunisian inflation's dynamics in terms of persistence and volatility. The Smooth Transition Autoregressive Model STAR was developed by Teräsvirta (1994), but if the term "smooth transition" was first introduced by Bacon and Watts (1971) explaining fluctuations with econometric nonlinear modeling goes back to Kaldor (1940). The analysis of inflation dynamics in a nonlinear fashion will make it possible to distinguish between two regimes with different inflation levels and volatility. While dividing the sample in three different sub-periods following each monetary reform will offer us insight on the impact of these reforms on the dynamics of inflation through the evolution of its persistence and volatility. We will also be able to determine the threshold level of inflation and the speed of transition between regimes in each sub-period. In doing so, we assess the effectiveness of the Tunisian monetary reforms through its impact on inflation persistence and volatility. Economic literatures suggest that attaching primary importance to price stability can reduce inflation persistence (Gerlach and Tillman, 2012; Walsh, 2009), while less persistence is associated with less volatility (Cogley and Sargent, 2002; Amano, 2007).

No work has been done on inflation persistence using STAR models in particular for the case of Tunisia to our knowledge. Most studies focus either on the relation of inflation with other macroeconomic variables or just identify inflation nonlinearity. Therefore, we will try to not only estimates inflation persistence and volatility but to also push the analysis further by assessing the impact of monetary reforms on the evolution of inflation persistence and volatility. The lack of studies on inflation dynamics for Tunisia in a non-linear context, especially during the coexistence of important monetary reforms with unprecedented political turmoil, motivates us to fill this gap. Our contribution is an attempt to analyze the evolution of both volatility and persistence following each major monetary reform in the last three decades and their effectiveness even in the presence of political turmoil and democratic transition. The paper is organized as follows. Section 2 presents the theoretical and empirical review. Section 3 contains the research methodology and section 4 details the results, while Section 5 is dedicated to the conclusion and recommendations..

2. Theoretical and empirical review

Inflation's impact on the economy is somehow controversial; it depends on the inflation level, the phase of the business cycle in which the economy is and the central bank's actions. Generally speaking, inflation redistributes wealth in a distorted way; punishes some while favoring others. Cukierman and Leviatan (1992) argue that the lack of monetary policy credibility slows the stabilization process which leads to more inflation persistence.

In its reduced form interpretation, persistence is related to the sacrifice ratio which is the output costs of lowering inflation; while in its structural form interpretation, persistence is related to economic sources like marginal costs, output gap or monetary policy reaction function to shocks. Inflation volatility increase uncertainty which induces risk premia, hedging costs and distort wealth redistribution. On one hand higher persistence weakens the monetary transmission mechanism ability of monetary policy to stabilize inflation relative to output; on the other hand higher inflation volatility hampers economic growth with uncertainty.

Inflation tends to be persistent when the rate of change of price level shows a tendency to stay constant in the absence of shocks (Fuhrer, 2010). In the early eighties Gordon, King and Modigliani (1982) introduce the concept of sacrifice ratio, which means that lowering inflation requires losing output. But for Gordon (1982) inflation inherit persistence not only from real activity but also from its own past by including lags in an accelerationist Phillips curve. According to Cecchetti and Debelle (2006) and Mishkin (2007) the more inflation is persistent the more it is costly for the central bank to stabilize it.

For the Tunisian case, most research do not focus on inflation dynamics in itself but rather on its relation with other macroeconomic variables like the impact of inflation on the purchasing power (Rouissi and Frioui, 2014), the inflation–economic growth nexus (Boujelbène and Helali, 2017), the relationship between inflation and trade openness (Ben Jedidia et al, 2019) and the dynamic links between the exchange rate and inflation (Romdhane et al, 2019).

Few exceptions close to the methodology we use in this paper exist. Ben Ali and Ben Mim (2011) using generalized method of moments estimation over the period 1980-2009 for Algeria, Bahrain, Iran, Morocco, Oman, Saudi Arabia, Tunisia and the United Arab Emirates. They found that lagged inflation has an important and significant effect on present inflation. Khmiri and Ben Ali (2013) identified a low and a high inflation regime for the Tunisian economy using a Markov-switching regime model over the period 2001to 2009. Another attempt to tackle the issue of inflation dynamics in a nonlinear context was made by Ftiti et al. (2015) using an evolutionary spectral approach over the period 1987 to 2011. The authors found that inflation followed a stable regime, when its level is higher than 5%, since the adoption of price stability as an ultimate goal by the central bank but still suffers from a high persistence. Boujelbène and Helali (2016) used an unrestricted two-regime threshold autoregressive model with an autoregressive unit root over the period 1994 to 2011. They found evidence for the existing of a threshold and non-linearity in inflation.

3. Research methodology

Smooth transition models STR are state-dependent, nonlinear time series models, where the variable varies between two extreme regimes. In the case of smooth transition autoregressive model STAR, predetermined variables are lags of the dependent variable and regimes are endogenously determined.

$$y_t = \sum_{j=0}^{m-1} 1_j(s_t; c, \gamma)\, Z_t' \delta_j + X_t \alpha + \epsilon_t \qquad (1)$$

The Economic Research Guardian – Vol. 10(2)2020
Semi-annual Online Journal, www.ecrg.ro
ISSN: 2247-8531, ISSN-L: 2247-8531
Econ Res Guard 10(2): 122-143

$1_j(.)$ is a $(0,1)$ regime indicator depending on the observed variable s_t, c is one or more thresholds, $\gamma > 0$ is the slope parameter of threshold, Z denotes the variables with varying coefficients across the m regimes and X are the variables with regime invariant coefficients. Restricting ourselves to $m = 2$, as using the fact that $1_j(.) = 1$ for exactly one j, equation (1) can be rewritten as:

$$y_t = 1_0(s_t; c, \gamma)Z_t'\delta_0 + 1_1(s_t; c, \gamma)Z_t'\delta_1 + X_t\alpha + \epsilon_t$$
$$= \big(1 - 1_1(s_t; c, \gamma)\big)Z_t'\delta_0 + 1_1(s_t; c, \gamma)Z_t'\delta_1 + X_t\alpha + \epsilon_t \quad (2)$$

To construct the two-regime STAR model, the indicator function must be replaced with a continuous transition function G that returns values between 0 to 1. Then, we have:

$$y_t = \big(1 - G(s_t; c, \gamma)\big)Z_t'\delta_0 + +G(s_t; c, \gamma)Z_t'\delta_1 + X_t\alpha + \epsilon_t \quad (3)$$

where, G has different properties as $s \longrightarrow -\infty$, $s \longrightarrow +\infty$ and $s = c$, depending on the specific functional form. The key modeling choices in, are the choice of the threshold variable s and the selection of a transition function G . For a given s and G , we may estimate the regression parameters $(\delta_0, \delta_1, \alpha)$ and the threshold values and slope (c, γ) with nonlinear least squares.

Additionally, given a list of candidate variables for s, we can select a threshold variable using model selection techniques. Smooth transition autoregressive models was initially introduced by Bacon and Watts (1971) and later popularized by Teräsvirta (1994, 1998). Common transition function choices are given by: Logistic LSTAR, Normal NSTAR, Exponential ESTAR and Logistic, second-order L2STR. Choosing the right transition function is based on Teräsvirta (1994) linearity tests on the first-order Taylor approximation and will be the subject of the following section.

4. Results

Data is retrieved from the international monetary fund and the Tunisian national institute of statistics. We start by a sample covering the period 1990M01 to 2020M03 for the Tunisian consumer price index monthly frequency, year-on-year evolution and test for unit root with the breakpoint unit root test following Perron (1989). This specific procedure is justified by the need to take into account the structural breaks in the inflation series following previous work. In fact, Bleaney (2001) affirms that structural breaks induce shifts in the inflation mean, while for Levin and Piger (2004) and Cecchetti and Debelle (2006) inflation persistence estimates are biased in the presence of structural breaks.

The Economic Research Guardian – Vol. 10(2)2020
Semi-annual Online Journal, www.ecrg.ro
ISSN: 2247-8531, ISSN-L: 2247-8531
Econ Res Guard 10(2): 122-143

Table 1: Breakpoint unit root test

	Akaike information criterion				Hannan-Quinn information criterion			
	Intercept	Trend and intercept			Intercept	Trend and intercept		
		Intercept	Trend intercept	Trend		Intercept	Trend intercept	Trend
Break	91M7	91M7	91M3	92M1	91M7	91M7	91M3	92M1
Stat	-16.106	-16.221	-16.216	-15.980	-16.106	-16.221	-16.216	-15.980
P-value	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
Critical values								
1%	-4.949	-5.348	-5.719	-5.067	-4.949	-5.348	-5.719	-5.067
5%	-4.444	-4.860	-5.176	-4.525	-4.444	-4.860	-5.176	-4.525
10%	-4.194	-4.607	-4.894	-4.261	-4.194	-4.607	-4.894	-4.261

The inflation series is stationary in first difference; in fact all the p-value < 0.01 with both Akaike and Hannan-Quinn information criterion, for more detail see Table A1 in the appendix. The Break Selection is based on the minimization of Dickey-Fuller t-statistic. Now we exclude the break dates and determine the optimal lag length for the period 1993M4 to 2020M3.

Table 2: VAR Lag Order Selection Criteria

Lag	LogL	LR	FPE	AIC	SC	HQ
13	-71.51437	65.62272*	0.099266*	0.527866*	0.691232*	0.593073*

* indicates lag order selected by the criterion.

Table 2 indicates that 13 is the optimal lag which minimizes the log likelihood (LogL) following the sequential modified LR test statistic (LR), the final prediction error (FPE), the Akaike information criterion (AIC), the Schwarz information criterion (SC) and the Hannan-Quinn information criterion (HQ). Now we proceed by including these lags in our estimation. Estimating STAR model requires determining the value of the constant and the delay parameters. According to Teräsvirta (1998) the delay parameter is determined by the smallest *p-value* of LM statistic.

Table 3: Linearity Tests

Null Hypothesis	F-statistic	d.f	p-value
H04: b1=b2=b3=b4=0	1.555562	(39, 297)	0.0229
H03: b1=b2=b3=0	1.555562	(39, 297)	0.0229
H02: b1=b2=0	1.487646	(26, 310)	0.0627
H01: b1=0	1.393612	(13, 323)	0.1604
Terasvirta Sequential Tests			
H3: b3=0	1.614696	(13, 297)	0.0801
H2: b2=0 | b3=0	1.550787	(13, 310)	0.0984
H1: b1=0 | b2=b3=0	1.393612	(13, 323)	0.1604
Escribano-Jorda Tests			
H0L: b2=b4=0	1.224651	(26, 284)	0.2125
H0E: b1=b3=0	1.108525	(26, 284)	0.3299

The H0i test uses the i-th order Taylor expansion (bj=0 for all j>i) and all tests are based on the third-order Taylor expansion (b4=0).The linearity test is rejected for both the LSTAR hypothesis (($\varphi 4$ = 0) is rejected) and ESTR (hypothesis ($\varphi 3$ = 0) is rejected) models. But, the Escribano-Jorda Tests suggests the ESTAR model with nonzero threshold (Pr(H0L) < Pr(H0E) with Pr(H0L) >= 0.05).

In order to analyze inflation's dynamic we divide the sample in three periods. The first one from 1993M04 to 2006M3, a month before Tunisian's central bank declares that price stability is its first priority; the second period starts in 2006M4 and ends 2010M12 just before the Tunisian central bank adopt a proactive monetary policy aimed at anticipating inflation. The third period range from 2011M1 to 2020M03 and starts with the establishment of a corridor by the Tunisian central bank to its main interest rate. Also the third period coincides with the political turmoil which triggered the democratic transition in Tunisia in particular and the Arab spring in general.

The three periods do not contain structural breaks as shown by the CUSUM test (see Figures 1, 3 and 5 in the appendix) of Brown et al. (1975). The smooth transition estimation is carried with HAC (Newey West) covariance method using observed Hessian to overcome serial correlation and heteroskedasticity.

The choice of the transition lag and the fluctuations in each regime are based on the sum of squared residuals. The persistence level is determined as the sum of the threshold lag's coefficients in both regimes.

Table 4: Smooth Threshold Regression for the period 1993M04 2006M03

Variable	Coefficient	Std.Err	t-Statistic	Prob	Coefficient	Std.Err	t-Statistic	Prob
	Threshold Variables (linear part)				Threshold Variables (nonlinear part)			
INF(-1)	3.928602	1.683864	2.333087	0.0212	-2.861322	1.675837	-1.707399	0.0902
INF(-2)	-4.250093	2.582365	-1.645814	0.1023	4.127673	2.574851	1.603073	0.1114
INF(-3)	4.200745	1.843138	2.279126	0.0243	-4.122777	1.859444	-2.217209	0.0284
INF(-4)	-3.812364	1.243834	-3.065011	0.0027	3.911003	1.244366	3.142968	0.0021
INF(-5)	2.314489	1.471865	1.572487	0.1183	-2.606548	1.481612	-1.759265	0.0809
INF(-6)	-3.878271	1.700140	-2.281148	0.0242	3.877584	1.671818	2.319382	0.0220
INF(-7)	-0.160853	1.203904	-0.133610	0.8939	0.383510	1.228607	0.312150	0.7554
INF(-8)	7.956861	5.262577	1.511970	0.1330	-8.139965	5.270703	-1.544379	0.1250
INF(-9)	-3.178675	1.501754	-2.116642	0.0362	3.427017	1.483066	2.310766	0.0225
INF(-10)	-5.149208	3.296567	-1.561991	0.1208	5.052754	3.322141	1.520933	0.1308
INF(-11)	3.309294	1.382077	2.394436	0.0181	-3.548145	1.420534	-2.497755	0.0138
INF(-12)	-4.322209	1.921903	-2.248921	0.0262	4.113741	1.944879	2.115166	0.0364
INF(-13)	4.358613	2.008320	2.170278	0.0318	-3.988340	2.023175	-1.971327	0.0509
					R^2	0.962297	Mean dep var	3.384615
cons	0.175521	0.085166	2.060916	0.0414	$\bar{R}^2$	0.953984	S.D. dep var	1.31596
					SER	0.282291	AIC	0.474366
γ	8.313155	3.489337	2.382446	0.0187	$\sum\sigma^2$	10.12037	SC	1.041326
					Log L	-8.000553	HQC	0.704641
c	5.196624	0.097033	53.55534	0.0000			DW stat	2.069509
					F-stat	115.7653	Prob (F-stat)	0.000000

The Economic Research Guardian – Vol. 10(2)2020
Semi-annual Online Journal, www.ecrg.ro
ISSN: 2247-8531, ISSN-L: 2247-8531
Econ Res Guard 10(2): 122-143

Table 4 show that the threshold variable c chosen for the period 1993M04 2006M03 is the inflation's third lag. In this first period the slope γ or speed of transition between both regimes is 8,31, for more details see Table A3 in the appendix. Persistence in this period is 0,08 and the transition occurs when inflation is over 5,2%.

It is worth noticing that 90,38% of the data in this period are below the threshold and fit into the first regime, while 9.62% are in the second regime. Both regimes have a significant difference in fluctuations; the sum of squared residuals in the first one is 9,59% and 0,53 in the second one (see Table A4 in the appendix for more details).

The second period range from 2006M04 to 2010M12, it start with the adoption of price stability as main goal by the Tunisian central bank and ends before its pursuing of a proactive monetary policy aimed at anticipating inflation.

Table 5: Smooth Threshold Regression for the period 2006M04 2010M12

Variable	Coefficient	Std.Err	t-Statistic	Prob	Coefficient	Std.Err	t-Statistic	Prob
	Threshold Variables (linear part)				Threshold Variables (nonlinear part)			
INF(-1)	0.730690	0.303880	2.404539	0.0231	0.457803	0.403364	0.129644	0.8978
INF(-2)	-0.450919	0.370601	-1.216725	0.2339	0.457803	0.433377	1.056363	0.2998
INF(-3)	1.240503	0.618853	2.004518	0.0548	-0.920417	0.702578	-1.310057	0.2008
INF(-4)	-3.451624	1.087028	-3.175286	0.0036	3.413596	1.115247	3.060844	0.0048
INF(-5)	2.946144	1.369874	2.150667	0.0403	-2.796056	1.477822	-1.892011	0.0689
INF(-6)	-0.751476	0.650038	-1.156048	0.2574	0.562351	0.822060	0.684076	0.4996
INF(-7)	-0.059495	0.624194	-0.095315	0.9247	0.296277	0.735414	0.402871	0.6901
INF(-8)	0.130810	0.635012	0.205997	0.8383	-0.245557	0.711652	-0.345052	0.7326
INF(-9)	-1.649768	0.860907	-1.916314	0.0656	1.697657	0.897483	1.891576	0.0689
INF(-10)	0.828284	0.601957	1.375985	0.1797	-0.987055	0.718803	-1.373192	0.1806
INF(-11)	1.996249	0.785713	2.540686	0.0169	-2.004355	0.800000	-2.505444	0.0183
INF(-12)	0.886884	0.754724	1.175110	0.2498	-1.366542	0.868333	-1.573753	0.1268
INF(-13)	-1.178297	0.671542	-1.754614	0.0903	1.669150	0.693877	2.405543	0.0230
					R^2	0.915680	Mean dep var	3.514035
cons	-0.207008	0.372188	-0.556192	0.5825	$\bar{R}^2$	0.831360	S.D. dep var	0.641271
					SER	0.263343	AIC	0.475977
γ	13.93176	6.553033	2.126001	0.0425	$\sum\sigma^2$	1.941785	SC	1.515425
					Log L	15.43464	HQC	0.879942
c	3.136070	0.028666	109.3988	0.0000			DW stat	2.314850
					F-stat	10.85959	Prob (F-stat)	0.000000

Table 5 show that the threshold variable c chosen for the period 2006M04 2010M12 is the inflation's eleventh lag. In this second period the slope γ or speed of transition between both regimes is 13,93, which is faster than the first period The transition occurs when inflation is over 3,14%, for more details see Table A6 in the appendix.

Also the Persistence in this period is lower and equal -0,01. Only 19,30% of the data in this period are below the threshold and fit into the first regime, while 80.70% are in the second regime. Both regimes have different levels of fluctuations; the sum of squared residuals in the first one is 0,4 and 1,54 in the second one, for more details see Table A7 in the appendix. Inflation's volatility is lower compared to the first period. The monetary reform adopted by central bank of Tunisia in this period reduced considerably inflation's volatility and slightly its persistence

The third period is from 2011M01 to 2020M03; starts with the establishment of a proactive monetary policy, aimed at anticipating inflation, but also coincides with the start of political turbulence in the country. The latter complicated the task for the central bank of Tunisia.

Table 6: Smooth Threshold Regression for the period 2011M01 2020M03

Variable	Coefficient	Std.Err	t-Statistic	Prob	Coefficient	Std.Err	t-Statistic	Prob
	Threshold Variables (linear part)				Threshold Variables (nonlinear part)			
INF(-1)	1.355280	0.244990	5.531989	0.0000	-0.289809	0.279346	-1.037454	0.3026
INF(-2)	0.709472	0.442220	1.604343	0.1125	-1.163965	0.446016	-2.609693	0.0108
INF(-3)	-0.839762	0.180385	-4.655394	0.0000	1.190887	0.257420	4.626247	0.0000
INF(-4)	-0.198091	0.226395	-0.874978	0.3841	0.293176	0.272770	1.074810	0.2856
INF(-5)	0.189572	0.197403	0.960326	0.3397	-0.366886	0.253995	-1.444463	0.1524
INF(-6)	-0.205179	0.129916	-1.579320	0.1181	0.740350	0.180921	4.092126	0.0001
INF(-7)	1.048104	0.305191	3.434259	0.0009	-1.438010	0.331096	-4.343182	0.0000
INF(-8)	-0.456757	0.338252	-1.350346	0.1806	0.385996	0.382407	1.009387	0.3158
INF(-9)	-1.585783	0.588092	-2.696487	0.0085	1.753246	0.591694	2.963096	0.0040
INF(-10)	-0.122236	0.158829	-0.769607	0.4437	-0.010123	0.224393	-0.045114	0.9641
INF(-11)	0.679650	0.168295	4.038445	0.0001	-0.509959	0.252981	-2.015801	0.0471
INF(-12)	0.237653	0.257585	0.922623	0.3589	-0.907071	0.323823	-2.801133	0.0064
INF(-13)	0.220338	0.084765	2.599398	0.0111	0.236145	0.133781	1.765157	0.0813
					R^2	0.976433	Mean dep var	5.047748
cons	0.285698	0.117760	2.426106	0.0175	$\bar{R}^2$	0.968386	S.D. dep var	1.321284
					SER	0.234928	AIC	0.160635
γ	15.01815	3.784429	3.968407	0.0002	$\sum\sigma^2$	4.525669	SC	0.868530
					Log L	20.08477	HQC	0.447807
c	5.135680	0.019375	265.0729	0.0000			DW stat	1.949856
					F-stat	121.3390	Prob (F-stat)	0.000000

Table 6 show that the threshold variable c chosen for the period 2011M01 2020M03 is the inflation's ninth lag. In this last period the slope γ or speed of transition between both regimes is 15,02 (see Table A9 in the appendix for more details), which is the fastest of all three periods. The transition occurs when inflation is over 5,14% higher than the second period.

Also, 56,76% of the data in this period are below the threshold and fit into the first regime, while 43.24% are in the second regime. Both regimes have different levels of volatility; the sum of squared residuals in the first one is 2,59 and 1,94 in the second one (see Table A10 in the appendix for more details). Volatility is slightly higher than its level in the second period but persistence appears to be the highest in all three periods and equal 0,17.

It seems that the proactive monetary policy adopted by the central bank of Tunisia helped slow down the expected rise in inflation's volatility given the unstable political context that accompanied the democratic transition.

Table 7: The monetary reforms impact on inflation dynamics

Monetary policy orientation	Focusing on several objectives		Focusing on price stability		Price stability Proactive policy	
Sub-periods	1993M04 - 2006M3		2006M4 - 2010M12		2011M1 - 2020M03	
Persistence	0,08		−0,01		0,17	
Data in the regime	Regime 1 90,38%	Regime 2 9,62%	Regime 1 19,30%	Regime 2 80,70%	Regime 1 56,76%	Regime 2 43.24%
Volatility	9,59	0,53	0,4	1,54	2,59	1,94
Threshold	5,2%		3,14%		5,14%	
Speed of transition	8,31		13,93		15,02	

As expected the Tunisian central bank adoption of price stability as its main goal in 2006 at the beginning of the second period helped reduce inflation's persistence from 0.08 to -0.01 which confirms what was previously suggested by Gerlach and Tillman (2012) and Walsh (2009). Our results for the first sub-period in terms of high inflation persistence are in accordance with Ben Ali and Ben Mim (2011) despite they used a linear approach. Also the existence of two regimes is in accordance with the results of Khmiri and Ben Ali (2013). In addition, our results confirm that inflation volatility is relatively lower in the second regime for the first and the second sub-period which is in accordance with Ftiti et al. (2015).

Moreover the fall in inflation persistence during the second period was also accompanied by a drop in its volatility as suggested by Cogley and Sargent (2002) and Amano (2007). The last statement was also visible in the third sub-period when the rise in persistence induced more volatility, in fact the political instability through its impact on marginal costs and output gap contributed in raising the persistence of inflation which in turn raised the volatility. But still, during the third sub-period, which starts with the adoption of a proactive monetary policy by the Tunisian central bank, inflation expectations seemed anchored as the two regimes displayed closer level of volatility and data distribution than the previous sub-periods.

5. Conclusion and recommendations

We estimated a smooth transition autoregressive model STAR using monthly data to analyze inflation's dynamics evolution in Tunisia over three periods, through changes in its persistence and volatility. The first period from 1990M03 to 2006M3, just before Tunisian's central bank declares that price stability is its first priority; the second one starts in 2006M4 and ends in 2010M12 at the beginning of the political turbulence and the Arab spring. The third and last period range from 2011M1 to 2020M03.

We found evidence of non-linearity, in fact the non-linearity tests suggested that the ESTAR specification describes better the behavior of inflation in Tunisia. Our main findings are high level of volatility in the first period but a significant drop in the second period, with the adoption

of price stability by the Tunisian central bank as its primary goal. We also found a slight fall in Persistence. In the third period the Tunisian central bank started pursuing a proactive monetary policy aimed at anticipating inflation that kept inflation volatility close to its level in the second period. Unfortunately for the Tunisian economy, 2011 was also the beginning of inevitable political turmoil which complicated the task of the conduct of the monetary policy. Inflation reached unprecedented levels and according to our findings, the evolution of its dynamic, in a non-linear perspective, suggests that both regimes now have close levels of volatility. However, the depreciation of exchange rate, the multiple wage increases and the escalating public debt contribute to maintain inflation at high level. Since the recent multiple revisions of interest rate failed to reduce inflation due to the change in inflation dynamics through the rise in persistence and volatility, despite the early success of the price stability as a main objective, more monetary reforms becomes urgent.
The policy implications we derive from our results are the inevitability of more structural and institutional reforms to make the central bank able to commit to a specific inflation target, as it will reinforce its credibility and efficiency in the conduct of monetary policy.

References

Amano R (2007). Inflation Persistence and Monetary Policy: A Simple Result. *Economics Letters*. 94(1): 26-31.

Bacon D W, Watts D G (1971). Estimating the Transition between Two Intersecting Straight Lines. *Biometrika*. 58(3): 525-534.

Ben Ali M S, Ben Mim S (2011). What drives inflation in MENA countries? *International Journal of Economics and Finance*. 3(4): 119-129.

Ben Jedidia K, Boujelbene T, Helali K (2019). Trade-threshold Effect on Inflation in Tunisia: New Evidence Resulting from a Nonlinear Approach. *International Economic Journal*. 33(1): 149-169.

Bleaney M F (2001). Exchange rate regimes and inflation persistence. *IMF Staff Papers*. 47(3): 387-402.

Boujelbène T, Helali K (2016). A Nonlinear Approach to Tunisian Inflation Rate. *Romanian Economic Journal*. 19(61): 147-164.

Boujelbène T, Helali K (2017). Threshold Effects on the Relationship Between Inflation Rate and Economic Growth in Tunisia. *International Economic Journal*. 31(2): 310-325.

Brown R L, Durbin J, Evans J M (1975). Techniques for testing the constancy of regression relationships over time. *Journal of the Royal Statistical Society*. 37(2): 149–163.

Cecchetti S, Debelle G (2006). Has the inflation process changed? *Economic Policy*. 21(46): 311-352.

Cogley T, Sargent T J (2002). *Evolving Post-World War II U.S. Inflation Dynamics*. In: NBER Macroeconomics Annual, pp. 331-388, National Bureau of Economic Research, Inc.

Cukierman A, Leviatan N (1992). The Dynamic of Optimal Gradual Stabilizations. *The World Bank Economic Review*. 6(3): 439-458.

Fuhrer J C (2010). *Inflation Persistence*. In Friedman B M, Woodford M (Ed.), Handbook of Monetary Economics, pp. 423-486, Elsevier.

Ftiti Z, Guesmi K, Nguyen D, Teulon F (2015). Modelling inflation shifts and persistence in Tunisia: perspectives from an evolutionary spectral approach. *Applied Economics*. 47(57): 6200-6210.

Gerlach S, Tillmann P (2012). Inflation targeting and inflation persistence in Asia– Pacific. *Journal of Asian Economics*. 23(4): 360–373.

Gordon R J, King S R, Modigliani F (1982). The output cost of disinflation in traditional and vector autoregressive models. *Brookings Papers on Economic Activity*. 1982(1): 205–244.

Gordon R J (1982). Price inertia and policy ineffectiveness in the United States, 1890–1980. *Journal of Political Economy*. 90(6): 1087–1117.

Kaldor N (1940). A model of the trade cycle. *Economic Journal*. 50(197): 78 – 92.

Khemiri R, Ben Ali M S (2013). Exchange Rate Pass-Through and Inflation Dynamics in Tunisia: A Markov-Switching Approach. *Economics: The Open-Access, Open-Assessment E-Journal*. 7(43): 1–30.

Levin A T, Piger J M (2004). Is Inflation Persistence Intrinsic in Industrial Economies? *European Central Bank Working Paper Series* No w334.

Mishkin S F (2007). Inflation dynamics. *NBER Working Paper Series* No w13147.

Perron P (1989). The great crash, the oil price shock and the unit root hypothesis. *Econometrica*. 57(6): 1361–1401.

Romdhane Y B, Loukil S, Kammoun S (2019). Targeting Inflation and Exchange Rate Management in Tunisia Before and After the Revolution. *International Journal of Social Science and Economics Invention*. 5(04): 40-47.

Rouissi C, Frioui M (2014). The Impact of Inflation After the Revolution in Tunisia. *Procedia - Social and Behavioral Sciences*. 109(42): 246-249.

Teräsvirta T (1998). *Modelling Economic Relationships with Smooth Transition Regressions*. In Dekker M, (Ed.), Handbook of Applied Economic Statistics, pp. 507- 552, New York.

Teräsvirta T (1994). Specification, Estimation, and Evaluation of Smooth Transition Autoregressive Models. *Journal of the American Statistical Association*. 89(425): 208-218.

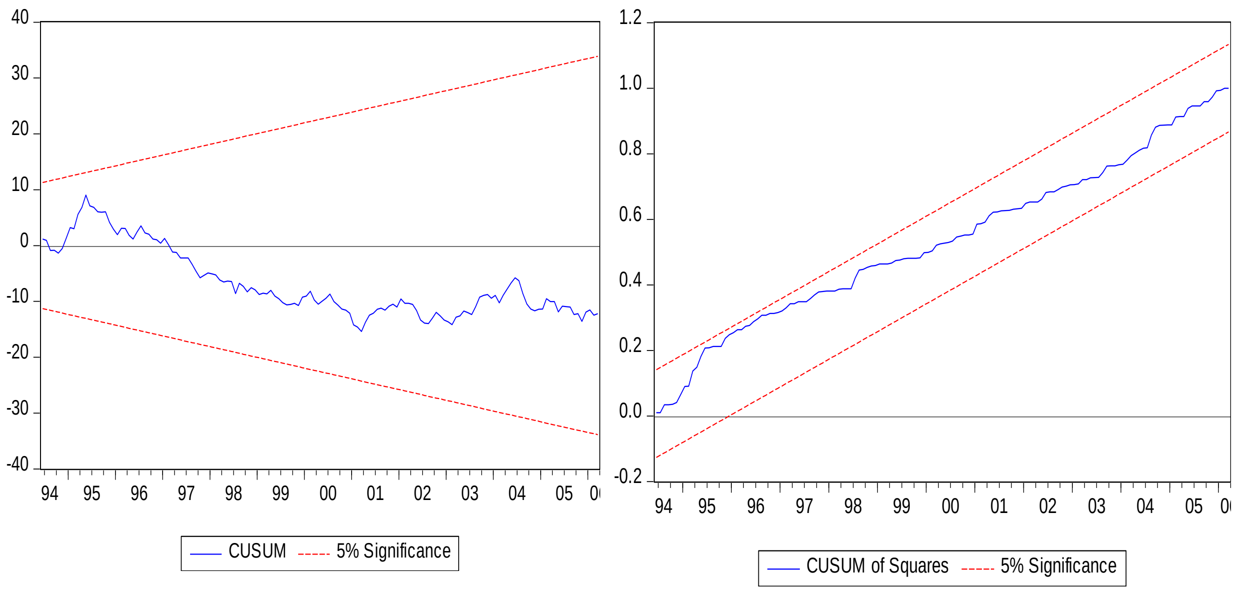
Walsh C E (2009). Inflation Targeting: What Have We Learned? *International Finance*. 12(2): 195-233.

Appendix

Table A1: Breakpoint unit root test Summary Statistics

R^2	0.0678	0.0748	0.0505	0.0346	0.0678	0.0748	0.0505	0.0346
$\bar{R}^2$	0.0600	0.0644	0.0371	0.0265	0.0600	0.0644	0.0371	0.0265
SER	0.3569	0.3561	0.3612	0.3632	0.3569	0.3561	0.3612	0.3632
$\sum\sigma^2$	45.472	45.131	46.317	47.090	45.472	45.131	46.317	47.090
Log L	-138.28	-136.92	-141.60	-144.59	-138.28	-136.92	-141.60	-144.59
F-stat	8.6559	7.1933	3.7741	4.2690	8.6559	7.1933	3.7741	4.2690
Prob F	0.0000	0.0000	0.0024	0.0056	0.0000	0.0000	0.0024	0.0056
M.d.v	-0.0017	-0.0017	-0.0017	-0.0017	-0.0017	-0.0017	-0.0017	-0.0017
S.D.d.v	0.3681	0.3681	0.3681	0.3681	0.3681	0.3681	0.3681	0.3681
AIC	0.7883	0.7863	0.8178	0.8232	0.7883	0.7863	0.8178	0.8232
SC	0.8313	0.8401	0.8824	0.8663	0.8313	0.8401	0.8824	0.8663
HQC	0.8054	0.8077	0.8435	0.8404	0.8054	0.8077	0.8435	0.8404
DW stat	1.9290	1.9294	1.9837	1.9815	1.9290	1.9294	1.9837	1.9815

Figure 1: Stability diagnosis for the first period



The Economic Research Guardian – Vol. 10(2)2020
Semi-annual Online Journal, www.ecrg.ro
ISSN: 2247-8531, ISSN-L: 2247-8531
Econ Res Guard 10(2): 122-143

Figure 2: Threshold weight function with kernel density for the first period

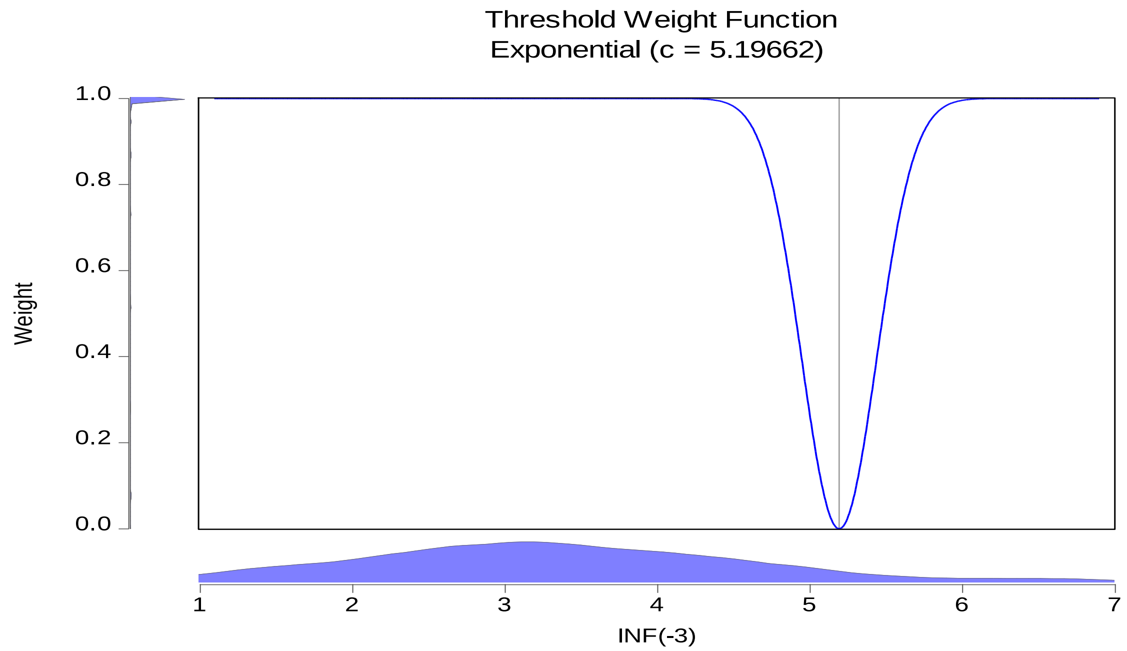


Table A4: Actual fitted residual for the first period

obs	Actual	Fitted	Residual	Residual Plot
1993M04	3.20000	3.64714	-0.44714	| * . | . |
1993M05	3.00000	2.78010	0.21990	| . | *. |
1993M06	3.60000	3.24890	0.35110	| . | .* |
1993M07	4.20000	4.28535	-0.08535	| . *| . |
1993M08	3.90000	4.07645	-0.17645	| .* | . |
1993M09	4.00000	3.92797	0.07203	| . |* . |
1993M10	4.50000	4.00085	0.49915	| . | . * |
1993M11	4.40000	4.37895	0.02105	| . * . |
1993M12	4.20000	4.22698	-0.02698	| . * . |
1994M01	4.40000	4.35370	0.04630	| . |* . |
1994M02	4.50000	4.47378	0.02622	| . * . |
1994M03	4.30000	4.56326	-0.26326	| * | . |
1994M04	5.10000	4.69465	0.40535	| . | . * |
1994M05	5.40000	5.20684	0.19316	| . | *. |
1994M06	4.90000	4.93989	-0.03989	| . *| . |
1994M07	4.80000	4.72696	0.07304	| . |* . |
1994M08	4.40000	4.43044	-0.03044	| . * . |
1994M09	4.60000	4.54233	0.05767	| . |* . |
1994M10	4.30000	4.58508	-0.28508	| * | . |
1994M11	4.70000	4.34324	0.35676	| . | . * |
1994M12	5.30000	5.11516	0.18484	| . | *. |

```
1995M01  5.50000  5.28180   0.21820 |      .  |  *.    |
1995M02  5.30000  5.45001  -0.15001 |      . *|   .    |
1995M03  6.00000  6.00734  -0.00734 |      .  *   .    |
1995M04  6.20000  6.14354   0.05646 |      .  |*  .    |
1995M05  6.60000  6.60447  -0.00447 |      .  *   .    |
1995M06  6.40000  6.67178  -0.27178 |      *  |   .    |
1995M07  6.70000  6.42795   0.27205 |      .  |   *    |
1995M08  6.80000  6.68092   0.11908 |      .  | * .    |
1995M09  6.80000  6.62701   0.17299 |      .  |  *.    |
1995M10  6.90000  6.72680   0.17320 |      .  |  *.    |
1995M11  6.20000  6.43868  -0.23868 |      *  |   .    |
1995M12  5.60000  5.82255  -0.22255 |      .* |   .    |
1996M01  5.10000  5.33888  -0.23888 |      *  |   .    |
1996M02  5.20000  4.96556   0.23444 |      .  |   *    |
1996M03  4.60000  4.44186   0.15814 |      .  | * .    |
1996M04  3.80000  3.80321  -0.00321 |      .  *   .    |
1996M05  3.40000  3.42887  -0.02887 |      .  *   .    |
1996M06  3.80000  3.59137   0.20863 |      .  |  *.    |
1996M07  3.90000  3.56089   0.33911 |      .  |   .*   |
1996M08  3.10000  3.58901  -0.48901 |   *  .  |   .    |
1996M09  2.90000  2.99420  -0.09420 |      . *|   .    |
1996M10  2.90000  2.97146  -0.07146 |      . *|   .    |
1996M11  3.20000  3.15794   0.04206 |      .  |*  .    |
1996M12  3.00000  3.23823  -0.23823 |      *  |   .    |
1997M01  3.40000  3.08158   0.31842 |      .  |   .*   |
1997M02  3.30000  3.47951  -0.17951 |      .* |   .    |
1997M03  3.30000  3.63262  -0.33262 |     *.  |   .    |
1997M04  3.80000  3.69706   0.10294 |      .  | * .    |
1997M05  3.80000  3.84050  -0.04050 |      . *|   .    |
1997M06  3.70000  3.49165   0.20835 |      .  |  *.    |
1997M07  3.80000  3.69100   0.10900 |      .  | * .    |
1997M08  4.10000  4.31112  -0.21112 |      .* |   .    |
1997M09  3.80000  4.03660  -0.23660 |      *  |   .    |
1997M10  3.40000  3.66851  -0.26851 |      *  |   .    |
1997M11  3.60000  3.37378   0.22622 |      .  |  *.    |
1997M12  3.90000  3.58874   0.31126 |      .  |   .*   |
1998M01  3.70000  3.70432  -0.00432 |      .  *   .    |
1998M02  3.60000  3.67900  -0.07900 |      . *|   .    |
1998M03  3.50000  3.62410  -0.12410 |      . * |  .    |
1998M04  3.30000  3.29399   0.00601 |      .  *   .    |
1998M05  3.30000  3.21725   0.08275 |      .  |*  .    |
1998M06  3.30000  3.29357   0.00643 |      .  *   .    |
1998M07  2.50000  3.12770  -0.62770 | *    .  |   .    |
1998M08  2.90000  2.31835   0.58165 |      .  |   .   *|
1998M09  3.10000  3.24041  -0.14041 |      . * |  .    |
1998M10  2.80000  3.18464  -0.38464 |     * . |   .    |
1998M11  2.80000  2.49902   0.30098 |      .  |   .*   |
1998M12  2.80000  2.90516  -0.10516 |      . * |  .    |
```

The Economic Research Guardian – Vol. 10(2)2020

Semi-annual Online Journal, www.ecrg.ro
ISSN: 2247-8531, ISSN-L: 2247-8531
Econ Res Guard 10(2): 122-143


```
1999M01  2.70000  2.92186  -0.22186  |    .* |  .    |
1999M02  2.70000  2.53870   0.16130  |    .  | *.    |
1999M03  2.80000  2.90556  -0.10556  |    . *|  .    |
1999M04  3.00000  2.78198   0.21802  |    .  |  *.   |
1999M05  2.70000  2.97236  -0.27236  |    *  |  .    |
1999M06  2.70000  2.92179  -0.22179  |    .* |  .    |
1999M07  2.80000  2.96148  -0.16148  |    . *|  .    |
1999M08  2.50000  2.61464  -0.11464  |    . *|  .    |
1999M09  2.40000  2.39052   0.00948  |    .  *  .    |
1999M10  2.60000  2.54982   0.05018  |    .  |* .    |
1999M11  2.50000  2.68698  -0.18698  |    .* |  .    |
1999M12  2.90000  2.43448   0.46552  |    .  |  . * |
2000M01  3.10000  3.08271   0.01729  |    .  *  .    |
2000M02  3.40000  3.15610   0.24390  |    .  |  *    |
2000M03  2.90000  3.29000  -0.39000  |   *.  |  .    |
2000M04  2.70000  2.92824  -0.22824  |    *  |  .    |
2000M05  3.10000  2.81764   0.28236  |    .  |  *    |
2000M06  3.20000  3.01121   0.18879  |    .  |  *.   |
2000M07  3.30000  3.13379   0.16621  |    .  |  *.   |
2000M08  3.00000  3.43618  -0.43618  |  * .  |  .    |
2000M09  3.00000  3.21092  -0.21092  |    .* |  .    |
2000M10  2.80000  2.93861  -0.13861  |    . *|  .    |
2000M11  2.70000  2.78374  -0.08374  |    . *|  .    |
2000M12  2.30000  2.44702  -0.14702  |    . *|  .    |
2001M01  1.40000  2.08665  -0.68665  |*   .  |  .    |
2001M02  1.20000  1.40127  -0.20127  |    .* |  .    |
2001M03  1.10000  1.47958  -0.37958  |   *.  |  .    |
2001M04  1.50000  1.14819   0.35181  |    .  |  .*   |
2001M05  1.60000  1.28986   0.31014  |    .  |  .*   |
2001M06  1.70000  1.72989  -0.02989  |    .  *  .    |
2001M07  2.10000  1.87215   0.22785  |    .  |  *    |
2001M08  2.40000  2.33029   0.06971  |    .  |* .    |
2001M09  2.40000  2.46967  -0.06967  |    . *|  .    |
2001M10  2.60000  2.33952   0.26048  |    .  |  *    |
2001M11  2.90000  2.77340   0.12660  |    .  | *.    |
2001M12  3.00000  3.18660  -0.18660  |    .* |  .    |
2002M01  3.80000  3.38452   0.41548  |    .  |  . *  |
2002M02  3.80000  4.05836  -0.25836  |    *  |  .    |
2002M03  3.80000  3.79939   0.00061  |    .  *  .    |
2002M04  3.70000  3.67434   0.02566  |    .  *  .    |
2002M05  3.40000  3.80094  -0.40094  |   *.  |  .    |
2002M06  2.70000  3.18116  -0.48116  |  * .  |  .    |
2002M07  2.10000  2.36143  -0.26143  |    *  |  .    |
2002M08  1.90000  2.07410  -0.17410  |    .* |  .    |
2002M09  2.00000  1.79186   0.20814  |    .  |  *.   |
2002M10  2.20000  1.97061   0.22939  |    .  |  *    |
2002M11  1.90000  2.18989  -0.28989  |    *  |  .    |
2002M12  1.60000  1.85968  -0.25968  |    *  |  .    |
```

Semi-annual Online Journal, www.ecrg.ro
ISSN: 2247-8531, ISSN-L: 2247-8531
Econ Res Guard 10(2): 122-143

2003M01	1.30000	1.40499	-0.10499	| . * | . |
2003M02	1.10000	1.31474	-0.21474	| .* | . |
2003M03	1.40000	0.97086	0.42914	| . | . * |
2003M04	1.50000	1.41993	0.08007	| . |* . |
2003M05	2.00000	1.75970	0.24030	| . | * |
2003M06	2.40000	2.49145	-0.09145	| . *| . |
2003M07	2.70000	2.89498	-0.19498	| .* | . |
2003M08	3.30000	2.81755	0.48245	| . | . * |
2003M09	3.90000	3.29444	0.60556	| . | . * |
2003M10	4.10000	3.90295	0.19705	| . | *. |
2003M11	4.30000	4.15701	0.14299	| . | * . |
2003M12	4.40000	4.57398	-0.17398	| .* | . |
2004M01	4.70000	4.54832	0.15168	| . | * . |
2004M02	4.30000	4.68791	-0.38791	| * . | . |
2004M03	4.50000	4.13737	0.36263	| . | . * |
2004M04	4.80000	4.82396	-0.02396	| . * . |
2004M05	4.90000	4.58254	0.31746	| . | .* |
2004M06	5.00000	4.67801	0.32199	| . | .* |
2004M07	4.70000	4.56885	0.13115	| . | * . |
2004M08	3.70000	3.87552	-0.17552	| .* | . |
2004M09	2.60000	2.61794	-0.01794	| . * . |
2004M10	2.00000	1.80297	0.19703	| . | *. |
2004M11	1.50000	1.71030	-0.21030	| .* | . |
2004M12	1.20000	1.19039	0.00961	| . * . |
2005M01	1.10000	1.19759	-0.09759	| . * | . |
2005M02	1.90000	1.40886	0.49114	| . | . * |
2005M03	1.90000	1.96422	-0.06422	| . *| . |
2005M04	1.80000	1.81700	-0.01700	| . * . |
2005M05	1.20000	1.76550	-0.56550	| * . | . |
2005M06	1.40000	1.15535	0.24465	| . | * |
2005M07	1.60000	1.52115	0.07885	| . |* . |
2005M08	2.00000	1.97942	0.02058	| . * . |
2005M09	2.20000	2.53997	-0.33997	| *. | . |
2005M10	2.70000	2.60991	0.09009	| . |* . |
2005M11	2.80000	3.25176	-0.45176	| * . | . |
2005M12	3.50000	3.00262	0.49738	| . | . * |
2006M01	3.70000	3.52747	0.17253	| . | *. |
2006M02	3.10000	3.31841	-0.21841	| .* | . |
2006M03	3.10000	3.05192	0.04808	| . |* . |

The Economic Research Guardian – Vol. 10(2)2020
Semi-annual Online Journal, www.ecrg.ro
ISSN: 2247-8531, ISSN-L: 2247-8531
Econ Res Guard 10(2): 122-143

Figure 3: Stability diagnosis for the second period

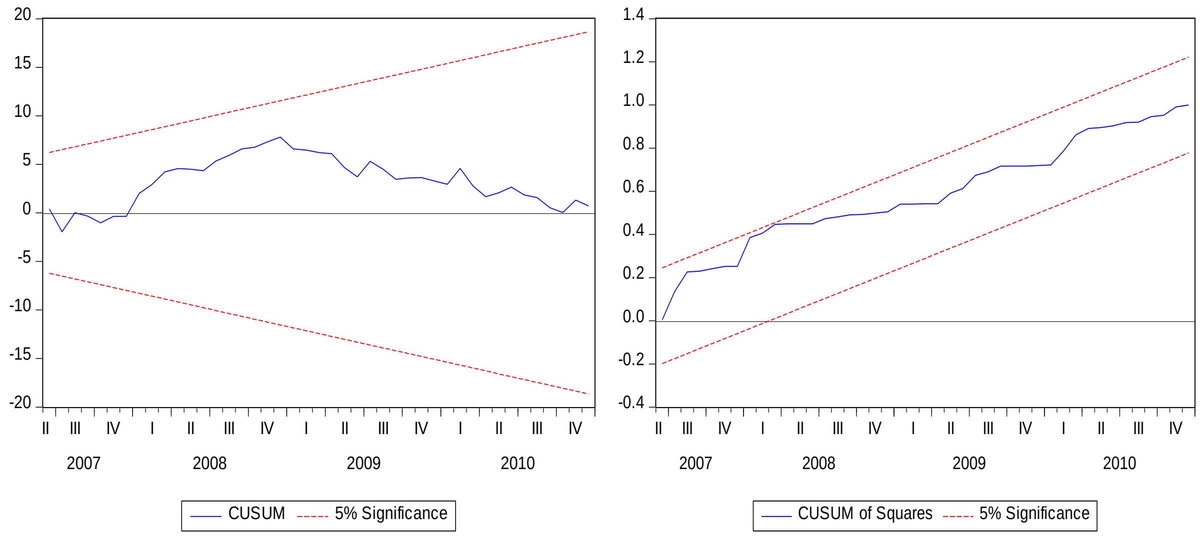
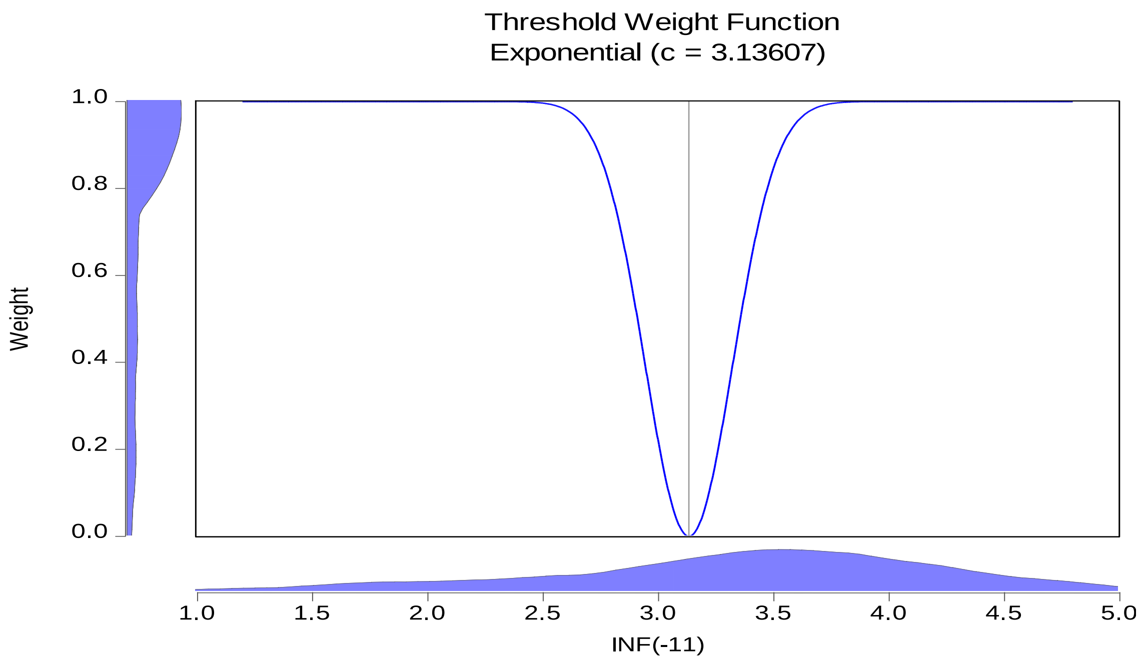


Figure 4: Threshold weight function with kernel density for the second period



Semi-annual Online Journal, www.ecrg.ro
ISSN: 2247-8531, ISSN-L: 2247-8531
Econ Res Guard 10(2): 122-143

Table A7: Actual fitted residual for the second period

<table>
<tr><th>obs</th><th>Actual</th><th>Fitted</th><th>Residual</th><th>Residual Plot</th></tr>
<tr><td>2006M04</td><td>3.40000</td><td>3.40769</td><td>-0.00769</td><td>| . * . |</td></tr>
<tr><td>2006M05</td><td>3.70000</td><td>3.84901</td><td>-0.14901</td><td>| . * | . |</td></tr>
<tr><td>2006M06</td><td>3.40000</td><td>3.52673</td><td>-0.12673</td><td>| . * | . |</td></tr>
<tr><td>2006M07</td><td>3.40000</td><td>3.40750</td><td>-0.00750</td><td>| . * . |</td></tr>
<tr><td>2006M08</td><td>2.90000</td><td>3.40065</td><td>-0.50065</td><td>| * . | . |</td></tr>
<tr><td>2006M09</td><td>3.00000</td><td>2.78587</td><td>0.21413</td><td>| . | * |</td></tr>
<tr><td>2006M10</td><td>3.00000</td><td>3.02688</td><td>-0.02688</td><td>| . * . |</td></tr>
<tr><td>2006M11</td><td>3.10000</td><td>2.96331</td><td>0.13669</td><td>| . | * . |</td></tr>
<tr><td>2006M12</td><td>2.60000</td><td>2.81338</td><td>-0.21338</td><td>| * | . |</td></tr>
<tr><td>2007M01</td><td>2.30000</td><td>2.24033</td><td>0.05967</td><td>| . |* . |</td></tr>
<tr><td>2007M02</td><td>2.00000</td><td>1.99727</td><td>0.00273</td><td>| . * . |</td></tr>
<tr><td>2007M03</td><td>2.10000</td><td>2.26293</td><td>-0.16293</td><td>| .* | . |</td></tr>
<tr><td>2007M04</td><td>2.00000</td><td>1.88923</td><td>0.11077</td><td>| . | * . |</td></tr>
<tr><td>2007M05</td><td>2.70000</td><td>2.67072</td><td>0.02928</td><td>| . * . |</td></tr>
<tr><td>2007M06</td><td>3.30000</td><td>3.31754</td><td>-0.01754</td><td>| . * . |</td></tr>
<tr><td>2007M07</td><td>2.90000</td><td>2.85716</td><td>0.04284</td><td>| . |* . |</td></tr>
<tr><td>2007M08</td><td>3.50000</td><td>3.52345</td><td>-0.02345</td><td>| . * . |</td></tr>
<tr><td>2007M09</td><td>3.70000</td><td>3.68466</td><td>0.01534</td><td>| . * . |</td></tr>
<tr><td>2007M10</td><td>3.40000</td><td>3.38929</td><td>0.01071</td><td>| . * . |</td></tr>
<tr><td>2007M11</td><td>3.70000</td><td>3.44677</td><td>0.25323</td><td>| . | * |</td></tr>
<tr><td>2007M12</td><td>3.90000</td><td>4.02436</td><td>-0.12436</td><td>| . * | . |</td></tr>
<tr><td>2008M01</td><td>4.40000</td><td>4.18725</td><td>0.21275</td><td>| . | * |</td></tr>
<tr><td>2008M02</td><td>4.60000</td><td>4.48576</td><td>0.11424</td><td>| . | * . |</td></tr>
<tr><td>2008M03</td><td>4.70000</td><td>4.52671</td><td>0.17329</td><td>| . | *. |</td></tr>
<tr><td>2008M04</td><td>4.80000</td><td>4.78462</td><td>0.01538</td><td>| . * . |</td></tr>
<tr><td>2008M05</td><td>4.10000</td><td>4.12502</td><td>-0.02502</td><td>| . * . |</td></tr>
<tr><td>2008M06</td><td>3.60000</td><td>3.67720</td><td>-0.07720</td><td>| . *| . |</td></tr>
<tr><td>2008M07</td><td>4.30000</td><td>4.09891</td><td>0.20109</td><td>| . | *. |</td></tr>
<tr><td>2008M08</td><td>4.00000</td><td>4.09811</td><td>-0.09811</td><td>| . * | . |</td></tr>
<tr><td>2008M09</td><td>4.20000</td><td>4.14543</td><td>0.05457</td><td>| . |* . |</td></tr>
<tr><td>2008M10</td><td>4.60000</td><td>4.39256</td><td>0.20744</td><td>| . | *. |</td></tr>
<tr><td>2008M11</td><td>4.40000</td><td>4.28628</td><td>0.11372</td><td>| . | * . |</td></tr>
<tr><td>2008M12</td><td>4.40000</td><td>4.25114</td><td>0.14886</td><td>| . | * . |</td></tr>
<tr><td>2009M01</td><td>3.80000</td><td>4.00034</td><td>-0.20034</td><td>| .* | . |</td></tr>
<tr><td>2009M02</td><td>3.80000</td><td>3.86049</td><td>-0.06049</td><td>| . *| . |</td></tr>
<tr><td>2009M03</td><td>3.90000</td><td>3.87140</td><td>0.02860</td><td>| . * . |</td></tr>
<tr><td>2009M04</td><td>3.70000</td><td>3.85346</td><td>-0.15346</td><td>| .* | . |</td></tr>
<tr><td>2009M05</td><td>3.90000</td><td>4.10851</td><td>-0.20851</td><td>| .* | . |</td></tr>
<tr><td>2009M06</td><td>3.90000</td><td>4.04504</td><td>-0.14504</td><td>| . * | . |</td></tr>
<tr><td>2009M07</td><td>3.90000</td><td>3.52369</td><td>0.37631</td><td>| . | . * |</td></tr>
<tr><td>2009M08</td><td>3.80000</td><td>3.88102</td><td>-0.08102</td><td>| . *| . |</td></tr>
<tr><td>2009M09</td><td>3.30000</td><td>3.60036</td><td>-0.30036</td><td>| *. | . |</td></tr>
<tr><td>2009M10</td><td>3.30000</td><td>3.17889</td><td>0.12111</td><td>| . | * . |</td></tr>
<tr><td>2009M11</td><td>3.40000</td><td>3.43432</td><td>-0.03432</td><td>| . *| . |</td></tr>
</table>

2009M12	3.30000	3.33872	-0.03872	| . *| . |
2010M01	3.60000	3.50677	0.09323	| . | * . |
2010M02	4.10000	3.46027	0.63973	| . | . *
2010M03	3.40000	3.81538	-0.41538	| * . | . |
2010M04	3.10000	3.41760	-0.31760	| *. | . |
2010M05	3.20000	3.15111	0.04889	| . |* . |
2010M06	3.40000	3.16171	0.23829	| . | * |
2010M07	3.20000	3.31928	-0.11928	| . * | . |
2010M08	3.30000	3.39298	-0.09298	| . * | . |
2010M09	3.30000	3.29489	0.00511	| . * . |
2010M10	3.00000	3.11323	-0.11323	| . * | . |
2010M11	3.30000	3.22074	0.07926	| . |* . |
2010M12	3.30000	3.20604	0.09396	| . | * . |

Figure 5 Stability diagnosis for the third period

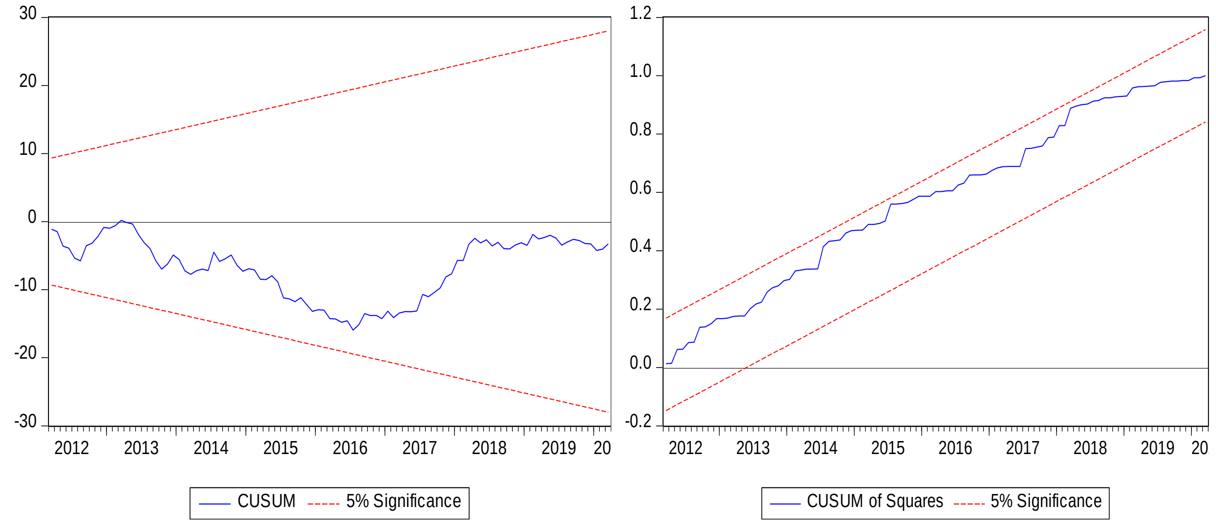


Figure A9: Threshold weight function with kernel density for the second period

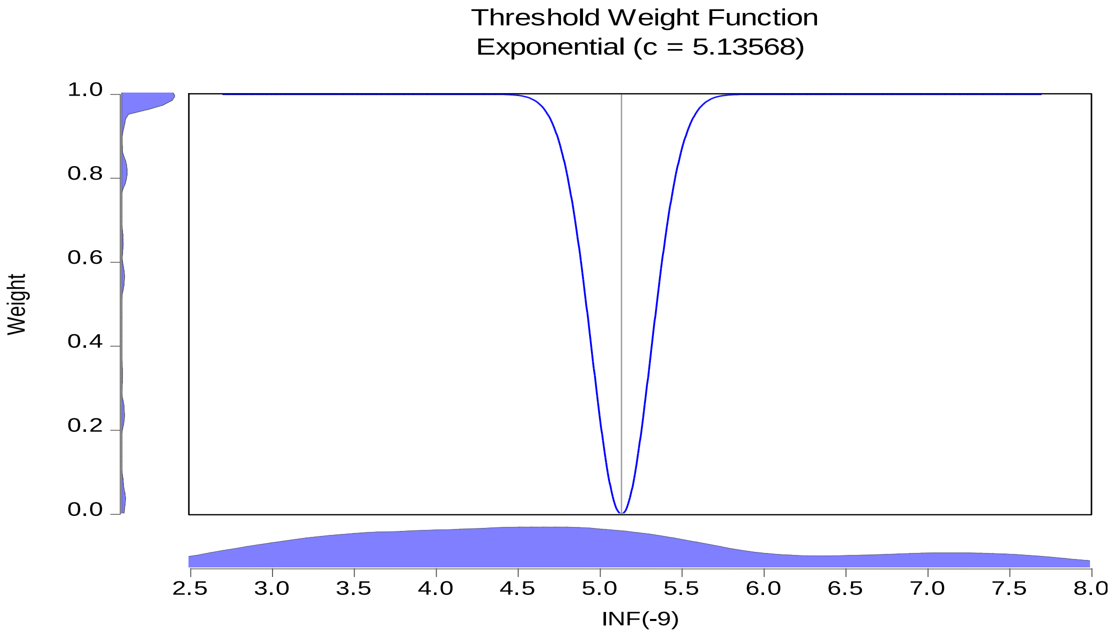


Table A10: Actual fitted residual for the third period

obs	Actual	Fitted	Residual	Residual Plot
2011M01	3.20000	3.10571	0.09429	| . | * . |
2011M02	2.70000	2.93323	-0.23323	| * | . |
2011M03	2.90000	3.16901	-0.26901	| *. | . |
2011M04	3.00000	3.19170	-0.19170	| .* | . |
2011M05	3.00000	3.17308	-0.17308	| .* | . |
2011M06	3.00000	2.93689	0.06311	| . |* . |
2011M07	3.00000	3.19684	-0.19684	| .* | . |
2011M08	3.20000	2.87400	0.32600	| . | . * |
2011M09	3.60000	3.33346	0.26654	| . | .* |
2011M10	4.20000	3.91465	0.28535	| . | .* |
2011M11	3.60000	3.98095	-0.38095	| * . | . |
2011M12	3.30000	3.44101	-0.14101	| . * | . |
2012M01	3.90000	3.57968	0.32032	| . | . * |
2012M02	4.80000	4.54756	0.25244	| . | * |
2012M03	4.60000	4.75594	-0.15594	| . * | . |
2012M04	4.80000	4.59769	0.20231	| . | *. |
2012M05	4.50000	4.82373	-0.32373	| * . | . |
2012M06	4.20000	4.39360	-0.19360	| .* | . |
2012M07	4.40000	4.66393	-0.26393	| *. | . |
2012M08	4.80000	4.98556	-0.18556	| .* | . |
2012M09	4.90000	4.60563	0.29437	| . | .* |
2012M10	4.30000	4.56592	-0.26592	| *. | . |

```
2012M11  4.70000  4.35553   0.34447 |     .   |   . *  |
2012M12  5.40000  5.09838   0.30162 |     .   |   .*   |
2013M01  5.40000  5.35401   0.04599 |     .   |*  .    |
2013M02  4.90000  4.80160   0.09840 |     .   | * .    |
2013M03  5.60000  5.10625   0.49375 |     .   |   .    *
2013M04  5.60000  5.48395   0.11605 |     .   | * .    |
2013M05  5.70000  5.63184   0.06816 |     .   |*  .    |
2013M06  6.00000  6.04030  -0.04030 |     .  *|   .    |
2013M07  5.80000  6.02759  -0.22759 |     *   |   .    |
2013M08  5.10000  5.37214  -0.27214 |    *.   |   .    |
2013M09  4.60000  4.79463  -0.19463 |     .*  |   .    |
2013M10  4.90000  4.73011   0.16989 |     .   |  *.    |
2013M11  5.10000  5.15060  -0.05060 |     .  *|   .    |
2013M12  5.20000  4.92032   0.27968 |     .   |   .*   |
2014M01  4.80000  5.02578  -0.22578 |     *   |   .    |
2014M02  4.50000  4.86906  -0.36906 |   * .   |   .    |
2014M03  3.80000  4.09216  -0.29216 |    *.   |   .    |
2014M04  4.00000  3.98270   0.01730 |     .   *   .    |
2014M05  4.50000  4.51238  -0.01238 |     .   *   .    |
2014M06  4.40000  4.31972   0.08028 |     .   | * .    |
2014M07  5.00000  4.94057   0.05943 |     .   |*  .    |
2014M08  5.00000  5.00080  -0.00080 |     .   *   .    |
2014M09  5.10000  5.18035  -0.08035 |     . * |   .    |
2014M10  5.10000  4.97677   0.12323 |     .   |  *.    |
2014M11  4.80000  5.25764  -0.45764 | *   .   |   .    |
2014M12  4.40000  4.48111  -0.08111 |     . * |   .    |
2015M01  5.00000  4.91415   0.08585 |     .   | * .    |
2015M02  5.30000  5.34213  -0.04213 |     .  *|   .    |
2015M03  5.20000  5.51393  -0.31393 |    * .  |   .    |
2015M04  5.20000  5.29744  -0.09744 |     . * |   .    |
2015M05  4.80000  4.87808  -0.07808 |     . * |   .    |
2015M06  4.50000  4.55081  -0.05081 |     .  *|   .    |
2015M07  3.70000  3.65430   0.04570 |     .   |*  .    |
2015M08  3.80000  3.97072  -0.17072 |     .*  |   .    |
2015M09  3.90000  3.96543  -0.06543 |     .  *|   .    |
2015M10  4.20000  4.19544   0.00456 |     .   *   .    |
2015M11  4.00000  4.04771  -0.04771 |     .  *|   .    |
2015M12  3.80000  3.72711   0.07289 |     .   | * .    |
2016M01  3.40000  3.33633   0.06367 |     .   |*  .    |
2016M02  3.10000  3.21211  -0.11211 |     . * |   .    |
2016M03  3.10000  3.29631  -0.19631 |     .*  |   .    |
2016M04  3.20000  3.21506  -0.01506 |     .   *   .    |
2016M05  3.50000  3.32211   0.17789 |     .   |  *.    |
2016M06  3.60000  3.47441   0.12559 |     .   |  *.    |
2016M07  3.60000  3.86355  -0.26355 |    *.   |   .    |
2016M08  3.60000  3.45415   0.14585 |     .   |  *.    |
2016M09  4.10000  3.66792   0.43208 |     .   |   .  * |
2016M10  4.00000  4.00209  -0.00209 |     .   *   .    |
```

2016M11	4.10000	4.01172	0.08828	| . | * . |
2016M12	4.20000	4.28317	-0.08317	| . * | . |
2017M01	4.70000	4.43879	0.26121	| . | .* |
2017M02	4.70000	4.91118	-0.21118	| * | . |
2017M03	4.90000	4.87093	0.02907	| . |* . |
2017M04	5.00000	4.97363	0.02637	| . |* . |
2017M05	4.80000	4.93800	-0.13800	| . * | . |
2017M06	4.80000	4.83637	-0.03637	| . *| . |
2017M07	5.60000	5.16564	0.43436	| . | . * |
2017M08	5.80000	5.83463	-0.03463	| . *| . |
2017M09	5.50000	5.37087	0.12913	| . | * . |
2017M10	5.70000	5.64142	0.05858	| . |* . |
2017M11	6.10000	5.79328	0.30672	| . | . * |
2017M12	6.20000	6.22286	-0.02286	| . * . |
2018M01	6.60000	6.52205	0.07795	| . | * . |
2018M02	6.80000	7.02080	-0.22080	| * | . |
2018M03	7.20000	6.84998	0.35002	| . | . * |
2018M04	7.50000	7.19681	0.30319	| . | . * |
2018M05	7.50000	7.68675	-0.18675	| .* | . |
2018M06	7.70000	7.65790	0.04210	| . |* . |
2018M07	7.30000	7.53849	-0.23849	| * | . |
2018M08	7.30000	7.13507	0.16493	| . | *. |
2018M09	7.40000	7.73155	-0.33155	| * . | . |
2018M10	7.50000	7.55789	-0.05789	| . *| . |
2018M11	7.40000	7.22127	0.17873	| . | *. |
2018M12	7.50000	7.48516	0.01484	| . * . |
2019M01	7.10000	7.19884	-0.09884	| . * | . |
2019M02	7.30000	6.90255	0.39745	| . | . * |
2019M03	7.10000	7.29507	-0.19507	| .* | . |
2019M04	6.90000	6.78070	0.11930	| . | * . |
2019M05	7.00000	6.79721	0.20279	| . | *. |
2019M06	6.80000	6.91479	-0.11479	| . * | . |
2019M07	6.50000	6.64813	-0.14813	| . * | . |
2019M08	6.60000	6.53126	0.06874	| . |* . |
2019M09	6.70000	6.57220	0.12780	| . | * . |
2019M10	6.40000	6.32953	0.07047	| . | * . |
2019M11	6.30000	6.36813	-0.06813	| . *| . |
2019M12	6.10000	6.12344	-0.02344	| . *| . |
2020M01	5.90000	6.09292	-0.19292	| .* | . |
2020M02	5.80000	5.76680	0.03320	| . |* . |
2020M03	6.10000	5.90488	0.19512	| . | *. |