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Is the Tunisian Central Bank following a Linear or a Nonlinear Augmented Taylor Rule?

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ABSTRACT

The political transition in the Arab spring countries has been accompanied by a deterioration of economic and financial indicators like in the Tunisian case. This paper aims to get a deeper understanding of the nature of the rule that reflects the behavior of the Tunisian monetary authority in the current dominance of economic and financial instability. In particular, this paper assesses whether the Tunisian Central Bank is indeed following a linear or a non-linear augmented Taylor rule. For our purpose, we use a forward looking version of Taylor rule augmented by including the effect of exchange rate to estimate the linear and the nonlinear models. A smooth transition regression model is used to estimate the nonlinear rule. The results obtained imply that the Tunisian Central Bank follows a nonlinear Taylor rule in the conduct of monetary policy. In addition, our evidence suggests that the reaction of monetary authority in Tunisia to the deviation of forecasts of inflation rate, output gap and exchange rate changes in terms of magnitude and statistical significance across the high and low interest rate regimes. In particular, when the lagged interest rate is above the threshold level of 4.76%, the main objective of the policy makers is to fight the inflation rate and to limit the depreciation of exchange rate rather than to boost the economic activity.

Keywords: Taylor Rule, Smooth Transition Regression Model, Interest Rate Reaction Function, Nonlinearity
JEL Classifications: C22, E17, E43, E52, E58

1. INTRODUCTION

Assessing the behavior of monetary authority in response to economic fundamentals is the subject of an intense debate among policymakers. That's way, a number of macroeconomists have been focusing on modeling central bank's reaction function.

The popular reaction function proposed by Taylor (1993), establishes a linear link between the central bank interest rate, inflation and the output gap. It describes how the policy interest rate reacts to the deviation of inflation from its target and to the deviation of output from its potential:

$$i_t = r^* + \pi_t + \theta\left(\pi_t - \pi_t^*\right) + \beta_y y_t \quad (1)$$

where i_t is the short term nominal interest rate that the central bank uses as its monetary policy instrument, r^* is the long run equilibrium real interest rate, π_t^* is the target inflation rate, π_t is the inflation rate, and y_t is the output gap.

The Taylor rule principal requires that the nominal interest rate should react more than proportionally to the deviation of inflation rate and the coefficient of the output gap must be positive to stabilize the monetary policy.

In the standard form of Taylor rule, the central banks use past or current values of inflation and output gap to set up the interest rate. Nevertheless, in reality, they tend to use all available information concerning the expected inflation when sitting the interest rate. That's why Clarida et al. (1998, 2000) have established a forward-looking version of Taylor rule where central bank target the interest rate depending on the expected inflation and the expected output gap instead of their past or current values. In the same line, Huang et al. (2001) and Orphanides (2003) point out that a forward-looking rule is a good indicator for the following monetary policy. Moreover, the baseline Taylor rule was extended by taking into account the effect of other variables other than inflation and output that can affect the implementation of monetary policy. Some studies (Clarida et al., 1998: 2000; Amato and Laubach, 1999; Woodford, 1999; Goodhart, 1997; Sack and Wieland, 2000; Minella et al., 2002; Mohanty and Klau, 2005) suggest to introduce the interest rate smoothing to take into account the inertia of monetary policy. The interest rate smoothing allows the central banks to avoid the erratic fluctuations of interest rate that can disturb the capital markets and affect the confidence of investors. Likewise, Moura and de Carvalho (2010) require that the lagged interest rate is a common practice in many central banks. Furthermore, the traditional Taylor rule has been formulated for a closed economy which makes it inappropriate for open economies exposed to external shocks. In this case, it might be necessary to include other variables such as the exchange rate (Ball, 1999: 2000; Svensson, 2000; Obstfeld and Rogoff, 2000; Taylor, 2002; Leitemo and Söderström, 2005; Ostry et al., 2012; Galimberti and Moura, 2013; Caglayan et al., 2016). Other studies have focused on the role of asset prices and financial variables when setting the behavior of central banks (Cecchetti et al., 2000; Borio and Lowe, 2002; Goodhart and Hofmann, 2002; Chadha et al., 2004; Montagnoli and Napolitano, 2005; Rotondi and Vaciago, 2005; Castro, 2011).

The original Taylor rule is an optimal policy rule that is derived from the minimization of a symmetric quadratic central bank's loss function and the linearity of the aggregate supply function. But, in fact, a central bank can have asymmetric preferences in their loss functions. It might assign different weights to negative and positive deviations of inflation and output gap from their targets. Therefore, the nonlinear specification of Taylor rule seems to be the adequate policy rule to explain the preference of central bank.

The asymmetries in the reaction function of central banks can result either from the nonlinearity of the macroeconomic model (Dolado et al., 2005) or from their own nonlinear preference (Dolado et al., 2000; Favero et al., 2000; Orphanides and Wieland, 2000; Cukierman and Gerlach, 2003; Nobay and Peel, 2003; Ruge-Murcia, 2003; Taylor and Davradakis, 2006 Surico, 2007 and Ahmad, 2016).

Different non-linear models have been used to investigate the nonlinearity of monetary policy such as the Markov-switching model (Kaufmann, 2002, Altavilla and Landolfo, 2005, Assenmacher-Wesche, 2006). This model facilitates the modeling of non-stationarity due to abrupt sudden regime changes in the economy. However, it assumes that the regime switches are exogenous and conducted by an invisible mechanism. Therefore, the Markov-switching model doesn't able to take account the intuition behind the asymmetric policy behavior (Petersen, 2007). Besides, the Markov-switching model is unable to establish whether a central bank follows a point target or a target range or a threshold variable (Castro, 2011).

The nonlinearities in central bank policy rules can be captured also by the threshold autoregressive regression (TAR) models (Bunzel and Enders, 2010). These models provide a strong evidence for significant threshold effects in central banks' reaction functions. The TAR model could be generalized to a smooth transition regression (STR) model, which has been used in the empirical studies on time series (Quandt, 1958; Teräsvirta and Anderson, 1992; Teräsvirta, 1994; Teräsvirta, 1998; van Dijk and Franses, 1999 and van Dijk et al., 2002). Some empirical studies (Martin and Milas, 2004; Petersen, 2007; Castro, 2011) suggest that the STR model allows for endogenous regime switches and offers the economic intuition to understand the asymmetric behavior of central bank. Besides, the STR explains why and when the central bank changes its interest rate policy rule. Therefore, the STR model provides a better structural framework to explain the monetary policy rule according to the economic situation.

Despite the nonlinear specification of Taylor rule seems to be the adequate policy rule to describe the preference of central bank, most of the empirical studies are mainly focused on advanced economies and are limited on developing countries especially on the Arab spring countries. These economies are small and depend on foreign trade which makes them vulnerable to external shocks. On the other hand, the political transition in these countries has been accompanied by a deterioration of economic indicators like in the Tunisian case.

More than 8 years have passed since the Tunisian revolution which heralded the starting point of an era of freedom, dignity and economic growth. Unfortunately, this wasn't the case because the revolution was accompanied by political and economic instability, a deterioration of the security situation, a proliferation of the informal sector and the revision of the salary level, hence, the continued deterioration of economic and financial indicators. The inflation rate has reached levels that Tunisia has not experienced, the Dinar continued to slide and the economic growth continued also to degrade with the current dominance of economic and financial instability, the Tunisian central bank (BCT) may tend to behave differently to respond to economic booms and slumps in the way when it adjusts interest rate policy. Therefore, the linear model of the Taylor rule may be unable to capture the changes in the preferences of monetary authorities over time and to describe the structure of the economy. In the same context, the article 7 of the law n 2016-35 of 25 April, 2016 on the status of the Central Bank of Tunisia assigns as its main objective to ensure the price stability, and to contribute to the financial stability in order to support the economic growth in terms of growth and employment. To achieve its ultimate objective, price stability, the Central Bank of Tunisia uses the interest rate as a privileged instrument for conducting the monetary policy. According to its expectations on inflation and economic growth, the BCT adjusts its key interest rate which affects the financing conditions of all economic agents and consequently on economic growth and price stability via the transmission mechanisms of monetary policy. This implies that monetary policy implemented in Tunisia can follow a forwarded looking version of Taylor rule. Therefore, it is interesting in this paper to detect the nature of the rule that reflects the behavior of the Tunisian monetary authority in response to changes in the economy. In particulars, we assess whether the BCT flows a linear or a nonlinear augmented Taylor rule.

The remainder of the paper is organized as follows. Section 2 and 3 present the econometric methodology and data. The empirical results are discussed in Section 4. Finally, Section 5 contains some concluding remarks.

2. ECONOMETRIC METHODOLOGY

2.1. The Linear Taylor Rule

In this section, we start with the simple version of linear Taylor rule as presented by Qin and Enders (2008) as follows:

$$i_t=\omega+\beta_\pi \pi_t+\beta_y y_t$$
$$\omega=r^*-\theta\pi^* \qquad (2)$$
$$\beta_\pi=1+\theta$$

where *it* is the nominal interest rate, r^* is the long run equilibrium real interest rate, π_t^* is the target inflation rate, π_t is the inflation rate, and y_t is the output gap.

The reaction function expressed by equation 2 can be extended by including an additional variables as the lagged interest rate to take into account the inertia of monetary policy (Clarida et al., 1998: 2000) and the exchange rate (Ball, 1999: 2000; Svensson, 2000; Taylor, 2002) given that the standard form might be inappropriate for open economies exposed to the external shocks like the Tunisian economic. Therefore, the augmented Taylor rule can be written as follows:

$$i_t=\omega+\lambda i_{t-1}+\beta_\pi \pi_t+\beta_y y_t+\beta_e e_t \qquad (3)$$

Where i_t is the nominal short term interest rate, β_π designs the coefficient estimate of inflation rate (π_t), β_y represents the estimate coefficient of output gap (y_t), β_e indicates the estimate of real effective exchange rate (REER) e_t and λ denotesthe degree of interest rate smoothing (i_{t-1}).

The central bank of Tunisia may follow a monetary rule that takes into account future forecast when setting the behavior of the interest rate. Therefore, we choose to estimate a forward looking version of Taylor rule according to Clarida et al. (1998, 2000):

$$i_t=\omega+\lambda i_{t-1}+\beta_\pi E_t \pi_{t+k}+\beta_y E_t y_{t+k}+\beta_e E_t e_{t+k}>0 \qquad (4)$$

where $E_t \pi_{t+k}$ represents the forecast of inflation rate between the period t and $t+k$, $E_t y_{t+k}$ denotes the forecast of output gap, $E_t e_{t+k}$ is the forecast of reel exchange.

Equation 3 indicates the reaction of interest rate to forecasts of inflation, output gap and the REER with an interest rate smoothing term.

2.2. The Non-linear Taylor Rule

Given the possibility of non-linearity in the reaction function of central bank, we also estimate a smooth regression model to detect the asymmetric dynamics in the interest rate rule.

Following the work of Granger and Teräsvirta (1993), Teräsvirta (1998) and van Dijk et al. (2002), a two-regime STR model for a nonlinear Taylor rule can be represented as follows:

$$i_t=w' Z_t+\psi' Z_t G(\eta, c, S_t)+\varepsilon_t \qquad (5)$$
$$t=1\ldots T$$

where Z_t is the vector of the explanatory variables. The parameters $w' = (w_0, w_1, w_2 .... w_h)'$ and $\psi' = (\psi_0, \psi_1, \psi_2 ... \psi_h)'$ denote the linear and nonlinear parts of the model, respectively. The error term is *iid* with zero mean and constant variance, $\varepsilon \sim iid\,(0, \sigma^2)$.

The transition function $G(\eta, c, S_t)$ is continuous and bounded between 0 and 1 depending on the values of the transition variable S_t, the threshold parameter c and the smoothness parameter η.

The transition function can be presented in the form of a logistic STR model (LSTR1) where the transition function is assumed to a logistic function of one-order:

$$G(\eta, c, S_t)=[1+exp(-\eta(S_t-c)]^{-1}, \eta>0 \qquad (6)$$

The logistic function is a monotonically increasing function of s_t. *As* $s_t\rightarrow-\infty$, $G(\eta, c, S_t)\rightarrow 0$ and as $s_t\rightarrow+\infty$, $G(\eta, c, S_t)\rightarrow 1$. The slope parameter η denotes the smoothness of the transition from one regime to another while the location parameter c determines where the transition has taken place.

Another specification of the STR model is the exponential STR (ESTR) model that can take account the transition between regimes if the transition function is exponential:

$$G(\eta, c, S_t)=[1+exp(-\eta(S_t-c)^2)]^{-1}, \eta>0 \qquad (7)$$

where S_t denotes the transition variable, η indicates a slope parameter and $c$is a location parameter. The exponential transition function is symmetrically U-shaped.

As $S_t\rightarrow\pm\infty$ n$G(\eta, c, S_t)\rightarrow 1$ and as $S_t = c$, $G(\eta, c, S_t)\rightarrow 0$. Therefore, the adjustment for deviations of $S_t$above and below c, which can be interpreted as a threshold value, is symmetric, contrary to the logistic function.

Before estimating the nonlinear model, it is important to test whether the behavior of monetary policy can be described by a nonlinear Taylor rule. So, we test the null hypothesis of linearity

(H_0: $\eta = 0$) against the STR model (H_1: $\eta>0$)[1].

Luukkonen et al. (1988) point out that testing the presence of non-linearity is not a simple task, since the model is only identified under the alternative hypothesis of nonlinearity. In particular, η and c are nuisance parameters that are not presented under the null hypothesis of linearity. To solve the problem of identification, Teräsvirta (1998) and van Dijk et al. (2002) demonstrate that transition function can be substituted by its third-order Taylor expansion. Thereby, the auxiliary regression is presented as follows:

$$i_i = \beta_0' z_t + \beta_1' z_t s_t + \beta_2' z_t s_t^{\,2} + \beta_3' z_t s_t^{\,3} + \varepsilon_t^* \qquad (8)$$

So, the null hypothesis of linearity becomes $H_0 : \beta_1^{'} = \beta_2^{'} = \beta_3^{'} = 0$ and the alternative hypothesis is $H_1 : \beta_1^{'} \neq \beta_2^{'} \neq \beta_3^{'} \neq 0$. The null hypothesis of linearity can be tested by Fisher-distribution. Once, the linearity is rejected, we pass to estimate the non-linear model. At this stage, we proceed to choose the suitable transition variable.

1 If $\eta\rightarrow 0$, the logistic transition function converges to 0.5 and the model is linear.
If $\eta\rightarrow\infty$, the LSTR1 model becomes a two regime switching regression model.

Following Teräsvirta (1998), we choose the transition variable which has the lowest P-value (strongest rejection of linearity). After having specified the transition variable, we proceed to select the transition function before estimating the non-linear model.

The decision between a LSTR1 and ESTR model can be made by testing the following three tests based on the auxiliary regression:

$$H_{01}:\beta_3=0/H_{03}:\beta_2=0/H_{03}:\beta_1=0/\beta_2=\beta_3=0 \tag{9}$$

Granger and Teräsvirta (1993) note that LSTR1is selected if the P-value of H_{01} or H_{03} is the lowest; otherwise the ESTR must be chosen. After having chosen the nature of the estimated model, it is necessary to proceed to estimate the nonlinear model and subsequently to test the quality of the residuals resulting from the nonlinear model (ARCH test and autocorrelation test of residuals).

3. DATA

To estimate the monetary policy reaction function of Central Bank of Tunisia (BCT), we rely on quarterly data collected from International Financial Statistics over the period 2000:Q1-2018:Q4.

The inflation rate is calculated from the changes in consumer price index (CPI). The output gap is defined as the difference between actual output measured from the index of industrial production, and potential output which is calculated using Hodrick Prescott filter. The money market rate (MMR) was used as a proxy for the nominal interest rate. Finally, the REER is used as the exchange rate.

All variables are expressed in logarithmic form expect the interest rate. The inflation rate is the difference between the quarterly CPI index and the lagged of CPI from the current CPI.

Following Figure 1, we observe that the general price level was in acceptable levels in 2010. Since 2011, the inflation rate has continued to climb; it rose from 3.6% in 2011 to 7.5% in 2018. Theincrease of the inflation rate is mainly due to the expansion of wage bill without productivity improvement, the rise of international prices (energy, raw materials…) as well as the effect of the depreciation of the Dinar against the main foreign currencies, in particular, the Euro and the Dollar. The continued depreciation of the dinar is closely linked to the strong tension exerted by the demand for foreign currencies by the economic agents, whether there are importers, industrialists or investors. To fight the increase of inflation rate, the BCT, through preventive actions, increased its key rate 4 times between 2012 and 2014, bringing it up from 3.5% in 2012Q_2 to 4.75 % in 2014Q_3. This action contributed to the decrease of consumer prices observed in 2016 where the inflation rate was contained at 4.2% against 6 % in 2013. Likewise, anticipating the resurgence of inflationary pressures, the central bank of Tunisia tightened its monetary policy, and raising its key rate 4 times between 2017 and 2018, by bringing it from 4.25% 2016Q_1 to 6.75% in 2018Q_2.

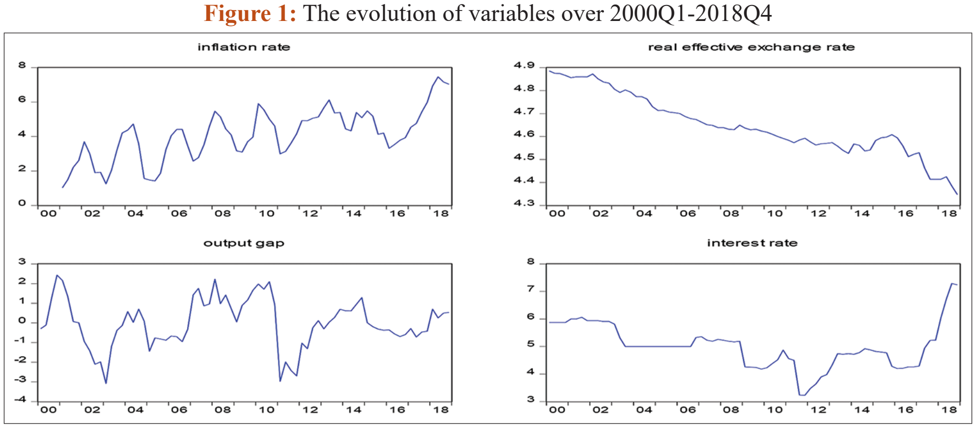
Concerning the output gap, this variable is characterized by a volatility period especially after the revolution of 2011 given that the economic growth has steadily deteriorated. This situation is partly due to the decline of the agricultural sector and the decline of the value added of non-manufacturing industries, in particularly the hydrocarbon sector and mineral extraction (by 3% and 3.3% respectively). The downturn of tourism activity was also the cause of modest growth in 2016. The instability of security and the series of attacks that hit the country in 2015 led to a drop of the tourism receipts. The fall in investments may also explain the weak performance in terms of economic growth. Since 2011, the instability of the security and economic environment have been the causes of unwillingness for investors. Therefore, the investment represented 21.7% in 2016 of GDP in against 23% of GDP in 2011. In the same context, public debt continues to grow, which increased from 40% in 2010 to more than 60% of GDP in 2016. This debt is particularly reflected by loans granted by international organizations, especially the IMF, on favorable terms (long period and low interest rates). However, this debt, usually denominated in foreign currencies, remains a burden to control especially in the current context of Tunisia characterized by a decline of the value of the Dinar, which increases the cost of the debt. The current account balance deficit widened further at unsustainable level, estimated at 11.2% of GDP in 2018.

4. EMPIRICAL RESULTS

4.1. Results of the Linear Taylor Rule

Before proceeding to estimate the Taylor rule, it is necessary to investigate the properties of the series. The KPSS and ADF

Figure 1: The evolution of variables over 2000Q1-2018Q4



stationarity of the variables was tested by standard unit root tests (KPSS and ADF). The results are reported in Table 1.

The KPSS test rejects the null hypothesis of stationarity for inflation rate, interest rate and REER. The same result was obtained by the ADF test which accepts the null hypothesis of unit root for all variables expect for output gap. So, the ADF and KPSS tests show that all variables are non-stationary in levels, expect the output gap. However, the visual inspection of the different variables (Figure 1) shows that the structural breaks might have occurred. Therefore, we carried out two unit root tests taking into account structural breaks, namely Lumsdaine and Papell (LP), 1997 and Lee and Strazicich (LS), 2003. These tests allow for the possibility of up to two structural breaks (Table 2).

In Table 2, the LP test results shows that the inflation rate and the output gap are stationary in levels, contrast to the MMR and the exchange rate which are stationary in first difference. On the other hand, the LS test (2003) results reject the null hypothesis of unit root for all variables, expect the exchange rate variable which has proved to be non-stationary.

The order of integration of the variables specially the interest rates is a litigious problem. Nelson and Plosser (1982) considerate the interest rate as a non-stationary variable. However, Clarida et al. (2000) suggest that such variable should be treated as a stationary variable following several theoretical models. In the same line, Martin and Milas (2004, 2013) and Castro (2011) found that the order of integration of both interest rate and inflation is ambiguous, but they decided to consider them as stationary variables. Therefore, on the basis of the unit root tests, all variables can be treated as I(0),expect the exchange rate.

After having tested the properties of series, we proceed to estimate the linear model using the generalized method of moments (GMM). Following Clarida et al. (1998, 2000), this technique is well suited to analyze the interest rate rules when the regressions are effectuated on unknown variables by the central bank at the time of decision-making. Besides, the GMM model is used to correct the endogeneity problems of the explanatory variables. The time horizons selected for the series presented in the form of expectation is chosen respectively k=0, 1, 2, 3, 4 quarterly. The horizons selected can give a sensible description of the actual way the BCT works.

To forecast the reaction function of equation 3, we choose the instruments that include a constant and the lags 6, 9,12 of each variable i.e., the interest rate, inflation output gap and REER.

The estimation results of forward looking Taylor rule presented in Table 3 show that the BCT reacts significantly to inflation pressure given that the coefficient of the expected inflation rate is significant and positive. However, the estimated value of β_π is less than one during the period of our study, which means, that the BCT's monetary policy doesn't seem to satisfy the Taylor's principle, which exerts a destabilizing effect on inflation. Indeed, the policy makers seem to be concerned about the stabilizing of the output gap given that the coefficient of β_y is positive. Besides, the estimated coefficient of the expected exchange rate is proved to be statistically significant, so the monetary authority gives an importance to the depreciation of exchange rate. Concerning the estimated coefficient of the lagged interest rate is statistically significant and high in magnitude, which means that the BCT adjusts its interest rate with the smoothing parameter.

Table 1: Standard unit root test (without breaks)

	KPSS test		ADF test	
	Intercept	Intercept and trend	Intercept	Intercept and trend
Interest rate(i)	0.44	0.205	–1.38	0.51
Inflation rate(π)	1.09	0.05	–0.45	–2.10
Exchange rate(e)	1.51	0.214	0.31	–1.62
Output gap(y)	0.05*	0.05*	–3.14*	–4.12*
D(e)	0.148*	0.133*	–7.711*	–7.70*
D(i)	0.34*	0.09*	–6.32*	–6.63*
D(π)	0.03*	0.028*	–6.59*	–10.72*
5% Critical value	0.463	0.146	–2.90	–3.47

*Indicates the significance at the 5%. (D) represent the first-difference, D(π) is the first difference of inflation rate. D(e) is the first difference of exchange rate. D(i) is the first difference of interest rate

Table 2: Unit root tests results (with two breaks)

	Lumsdaine and Papell test, 1997				Lee and Strazicich test, 2003			
	Intercept		Intercept and trend		Intercept		Intercept and trend	
	Value	Break dates	Value	Break dates	Value	Break dates	Value	Break dates
Interest rate (i)	–1.69	2003 Q_1 2008 Q_4	–4.90	2011 Q_2 2015 Q_3	–3.59*	2008 Q_4 2017 Q_1	–6.57*	2010 Q_4 2013 Q_4
Inflation rate(π)	–6.82	2010Q_1 2014 Q_3	–8.09	2012 Q_4 2015 Q_4	–4.24*	2006 Q_4 2013 Q_2	–6.39*	2011 Q_3 2015 Q_3
Exchange rate (e)	–2.27	2008 Q_3 2013 Q_4	–5.55	2014 Q_4 2004 Q_3	–2.228	2015 Q_2 2017 Q_1	–4.75	2004 Q_2 2015 Q_1
Output gap(y)	–6.18*	2006 Q_3 2010 Q_3	–7.50*	2003 Q_1 2010 Q_3	–5.05*	2006 Q_4 2010 Q_4	–6.72*	2010 Q_4 2013 Q_2
D(e)	–10.74*	2013 Q_3 2016 Q_1	–11.28*	2013 Q_1 2015 Q_4	–8.59*	2007 Q_4 2015 Q_4	–10.37*	2014 Q_2 2016 Q_2
D(i)	–7.53*	2011 Q_4 2016 Q_2	–8.07*	2011 Q_4 2015 Q_3	-		-	
5% Critical value	–6.16		–6.75		–3.56		–6.16	

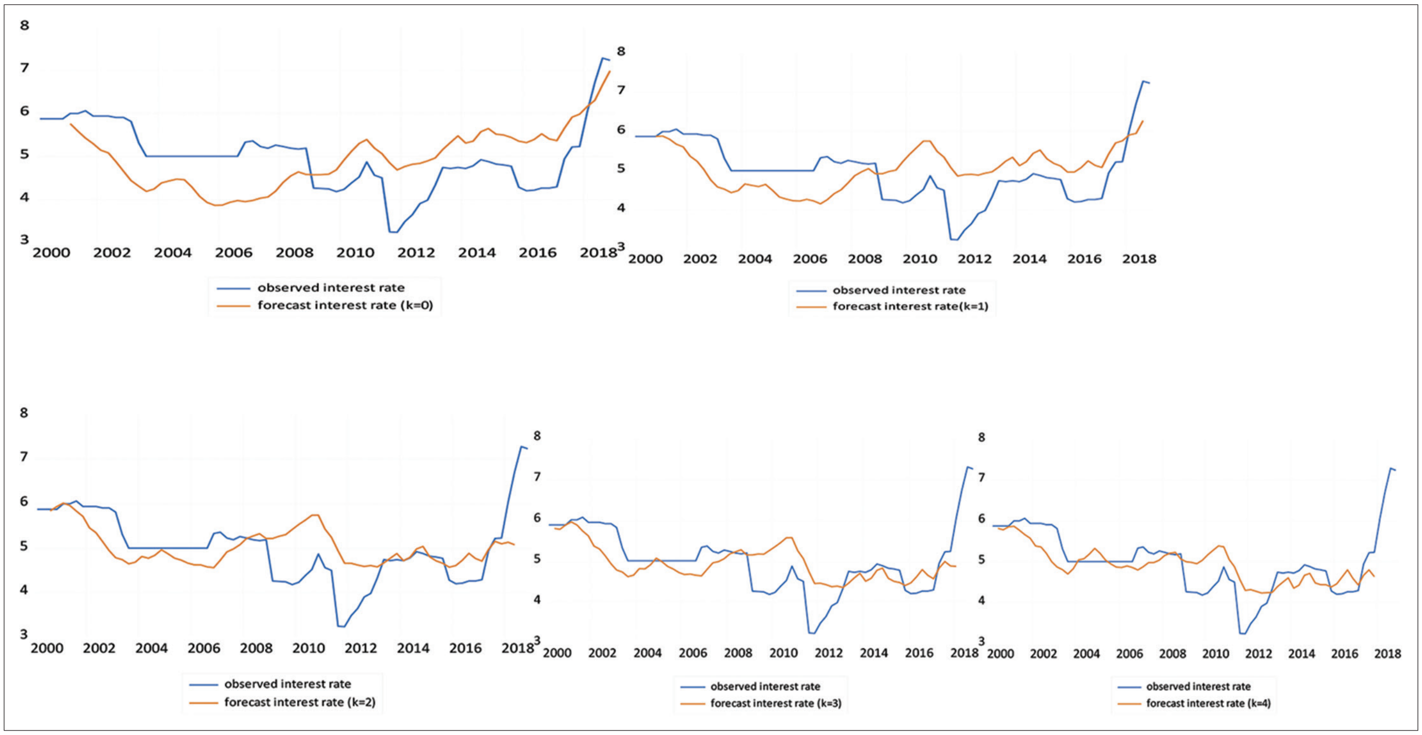
*Indicates the significance at the 5%. (D) represent the first-differences, D(e) is the first difference of exchange rate, D(i) is the first difference of interest rate

Table 3: The estimation results of the linear model

	k=0	k=1	k=2	k=3	k=4
ω	–0.14 (0.31)	–0.02 (–0.47)	0.39 (0.52)	0.58 (0.43)	0.90** (0.42)
λ	0.96 (0.02)	0.959*** (0.07)	0.907*** (0.08)	0.879*** (0.07)	0.835*** (0.06)
β_π	0.06** (0.03)	0.04 (0.03)	0.008 (0.038)	0.008 (0.03)	0.03*** (0.01)
β_e	–0.045*** (–0.01)	–0.054*** (–0.01)	–0.047*** (–0.017)	–0.05*** (–0.01)	–0.05**** (–0.02)
β_y	0.04 (0.02)	0.06** (0.02)	0.08*** (0.03)	0.079*** (0.03)	0.068*** (0.02)
Auto(1)	1.41 (0.23)	2.44 (0.12)	2.43 (0.12)	1.69 (0.19)	2.55 (0.11)
Auto(4)	2.44 (0.12)	0.75 (0.55)	1.59 (0.18)	0.85 (0.49)	0.84 (0.50)
ARCH(1)	1.41 (0.23)	0.12 (0.97)	0.36 (0.54)	0.32 (0.56)	0.35 (0.55)
ARCH(4)	0.11 (0.97)	0.01 (0.91)	0.17 (0.94)	0.22 (0.92)	0.24 (0.90)
Sargan test	0.11 (0.73)	1.03 (0.30)	1.33 (0.24)	1.20 (0.27)	0.55 (0.45)
R-squared	0.899	0.879	0.849	0.852	0.871

***, **, *Represent the statistical significance at the 1%, 5% and 10%, level respectively .Standard errors are given in parentheses. P-values are reported in square brackets. ARCH(1) and ARCH(4) denote the LM test for autoregressive conditional heteroskedasticity of order 1 and 4 respectively. Auto (2) and Auto (4) represent the LM test of residual autocorrelation of order 1 and 4 respectively

Figure 2: Comparative evolution between observed and forecast interest rate during the study period



The validity of the instruments used is proved at a significance level of 5% by the Sargan test. The fit quality of the model is good (the R squared value is close to unity). Finally, there is no evidence of autocorrelation, or heteroskedasticity in the residuals of the estimated linear forward looking Taylor rule.

In the other side, the Figure 2 shows that there is a differentiation between the evolution of the observed and the forecast interest rate during our study period. The linear forward looking cannot describe well the reaction of central bank in reaction to the deviation of variables.

Therefore, the obtained results prove the inability of the linear model to describe the conduct of monetary policy in special events. So, the non-linear model may have a better predictive power and may describe better the setting behavior of BCT.

4.2. Results of the Nonlinear Taylor Rule

According to the results of Table 4 of linearity test, it's clear that BCT follows a nonlinear Taylor rule, hence the rejection of the linear model. This implies that the inflation rate, output gap, exchange rate and the lagged interest rate are related to the non-linear behavior of the BCT.

The interest rate smoothing seems to be the appropriate transition variable given that it has the lowest P-value for the rejection of linearity. The Tunisian monetary authority puts an important weight on this variable given that it allows the central bank to avoid the erratic fluctuations of interest rate that can disturb the capital markets and affect the economic fundamentals. Indeed, LSTR1 is the appropriate nonlinear model selected to describe the central bank's interest rate setting behavior given that has the smallest P-value of F-statistics.

The estimation results of the LSTR1 model are presented in Table 5. We show that there are two regimes characterizing the interest rate policy in Tunisia: A low interest rate regime (linear part) and a high interest rate regime (non-linear part). When the lagged of interest rate is above the threshold level of 4.76% (for k=4 quarterly), the BCT makes a change in its interest rate decision from a low interest rate regime to a high interest rate regime. The transition from one regime to another means that monetary policy instruments do not respond in a classical way to changes in economic fundamentals. The transition speed parameter is statistically significant (15.66) which implies a rapid transition from one regime to another. Besides, the lagged interest rate is statistically significant in both regimes. Its magnitude is higher in the second regime than in the first regime. This result suggests that the Central Bank reacts more aggressively in situations characterized by higher macroeconomic risks.

Indeed, the results of LSTR1 model indicate that the BCT reacts significantly not ably to expected inflation in the high interest rate regime, given that the value of β_π is higher in non-linear part than in the linear part of the model (0.108 against 0.113). Therefore, it's clear that the Tunisian monetary authority is concerned about fighting against expected inflation. But, the coefficient of β_π is less than one, which means thatthe raise of the interest rate by the BCT in response to an expected increase of inflation is not sufficiently. Concerning the expected exchange rate, the policy makers in Tunisia give an importance to the exchange rate stability given that the depreciation of the exchange rate leads to inflationary effects. The coefficients of β_e are statistically significant in both high and low interest rate regime. When the lagged interest rate is above the threshold level of 4.76%, the BCT reacts more to the predictive depreciation of the exchange rate. Regardless of its main preoccupation for inflation, the BCT responds also to the real economy as the coefficient of the predictive output gap is positive and significantly in the linear part as well as in the nonlinear part of the model. However, the monetary authority is more concerned about the expected economic growth than about price stabilization in the low interest rate regime. Therefore, the results obtained reveal that the STR model allows a smooth transition between endogenous regimes (high and low interest rates)according to the economic situation. When the lagged interest rate is above the threshold level of 4.76%, the main objective of the Tunisian monetary authority is to contain the inflationary pressures and the depreciation of exchange rate. However, the BCT's priority is to boost the economic activity when the interest rate smoothing is below the threshold level of 4.76%.

On the other hand, from the obtained estimation results of linear and non-linear regime, we suggest that the Tunisian policy-makers are relatively unconcerned about the month to month deviations of variables and they are instead more concerned about medium- and long-term trends to the deviation of expected inflation, output gap and exchange rate that's why in the analyze we focused on the forecast of fourth quarter horizon (k=4).

According to the Table 4, we can also note that there is no sign of autocorrelation, or heteroskedasticity in the residuals of the estimation results non linear model. Besides, there is no evidence for remaining nonlinearity.

To verify the validity of the estimated results of LSTR1, the Figure 3 shows that the deviation of the observed and the forecast interest rate is almost identical in the different horizons used in our

Table 4: Linearity test results: Linear model/STR models

Transition variable	H_0	H_{01}	H_{02}	H_{03}	Suggested model
Lagged interest rate	0.0147	0.009	0.34	0.68	LSTR1
Inflation rate	0.0409	0.0164	0.1078	0.9442	LSTR1
Exchange rate	0.1173	0.5605	0.0280	0.3955	Linear
Output gap	0.3282	0.6821	0.2338	0.2387	Linear

The table reports the P-values of F statistics; LSTR1: Logistic transition smooth

Table 5: The estimation results of the nonlinear model

	k=0	k=1	k=2	k=3	k=4
Linear model					
ω	–24.67*** (–7.09)	–25.40 (–7.54)	–23.29*** (–7.35)	–23.30*** (–7.61)	–0.53 (–0.84)
λ	0.496*** (0.16)	0.37** (0.17)	0.38** (0.17)	0.47** (0.18)	0.265* (0.15)
β_π	0.037 (0.07)	0.05 (0.07)	0.02 (0.07)	0.01 (0.073)	0.0108* (0.006)
β_e	0.049*** (0.016)	0.04*** (0.01)	0.04*** (0.01)	0.045*** (0.01)	0.06 (0.04)
β_y	0.191*** (0.05)	0.221*** (0.05)	0.20**** (0.04)	0.198*** (0.045)	0.15*** (0.045)
Non-linear model					
ω	25.25*** (7.62)	25.18*** (7.19)	28.00*** (6.89)	27.08 (7.05)	1.07* (0.62)
λ	0.542*** (0.15)	0.485*** (0.15)	0.49*** (0.14)	0.52*** (0.13)	0.64*** (0.13)
β_π	0.209** (0.08)	0.22*** (0.06)	0.17*** (0.06)	0.13** (0.054)	0.13*** (0.04)
β_e	0.05*** (0.015)	0.056*** (0.014)	0.05*** (0.014)	0.054*** (0.014)	0.07*** (0.02)
β_y	0.185** (0.06)	0.19*** (0.05)	0.18*** (0.05)	0.18*** (0.05)	0.137** (0.05)
η	26.16*** (2.87)	29.18*** (3.82)	28.70*** (3.39)	26.79*** (3.04)	15.66*** (2.46)
c	4.80*** (0.05)	4.79*** (0.05)	4.80*** (0.05)	4.80*** (0.04)	4.76*** (0.10)
Auto(1)	2.56 (0.056)	2.57 (0.0617)	2.57 (0.061)	2.58 (0.053)	2.57 (0.063)
Auto(4)	0.43 (0.806)	0.35 (0.87)	0.47 (0.77)	0.31 (0.899)	0.32 (0.876)
ARCH(1)	0.08 (0.77)	0.01 (0.91)	0.01 (0.92)	0.01 (0.93)	0.21 (0.64)
ARCH(4)	1.08 (0.89)	0.01 (0.91)	0.02 (0.935)	0.36 (0.98)	0.77 (0.94)
R-squared	0.97	0.90	0.88	0.88	0.97
Remaining nonlinearities	0.423	0.987	0.506	0.81	0.91

***, **, *Represent the statistical significance at the 1%, 5% and 10%, level respectively. Standard errors are given in parentheses. P-values are reported in square brackets. η is the slope parameter and c indicates the threshold level. ARCH(1) and ARCH(4) denote the LM test for autoregressive conditional heteroskedasticity of order1 and 4 respectively. Auto(2) and Auto(4) represent the LM test of residual autocorrelation of order 1 and 4 respectively

Figure 3: Comparative evolution between observed and forecast interest rate for the LSTAR model for different horizons (The residuals are presented in green color)

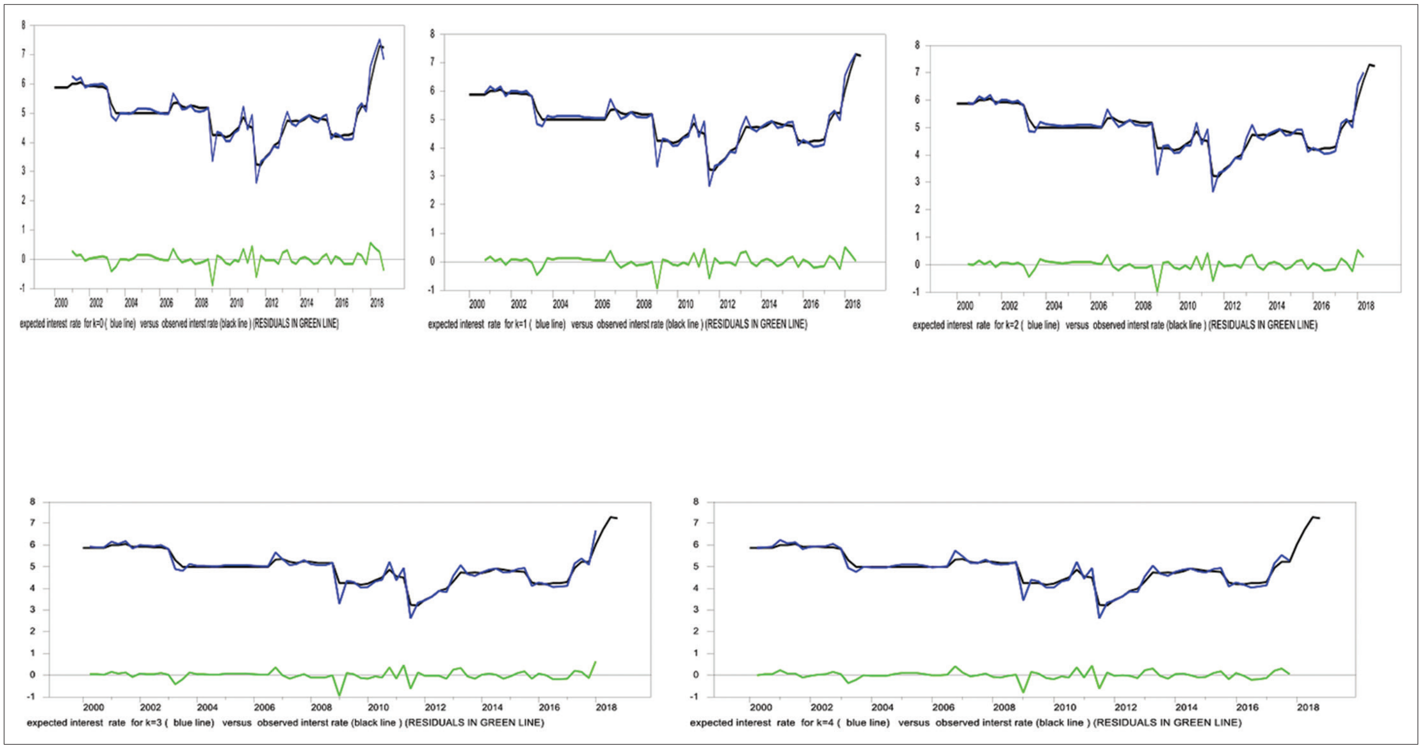


Table 6: Forecast performance of linear and non-linear model

	k=0	k=1	k=2	k=3	k=4
Non-linear model					
MAPE*(%)	7.31	6.2	6.7	5.6	5.4
Linear model					
MAPE*(%)	8.85	11.37	14.74	14.73	16.47

*Designs out of samples forecasts; MAPE: Mean absolute percentage error

estimation (k = 0, 1, 2, 3, 4). Therefore, the setting behavior of BCT can be well explained by a forward-looking nonlinear Taylor rule.

In order to evaluate the economic forecasts of the linear and the nonlinear models, we must identify whether the non-linear model provides accurate forecasts over the linear model. The comparison is made through the forecast performance evaluation criteria: the mean absolute percentage error (MAPE).

The results reported in Table 6 suggest that the nonlinear model exhibits a better projection quality compared to that of the linear model, for the four quarters of projections. The non-linear model has the lowest value of MAPE compared to the linear model. These findings are broadly in line with those of Teräsvirta and Anderson (2006) and McMillan (2009), which consider that the predictions of nonlinear models are better than the linear model, as they allow a better modeling of the dynamics of different variables.

5. CONCLUSION

This paper aims to investigates the behavior of Tunisian Central Bank in setting interest rate. The obtained results prove the inability of the linear model to describe the conduct of monetary policy in special events. In addition, our evidences suggest that the BCT follows a nonlinear Taylor rule in the conduct of monetary policy. Moreover, the STR model shows that there are two regimes characterizing the interest rate policy in Tunisia.

When the lagged interest rate is above the threshold level of 4.76%, the BCT makes a change in its interest rate decision by switching from a low interest rate to a high interest rate regime. In this situation, the main objective of the monetary authority in Tunisia is to contain the inflationist pressure and the depreciation of exchange rate rather than to boost the economic activity. Therefore, we can conclude that the STR provides a better structural framework to describe the monetary policy according to the economic situation. It allows a smooth transition between endogenous regimes (high and low interest rate regimes).

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