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Inflation Targeting and Exchange Rate Dynamics: Evidence From Turkey

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INFLATION TARGETING AND EXCHANGE RATE DYNAMICS: EVIDENCE FROM TURKEY

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Abstract : *This paper examines the constraints on the dynamics of the daily US dollar and the Euro exchange rates relative to the Turkish lira after the full fledged Inflation Targeting regime was adopted in 2006. We find that the single threshold specifications with two regimes that allow the conditional variance as well as the conditional mean to vary exhibit different dynamics in each regimes and produce superior forecasts below the threshold levels of the model for both the Euro and the US dollar than the forecasts produced by a random walk model. As a result, we conclude that the dynamics of the daily exchange rates are more constrained at the lower levels of the exchange rates and thereby embed a predictable process during the inflation targeting period in Turkey.*

JEL Classification : **F31; F47; E58; C22**

Keywords : **Inflation Targeting, Exchange Rates, Target Zone, Forecasting**

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1 Introduction

The implications of the FX market interventions on the exchange rate dynamics has been an interesting subject of research in countries, where the monetary policy strategies are guided by the Inflation Targeting (IT) framework (Amano et.al. 1997; Domaç and Mendoza 2004; Fidrmuc and Horvath 2008). The authorities in most of the IT countries, where the free float exchange rate regimes have now became a *de jure* exchange rate regime, announced that while they have no concern about the levels of exchange rates this should not mean not to intervene to the market under all conditions. In particular, the authorities emphasize that if they anticipate excess volatility in the foreign exchange (FX) market they will intervene in order to remove this possibility. However, this kind of announcements by the authorities that limit the variation of the exchange rates at some extreme points might affect the formation of expectations and thereby constrain the dynamics even before any possible interventions. The purpose of this study is to uncover these constraints on the exchange rate dynamics by exploiting the non-linear univariate specifications of the Turkish lira / US Dollar and the Turkish lira/Euro daily exchange rates since the beginning of the full-fledged Inflation Targeting regime launched in 2006[1].

This subject is of particular interest in emerging market economies, since most of these economies have high degree of pass-through from exchange rate swings to inflation rates. At the same time most of these economies are characterized by open economy features and suffer from asset and liability dolarizations, which are generally associated with an undiversified financial markets. Therefore, unfavorable shocks to the exchange rates in emerging market economies can easily infect the long-term inflation expectations compared to the developed economies and thereby might potentially create credibility problems for the monetary policy. Under such environment, the policy attitudes toward the excess volatility partly reflect “fear of floating” as argued in Calvo and Reinhart (2000) and the concerns of the authorities for competitiveness and inflation targets. On the other hand, the target zone literature (Krugman 1988; Froot and Obstfeid 1991; Bertola and Cabillero 1992) argues that the authorities’ concern for the excess volatility in the nominal exchange rate is reflected into a fluctuation

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[1] Turkey started using the New Turkish lira as its monetary unit after dropping 6 zeros from the Turkish lira at the beginning of 2005. Therefore, the Turkish lira indicates the New Turkish lira throughout the text.

band for the fundamentals that, in turn, reduces the volatility of exchange rates[2]. However, the reduction in the volatility can only occur if interventions by the central bank are credible enough at certain levels of exchange rates. One of the implications of this conclusion on the exchange rate dynamics is that the nominal exchange rates can no longer be modeled by assuming the random walk behavior, since the authorities regulates the stochastic process that governs the fundamentals.

The Central Bank of the Republic of Turkey (CBRT) also announced a similar intervention policy[3]. In this context it responds to the excess volatilities, either existing or anticipated, in the exchange rate market. As a reflection of this policy the CBRT has experienced fluctuations in some variables since the adoption of the free-floating exchange rate regime in the aftermath of the banking crisis in 2001. First of all, the CBRT has accumulated international reserves, which rises from around 20 billon US dollar at the beginning of the 2001 to about 75 billion dollar in the second half of 2008. Moreover, it had to intervene to the FX market time to time by providing foreign currencies either through direct or indirect intervention methods during the IT period. The Central Bank of Turkey also sharply raised the interest rate during the financial turmoil at the end of the second quarter of 2006 in order to prevent the further deterioration in the long-term inflation expectations following the sharp depreciation of the Turkish lira against foreign currencies. Therefore, it is also of interest to know whether these fluctuations in policy variables have been the result of the departure from the free-floating exchange rate regime in Turkey.

The structure of the paper is as follows. Section II reviews the target zone exchange rate model first introduced by Krugman (1988). Section III presents a brief description of the methodology used in the empirical part of the study. The fourth section estimates the TARCH and SETAR-TARCH-M models by using the daily exchange rates of the Euro and the US Dollar in Turkey. This section also presents forecasts from alternative linear and non-linear univariate models of exchange rates and evaluates their forecast accuracy. The final section provides conclusions.

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[2] A good discussion of target zone literature can be found in Besec (2003).

[3] The forms of intervention by the CBRT are discussed in Çaşkurlu et. al. (2008). The Central Bank of Turkey also regularly announces its monetary and FX policy for the coming year at the end of each year.

2 Model

As mentioned in the previous section the monetary authorities in emerging market economies might be concerned with the excess volatility or the resulted misalignments in the level of the exchange rates due to the reasons such as, the fear of floating, the loss of competitiveness and/or the pass-trough from exchange rate swings to the inflation rates. Thus, it can be argued that the market participants in these countries might expect the monetary authorities to regulate the exchange rate movements at lower and upper values either through direct or indirect intervention methods in order to mitigate these worries[4].

The basic model that can be used to analyze the behavior of exchange rate when the exchange rates are constrained to move within a band is the target zone model introduced by Krugman (1988). In fact, this model is flexible enough to incorporate a wide range of exchange rate regimes from free floating to fixed exchange rate regimes. Krugman (1988) argues that the constraints on the exchange rates at some extreme points produce interesting dynamics even before they reach at these points. One of the striking differences is that the presence of credible upper and lower bounds achieve some reductions in the variability of exchange rate as compared to the variation under the free float regime. That is when the exchange rate approaches to the bounds, the expected change in exchange rate diverge from the random walk behavior and generates expected depreciation at the lower bound or the appreciation at the upper bound, which stabilize the movements of exchange rates.

The general version of Krugman's model starts with a standard flexible-price model of exchange rate[5];

$$s(t) = f(t) + \alpha \frac{E[ds(t)]}{dt} \tag{1}$$

where $s(t)$ is the logarithm of the nominal exchange rate, $f(t)$ is a linear combination of fundamental variables that play roles in the determination of exchange rate. In a monetary approach to the exchange rate determination this combination might include money supply of

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[4] Other factors may also lead the market participants to think the central bank to intervene in the FX market. One of these factors, as the referee rightly emphasized, is the misalignment in the exchange rates.

[5] This equation can be derived from a system that includes the money market equilibrium condition, currency arbitrage condition, purchasing power parity condition and the motion described in equation (2).

the domestic and foreign countries and monetary disturbances. In this approach (α) can be interpreted as the interest rate semi elasticity of the money demand. The last term on the right hand side is the expected change in the exchange rate. Flood and Garber (1989) extends Krugman's model by incorporating a Brownian motion for the stochastic behavior of the fundamentals.

$$df_t = \eta dt + \sigma dW_t \tag{2}$$

where η and σ are positive constant terms, and dW is a standard Weiner process, which shows the stationary increments, $W(t) \approx N(0,t)$. If there is no concern by the authority for the level of the exchange rate, the fundamentals follow the motion described by equation (2) without any intervention. In this case it can be shown that the expected value of the future fundamentals at time *(t),* $E[f_{t+i} | f_t] = f_t + \eta i$ for *i=0,1,.....n.* However, if the authorities have concern for the variability of the exchange rate at a level that is not acceptable within the framework of current monetary policy, they might regulate this motion and prevent it from exceeding this level. In the symmetric case the authority has equal concern for exchange rate exceeding some certain upper or lower levels and direct its resources to keep the exchange rate inside these limits.

This setting of the model combined with the rational expectations implicitly defines the equilibrium exchange rate as a function of a linear combination of fundamental variables and the authorities concern for the upper and lower limits on the exchange rate. This relationship can be written in the following general form;

$$s = g(f, \bar{s}, \underline{s}) \tag{3}$$

where $\bar{s}$ is the upper limit and $\underline{s}$ is the lower limit of the exchange rates. A general solution to equation (1), given the motion in equation (2) can be obtained by appealing to the rule of the stochastic calculus. If we assume the function described in equation (3) is a twice continuously differentiable function of the state variable *(f),* we can obtain an expression for the $E[ds(t)]/dt$ by applying Ito's lemma;

$$E\left[ds(t)\right]/dt = g'(f,\bar{s},\underline{s})\eta + 0.5g''(f,\bar{s},\underline{s})\sigma^2 \tag{4}$$

This equation describes the motion followed by equation (3) conditional on the stochastic process given in equation (2). Substituting equation (4) into (1), we obtain,

$$g(f,\bar{s},\underline{s}) = f + \alpha\left[g'(f,\bar{s},\underline{s})\eta + 0.5g''(f,\bar{s},\underline{s})\sigma^2\right] \tag{5}$$

The general solution to (5) can be written as follows,

$$g(f,\bar{s},\underline{s}) = f + \alpha\eta + A\exp(\lambda_1 f) + B\exp(\lambda_2 f) \tag{6}$$

where,

$$\lambda_1 = \frac{-\eta + \sqrt{(n^2 + 2\sigma^2)/\alpha}}{\sigma^2} \text{ and } \lambda_2 = \frac{-\eta - \sqrt{(n^2 + 2\sigma^2)/\alpha}}{\sigma^2} \tag{7}$$

are two distinct negative and positive real roots of the characteristic equation. By assuming infinitesimal interventions the target zone solutions are characterized by “tying down the end of the curve” implied by equation (6) as argued in Krugman (1988). As a result the solution for the constants *A* and *B* must be tangent to the upper and lower bounds on the exchange rate. This condition is also known as “smooth pasting” condition in the literature. Note that the solution consists of two parts which describes the equilibrium solution under a free float exchange rate regime ($f + \alpha\eta$) and the additional effect due to the expected intervention by the authorities ($A\exp(\lambda_1 f) + B\exp(\lambda_2 f)$. Therefore, the relationship between exchange rate and fundamentals are not linear and the weight of the nonlinear components increases toward the edges of the band. This conclusion has also important implications on the dynamics of exchange rate. In the presence of interventions the dynamic of the nominal exchange rate diverge from the martingale dynamics as described in (2) as the authorities regulate the process to prevent the exchange rate moving outside the upper and lower bounds. In the next section we analyze this issue by exploiting the non-linear univariate speciation for the Turkish lira / US dollar and the Turkish lira / Euro rates under the assumption that there are implicit currency bands at some lower and upper levels.

3 Empirical Methodology - SETAR-TARCH-M Model

One of the most popular non-linearity in the high frequency exchange rate data documented in the literature (Chapphell and Padmore,1995 and the reference there in) is the time varying volatility in the errors of the univariate models. This observation led to an extensive use of GARCH-type models (Generalized Autoregressive Conditional Heteroscedasticity) initially proposed by Bollerslev (1987) in modeling the volatility clustering in exchange rate innovations. Different variants of this model are also proposed to analyze the risk-return behavior and the asymmetric responses to shocks such as the effects of good and bad news on exchange rate volatility through GARCH-M (Generalized Autoregressive Conditional Heteroscedasticity in Mean) and TARCH (Threshold Autoregressive Conditional Heteroscedasticity) versions respectively. An alternative type of non-linearity in the exchange rate is the regime switching behavior. In regime switching behavior conditional dependence can be observed in the mean rather than the variance of the series with different dynamic structures in each regimes. These models have wide applications under explicit or implicit target zone exchange rate regimes in which authorities are expected to defend its currency (Crespo-Cuaresma et al. 2005; Boero and Marrocu 2004; Brooks 2001; Pippenger and Goering 1998; Chappell *et al.* 1996). For example, if we consider an intervention policy that constrain the exchange rates to lie within a lower and upper limits, it will be natural to expect that exchange rates follow different dynamic structures close to the upper and lower limits than the dynamic exhibited within the band.

However, either the GARCH-type or regime switching models might be unable to capture all the observed non-linearity of the series on its own (Hsieh 1991; Brooks 2001). One possible solution is to combine both type of models and allow GARCH-type errors over a number of states. This study attempts to carry out this solution by first using a SETAR model (Self-Exciting Threshold Autoregressive) (Tong and Lim 1980; Tong 1983, 1990; Chan and Tong 1986) to find out the number of different states and their dynamic structures implied by each regimes. Following the identification of the regime we estimate errors in each regime through TARCH-M process. As a result we follow a similar strategy in Brooks (2001) and Cuaresma et.al. (2005), but their methodologies are extended by using SETAR-TARCH-M model instead of the SETAR-GARCH model. The main advantage of the SETAR-TARCH-M model over SETAR-GARCH model is that it allows the asymmetric responses of the conditional volatility to the innovations in the exchange rate have different signs and magnitudes in each regime. Additionally, the SETAR-TARCH-M model does not assume a single feedback rule from the conditional volatility to the level of exchange rate, as captured by the M term in the mean equation, but it also allows this feedback rule to differ in each regime.

The SETAR-TARCH-M specification estimated in this study can be shown by considering two thresholds for a covariance stationary process (Y_t). Given these two thresholds we can distinguish three regimes in which Y_t process follows a particular autoregressive process ($AR(p)$) in each regime. If we further assume TARCH(1,1) process for the variance equation, as it is now fairly widely accepted order of the variance equation in the literature for modeling exchange rates (Brooks 2001; Chappell and Padmore1995), the final SETAR-TARCH-M(1,1) model can be written as fallows,

$$Y_t = \begin{Bmatrix} \varphi_{1,0} + \sum_{i=1}^{p_1} \varphi_{1,i} Y_{t-i} + \beta_1 h_t^2 + \sigma_1 \varepsilon_t \\ \varphi_{2,0} + \sum_{i=1}^{p_2} \varphi_{2,i} Y_{t-i} + \beta_2 h_t^2 + \sigma_2 \varepsilon_t \\ \varphi_{3,0} + \sum_{i=1}^{p_3} \varphi_{3,i} Y_{t-i} + \beta_3 h_t^2 + \sigma_3 \varepsilon_t \end{Bmatrix} \quad if \quad \begin{Bmatrix} Z_{t-d} \geq T_1 \\ T_1 > Z_{t-d} \geq T_2 \\ Z_{t-d} < T_2 \end{Bmatrix} \tag{8}$$

where,

$$\varepsilon_t | \Omega_{t-1} \approx N(0, h_t^2) \tag{9}$$

$$h_t^2 = \alpha_0 + \alpha_1 \varepsilon_{t-1}^2 + \alpha_2 \varepsilon_{t-1}^2 I_{t-1} + \delta_1 h_{t-1}^2 \tag{10}$$

$$\begin{aligned} \varepsilon_t < 0 \Rightarrow I_t = 1 \\ \varepsilon_t \geq 0 \Rightarrow I_t = 0 \end{aligned} \tag{11}$$

In equation (8) T_1 and T_2 are the threshold values, Z_t is the transition variable, subscript d denotes the delay in the transition, ε_t is the standardized iid. errors and σ_j for $j = 1,2,3$ are for the variance of these processes. If we replace the transition variable Z_t with Y_t the model in equation (8) is called self-exciting threshold autoregressive process (SETAR). $\varphi_{1,i}, \varphi_{2,i}$ and

$\varphi_{3,i}$ are the coefficients of the autoregressive terms in each regimes where the order of the autoregressive process is denoted by $i = 1,2,....p_j$. The reason for including one period ahead forecast variance into the mean equations is to capture any possible trade-off between volatility and the conditional mean of the exchange rates. Equations (9) to (11) specify the conditional mean (h_t^2) in terms of past periods squared errors (ε_{t-1}) and the lagged one period ahead forecast variance (h_{t-1}^2). In addition to these arguments the variance equation (10) includes a dummy variable I_t, which take 1 if $\varepsilon_t < 0$ and 0 otherwise. The purpose of including this dummy term into the model is to introduce asymmetric responses of volatility to the shocks if they exist in the data. This kind of asymmetric responses might exist in the exchange rate data as negative shocks to the exchange rate (devaluation) embed more destabilizing effects than positive shocks (revaluation). However, we also propose that the direction and the size of the asymmetric responses differ in each regime. For example, if a negative shock hits at the upper regime it might be possible to trigger further speculations while the same shock discourages holding FX assets and transactions at the lower regime. Finally, $\alpha_0, \alpha_1, \alpha_2$ and δ_1 are the coefficients of the model.

4 Empirical Results

This section applies the model discussed in the previous section to the Turkish lira/Euro and Turkish lira/US Dollar rates. The reason for including two exchange rates is to account for the effects of the variation in the cross parity between the US dollar/Euro rate. If this variation dominates the movements of the Turkish Lira/Euro or the Turkish Lira/US dollar, then we might expect different dynamic structures for these two rates. The data set includes 690 daily observations that span the period from 2 January 2006 to 15 September 2008. The model is estimated in the natural logarithms of the level rather than the first difference form, since the expected intervention by the CBRT is most likely to happen when the exchange rate approach to some upper or lower limits.

Before estimating the SETAR-TARCH-M model, table 1 presents some specification tests carried out on the residuals of the Random Walk Model. The purpose for performing these tests is to see whether there exist evidences of non-linear structure in the random walk model. In this context, we performed the McLeod-Li and BDS tests for the presence of non-linear

Table 1- Specification Tests for the Random Walk Model

Test Statistic[a]	Turkish lira/ Euro	Turkish lira/US Dollar	Critical Level- %5
$Phillips - Perron$	-2.3995	-1.2838	-2.86
$Ljung - Box$	29.3638	25.0355	31.4
$McLeod - Li$	184.7526	191.9331	31.4
$BDS:$			
$m = 2, \varepsilon = 0.7$	8.1565	7.0104	1.96
$m = 3, \varepsilon = 0.7$	10.1119	8.9600	
$m = 4, \varepsilon = 0.7$	10.9375	10.1591	
$ARCH_1$	28.4459	23.4721	3.84

a-The null hypothesis for the Phillips-Perron test is that there is unit root in the series. The null hypothesis for the Ljung-Box test is the series is white noise. The null hypothesis for the BDS and McLeod-Li tests are that the series is IID. Finally, the null hypothesis for ARCH test is that there is no ARCH effect in the series.
** Significant at the 10% level

effects and the Ljung and Box test for the whiteness of the residuals[6]. While the McLeod-Li and Ljung-Box tests are distributed as the χ^2 distribution with the lag length as the degrees of freedom, the BDS statistic is asymptotically distributed as *N(0,1)*. Finally, the table also includes the ARCH test to detect the presence of any ARCH effect in the residuals. The results reported in table 1 reveal that there are strong evidences against the null hypothesis that the residuals of the random walk models are IID for both the Turkish lira/Euro and the Turkish lira/US Dollar exchange rates. That is the calculated statistics for the McLeod-Li test with 20 degrees of freedom and the BDS test reject the null hypothesis at 5 percent significance level. The null hypothesis of the whiteness of the residuals can be only marginally accepted at 5 percent significance level. Finally, the ARCH test indicates there are significant ARCH effects in the exchange rate series.

Following the failure of the Random Walk model we attempt to exploit the univariate non-linear specifications of the exchange rates. Table 2 and 3 present the estimation results for the Euro and the US Dollar exchange rates by applying the specifications presented in the previous section. The set of estimated values shown in the first column of the tables are obtained from a single regime TARCH-M (1,1) model. This additional specification is estimated in order to compare and assess the results obtained from the SETAR-TARCH-M(1,1) specification. The results obtained from this latter specification are presented in the second and third columns of the tables. The crucial parameters, the delay and thresholds parameters of the SETAR specification are taken as proposed in the literature (Tong 1983;

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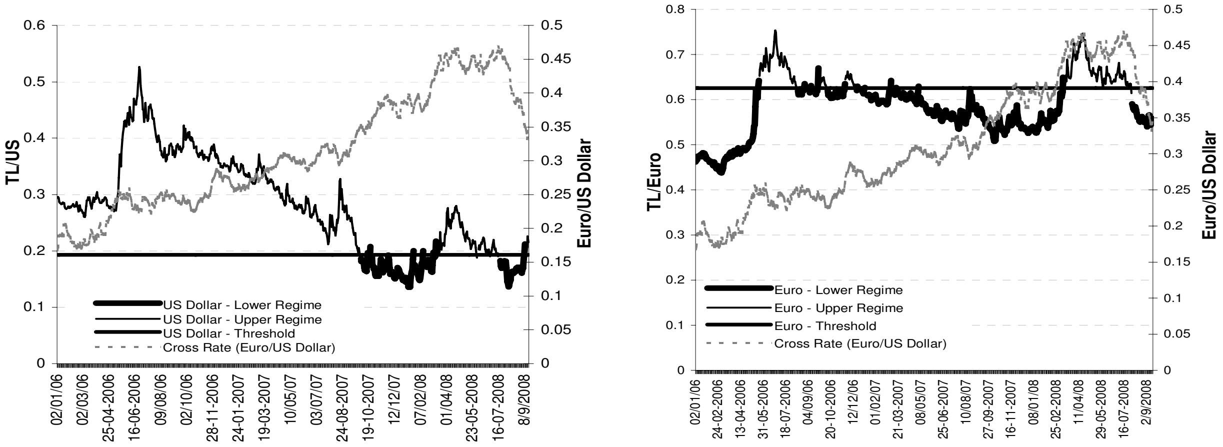
[6] The non-linearity test used in this study are explained in the Appendix.

Brooks 2001; Pippenger and Goering 1998). In particular, the delay parameter is taken to be one since it is commonly accepted that the current state is determined by the level of exchange rate in the previous day. On the other hand, the threshold values are calculated by performing a grid search as in Tong(1983) and choosing the specification that produce the lowest Akaike Information Criterion[7][8]. In this search we first started with two thresholds, but they turned out to be very close to each other. Therefore, following Chappell (1996) we concluded that this finding might be spurious, as the balance of economic forces has always worked the Turkish lira to appreciate against the US dollar and Euro currencies during our sample period. Therefore, the upper limit has actually not been seriously tested in the sample period in order to be able to conclude whether the Central Bank also intends to regulate the fundamentals to defend an implicit upper limit for the exchange rates. Thus, we proceeded to estimate a single threshold for the SETAR specification in the second stage. We denote this specification as SETAR(2) that indicates two regime, above the threshold (upper regime) and below the threshold (lower regime) Self Exciting Threshold Autoregressive model. As seen in table 2 and 3 the thresholds for the euro and the US Dollar rates are found to be log(1.8693)=0.6256 and log(1.2135)=0.1935. These threshold values and the ordered observations are also illustrated in Figure 1.

Figure 1 Upper and Lower Regime Decomposition of the Exchange Rates



Note: Values are log levels. The threshold value for the Turkish Lira/Euro exchange rate is log(1.8693) and the threshold value for the Turkish lira/US dollar is log(1.2135)

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[7] The lag length for the autoregressive processes are determined using Akaike Information Criterion.

[8] The estimation of thresholds values are based on Tong (1983). First we define the percentage of the candidates for the threshold values. Second the observations are re-ordered by using the each possible set of threshold values. Then a grid search is conducted on each possible set of threshold values according to the Akaike Information Criterion. As a result we determine a set of estimated threshold values that minimizes the sum of the Akaike Infromation Criterion from each regimes. The algorithm for this grid search has been provided by .A. Beliak, M. Peat and M. Stevenson from University of Technology, Sydney.

Table 2 Turkish lira/Euro – Estimation Results from SETAR(2)-TARCH-M Model

	Single Regime		**Upper Regime**		**Lower Regime**	
	Coef. Values	*z- Stat.*	*Coef. Values*	*z- Stat.*	*Coef. Values*	*z- Stat.*
β_0	0.0087	3.4129	0.0705	2.4632	0.0013	0.3370
β_1	0.9849	225.3180	0.8808	19.5911	1.1355	22.6940
β_2	-	-	-	-	-0.2158	-3.1419
β_3	-	-	-	-	0.1874	3.1158
β_4	-	-	-	-	-0.1051	-2.6422
γ	-	-	54.1335	3.0466	-32.6297	-2.5572
α_0	0.0000	5.8513	0.0000	0.8938	0.0000	4.3553
α_1	0.2865	6.3658	0.0651	3.0702	0.2101	4.1923
α_2	-0.2802	-6.5820	0.1011	1.7778	-0.3116	-6.6307
δ_1	0.7726	25.6059	0.8723	22.8045	0.6254	7.2073

Diagnostics Statistics:

Test Statistic	***Value***			***Critical Level-%5***
	Single Regime No.of Obs: 690 Threshold: -	**Lower Regime No.of Obs: 479 Threshold: $Y_{t-1} < \mathbf{0.6256}$**	**Upper Regime No.of Obs: 211 Threshold: $Y_{t-1} \geq \mathbf{0.6256}$**	
$\overline{R}^2$	0.9783	0.9699	0.8609	
AIC	-6.6861	-6.8801	-6.1663	
$Ljung-Box$	20.8893	13.5068	14.2650	31.4
$McLeod-Li$	8.4989	8.9465	17.7627	31.4
BDS :				
$m=2, \varepsilon=0.7$	0.4154	0.8976	0.9707	1.96
$m=3, \varepsilon=0.7$	0.3925	0.7678	1.7964	
$m=4, \varepsilon=0.7$	0.0633	1.1284	1.9116	
$ARCH_1$	0.1148	0.1756	2.0117	3.84

- General Specification: $Y_t = \beta_0 + \beta_1 Y_{t-1} + \beta_2 Y_{t-2} + \beta_3 Y_{t-3} + \beta_4 Y_{t-4} + \gamma h_t^2 + \varepsilon_t$ $\quad \varepsilon_t | \Omega_{t-1} \approx N(0, h_t^2)$

$h_t^2 = \alpha_0 + \alpha_1 \varepsilon_{t-1}^2 + \alpha_2 \varepsilon_{t-1}^2 I_{t-1} + \delta_1 h_{t-1}^2$ $\quad \varepsilon_t < 0 \Rightarrow I_t = 1$

$\varepsilon_t \geq 0 \Rightarrow I_t = 0$

Table 2 reports the estimation result for the Euro exchange rate against the Turkish lira. It can be seen that the upper regime includes fewer observations than the lower regime. The numbers of observations that fall into the upper regime are 211 while the numbers of observations in the lower regime are 479. Following these observations we estimated the SETAR(2)-TARCH(1,1)-M model for each regime by using the Maximum Likelihood Method. The best model fitted for the upper regime has turned out to be an AR(1) process with a GARCH term in the mean equation. Compared with the single regime TARCH(1,1) model the coefficient of the AR(1) term is lower and indicates significant feedback from the conditional variance to the level of the Euro exchange rate[9]. However, the estimated AR structure and the sign of the GARCH term in the lower regime are different. While the GARCH term has positive impact on the Turkish lira/Euro rate in the upper regime, it has negative impact in the lower regime. This might be an indication that an increase in the volatility of the Euro rate inside the lower regime discourages the holding of Euro assets, which put downward pressure on its level. On the other hand, the best fitted AR process for the lower regime has been found to be the AR(4) model with alternating signs for each lag. This kind of dynamic structure indicates more volatile dynamics for the lower regime than the structure found in the upper regime of the SETAR(2)-TARCH(1,1)-M model and the single regime TARCH(1,1) model. On the other hand, the variance equations represented in table 2 show that the negative and positive innovations to the Turkish lira/Euro exchange rates, as obtained from the mean equation, have different impact on the conditional volatility across each regime. The size and direction of this impact depend on the models as well as the specific regime of the SETAR(2)-TARCH(1,1) model. In particular, the sign of the TARCH term, α_2, indicates that the negative innovations in the TARCH(1,1) model have significant negative effects that lower the conditional volatility in the Euro exchange rate. Similarly, the negative innovations in the SETAR(2)-TARCH(1,1) model reduce the conditional volatility in the lower regime. By contrast, the negative innovations augment the volatility in the upper regime of the model. However, the positive innovations consistently increase the volatility in both model and through each regime in table 2. We can interpret these findings, as shocks that result in the Turkish lira to depreciate against the Euro increases the uncertainty of this rate. However, shocks that cause the Turkish lira to appreciate have no significant impact on the uncertainty in the TARCH(1,1) and reduces it in the lower regime and increases it in the upper regime of the SETAR(2)-TARCH(1,1)-M model. Lastly, if we look at the diagnostic statistics presented in the bottom panel of table 2, there is no further indication of remaining non-linear structure in the residuals for both TARCH(1,1) and SETAR(2)-TARCH(1,1)-M models.

The estimation results for the daily exchange rate of the US Dollar against the Turkish lira are presented in table 3. The first column is again for the results obtained from the single regime TARCH(1,1) model. The next two columns show the estimates of the coefficients for the upper and lower regime of the SETAR(2)-TARCH(1,1)-M model. Despite the greater number

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[9] The feedback effect from the conditional variance of the single regime on the level of exchange rate were not significant. Therefore we preferred to estimate the mean equation of the single regime without the GARCH term.

of observations that falls into lower regime in the Turkish lira/Euro rate, we obtained the opposite results for the Turkish lira/US Dollar rate. However, in both cases the best model for the upper regime are found to be the AR(1) process. As seen in the table 3 this is also the best specification of the single regime TARCH(1,1) model. The coefficient values of the AR(1) terms seem to be very similar for both the single regime TARCH(1,1) model and the upper

Table 3 Turkish lira/US Dollar–Estimation Results from SETAR(2)-TARCH-M Model

	Single Regime		**Upper Regime**		**Lower Regime**	
	Coef. Values	*z- Stat.*	*Coef. Values*	*z- Stat.*	*Coef. Values*	*z- Stat.*
β_0	0.0009	0.8516	-0.0004	-0.2472	0.0151	2.0742
β_1	0.9961	268.3857	0.9994	192.3222	1.1223	111.2804
β_2	-	-	-	-	-0.2070	-4.3290
β_3	-	-	-	-	-	-
β_4	-	-	-	-	-	-
γ	-	-	-	-	-	-
α_0	0.0000	5.8222	0.0000	4.3835	0.0000	3.3303
α_1	0.2115	6.0222	0.2203	5.5847	0.0278	0.6117
α_2	-0.2168	-5.4919	-0.1306	-2.7532	-0.2080	-2.8986
δ_1	0.8162	31.3697	0.7928	27.6534	0.9249	31.1309

Diagnostics Statistics:

Test Statistic	***Value***			***Critical Level-%5***
	Single Regime No.of Obs: 690 Threshold: -	**Lower Regime No.of Obs: 145 Threshold: $Y_{t-1} < 0.1935$**	**Upper Regime No.of Obs: 545 Threshold: $Y_{t-1} \geq 0.1935$**	
$\overline{R}^2$	0.9881	0.6998	0.9826	
AIC	-6.7033	-6.6940	-6.6933	
$Ljung-Box$	13.8973	15.4980	18.4177	31.4
$McLeod-Li$	9.7441	21.1668	7.4371	31.4
BDS :				
$m = 2, \varepsilon = 0.7$	0.6403	-0.9520	0.7220	1.96
$m = 3, \varepsilon = 0.7$	0.5635	0.0529	0.3011	
$m = 4, \varepsilon = 0.7$	1.0110	0.2785	0.6191	
$ARCH_1$	0.0993	0.1973	0.0211	3.84

- General Specification:

$$Y_t = \beta_0 + \beta_1 Y_{t-1} + \beta_2 Y_{t-2} + \gamma h_t^2 + \varepsilon_t \qquad \varepsilon_t | \Omega_{t-1} \approx N(0, h_t^2)$$

$$h_t^2 = \alpha_0 + \alpha_1 \varepsilon_{t-1}^2 + \alpha_2 \varepsilon_{t-1}^2 I_{t-1} + \delta_1 h_{t-1}^2 \qquad \varepsilon_t < 0 \Rightarrow I_t = 1$$

$$\varepsilon_t \geq 0 \Rightarrow I_t = 0$$

regime of the SETAR(2)-TARCH(1,1)-M model. As in the Turkish lira/Euro rate the order of the AR process is higher in the lower regime compared to the upper regime of the SETAR(2)-TARCH(1,1)-M model. However, the difference between the TARCH(1,1) and SETAR(2)-TARCH(1,1)-M models appear to be in the asymmetric response of the volatility to the negative and positive innovations in the Turkish lira / US Dollar rate. While both negative and positive innovations have positive impact on the Turkish lira/US Dollar volatility in the upper regime of the SETAR(2)-TARCH(1,1)-M model, negative innovations have no significant impact on the volatility in the single regime TARCH(1,1) model and have negative impact in the lower regime of the SETAR(2)-TARCH(1,1)-M model. On the other hand, positive innovations, which cause the Turkish lira to depreciate against the US Dollar, have positive impact on the volatility in all three regimes. Finally, as seen in table 3 we did not report the GARCH term in the mean equations of the models as this term turned out to be insignificant in these equations. There are also no major specification problems for the models presented in table 3.

The diagnostic statistics reported for the above models, the single regime TARCH(1,1) and the SETAR(2)-TARCH(1,1) models, do not choose one specification over the other. Therefore we proceed to obtain recursive point forecasts at horizons of 26 and 30 days for these models as well as some additional models presented in tables from 4 to 9. Those other

Table 4 Upper Regime Forecasts[a] – *Within Sample*

Panel A: The Turkish Lira /Euro Exchange Rates				
Model[b]	**Mean Squared Erros**		**Percentage Mean Absolute Error**	
	1 Step Ahead	*5 Step Ahead*	*1 Step Ahead*	*5 Step Ahead*
Random Walk	0.012447	0.014205	1.78	1.63
Best AR Process	0.012672	0.014226	1.81	1.65
TARCH(1,1)	0.012779	0.014295	1.83	1.66
SETAR(2)	0.012865	0.014275	1.84	1.67
SETAR(2)-TARCH-M	0.013873	0.014200	2.01	1.81
Panel B: The Turkish Lira/US Dollar Exchange Rates				
Model[b]	**Mean Squared Erros**		**Percentage Mean Absolute Error**	
	1 Step Ahead	*5 Step Ahead*	*1 Step Ahead*	*5 Step Ahead*
Random Walk	0.010202	0.010983	4.23	3.77
Best AR Process	0.010163	0.010933	4.21	3.75
TARCH(1,1)	0.010175	0.010953	4.22	3.76
SETAR(2)	0.010204	0.010990	4.23	3.77
SETAR(2)-TARCH-M	0.010219	0.010872	4.23	3.74

a- Forecast period is between 17-March-2008 and 24-April-2008 and includes 30 daily observations.

b- GARCH(1,1) and SETAR(2)-TARCH-M models are estimated by using the Maximum Likelihood method. Other models are estimated with the OLS method.

models are the Random Walk model, the best fitted AR model, the TARCH(1,1) model and the SETAR(2) model. The difference between SETAR(2) and SETAR(2)-TARCH-M models arises from the estimation method and the inclusion of the GARCH term into the mean equation of the SETAR(2)-TARCH-M model. Because there are lack of observations in the Euro exchange rate that fall into upper regime we only conducted within sample exercises for this regime. In the lower regime, however, we checked the performance of the models by conducting both within and out of sample forecast exercises.

First, table 4 present within sample forecast results for the Euro and Dollar exchange rates when they are above the calculated threshold values. The evaluation of the forecast performances is based on the MSFE (Mean Squared Forecast Errors) and PMAFE (Percentage Mean Absolute Forecast Errors) criterions for both one-step and five step-ahead recursive forecasts. As mentioned the forecast horizon is taken to be 30 daily observations between 17 March 2008 and 24 April 2008. The results reported in this table show that there is no significant advantages of the non-linear models, TARCH(1,1), SETAR(2) and SETAR(2)-TARCH(1,1)-M models over the linear models, Random Walk and AR models. Thus, the behaviors of exchange rates above the thresholds are close to the behavior expected under the free float exchange rate regime.

Second, the same forecast exercises are conducted for the lower regime. However, this time we also obtained out of sample forecasts in addition to the within sample forecasts. The out of sample forecast method uses the recursive estimation of the models that allow the sample period to extend one observation each time. The MSFEs and PMAFEs for one-step and five step-ahead forecasts are reported in table 5 for within sample and table 6 for out of sample forecasts. The results in those tables show that the SETAR type models improve the forecasting accuracy in comparison to the Random Walk model as well as the TARCH(1,1) and AR models. Moreover, a similar improvement can be reported for both within sample and out of sample forecast relative to the Random Walk model. The improvements are about 10 percent for the within sample forecast for both the Euro and the US Dollar rates while it is about 7 percent for the US Dollar exchange rate and about 5 percent for the Euro exchange rates in the out of sample forecast exercises. Therefore, these findings lead us to conclude that the behavior of the exchange rates below the thresholds is not consistent with the behavior under the free-float exchange rate regime as it predicts exchange rate to exhibit random walk

Table 5 Lower Regime Forecasts[a] – *Within Sample*

Panel A: The Turkish Lira /Euro Exchange Rates

Model[b]	**Mean Squared Erros**		**Percentage Mean Absolute Error**	
	1 Step Ahead	***5 Step Ahead***	***1 Step Ahead***	***5 Step Ahead***
Random Walk	0.005380	0.006690	0.96	1.04
Best AR Process	0.005390	0.006730	0.96	1.05
TARCH(1,1)	0.005340	0.006650	0.95	1.04
SETAR(2)	0.005080	0.006490	0.91	0.98
SETAR(2)-TARCH-M	0.004930	0.006580	0.88	1.00

Panel B: The Turkish Lira/US Dollar Exchange Rates

Model[b]	**Mean Squared Erros**		**Percentage Mean Absolute Error**	
	1 Step Ahead	***5 Step Ahead***	***1 Step Ahead***	***5 Step Ahead***
Random Walk	0.004907	0.006508	2.89	3.09
Best AR Process	0.004746	0.006336	2.80	2.98
TARCH(1,1)	0.004815	0.006404	2.84	3.03
SETAR(2)	0.004593	0.006268	2.73	3.01
SETAR(2)-TARCH-M	0.004517	0.006167	2.66	2.94

a- Forecast period is between 4-August-2008 and 8-September-2008 and includes 26 daily observations.

b- GARCH(1,1) and SETAR(2)-TARCH-M models are estimated by using the Maximum Likelihood method. Other models are estimated with the OLS method.

behavior. However the behaviors above the thresholds are consistent with the random walk behavior.

Finally, as seen in figure 1, the Euro exchange rate, which steadily appreciated against the US dollar until the beginning of 2008, has more observations in the predictable lower regime than the US dollar. This finding might indicate that the market expectations favor the intervention policy to be more effective for the strong currency rather than the weak currency. However, once the cross parity is stable this perception is valid for both the US dollar and the Euro exchange rates. The policy implication of this result is that the intervention policy should be stirred with respect to the strong currency rather than the weak currency if the authorities intend to intervene in the FX market.

5 Conclusion

This paper analyses the dynamics of exchange rates by using the daily US dollar and Euro exchange rates against the Turkish lira during the full fledged Inflation Targeting regime in Turkey. While the CBRT adhered to the free floating exchange rate regime in our sample period, the FX market interventions were not ruled out in the face of an anticipated excess

Table 6 Lower Regime Forecasts[a,b] – *Out of Sample*

Panel A: The Turkish Lira /Euro Exchange Rates

Model[c]	**Mean Squared Erros**		**Percentage Mean Absolute Error**	
	1 Step Ahead	*5 Step Ahead*	*1 Step Ahead*	*5 Step Ahead*
Random Walk	0.00539	0.00670	0.96	1.04
Best AR Process	0.00540	0.00674	0.96	1.05
TARCH(1,1)	0.00536	0.00667	0.96	1.04
SETAR(2)	0.00513	0.00656	0.92	1.00
SETAR(2)-TARCH-M	0.00505	0.00665	0.90	1.02

Panel B: The Turkish Lira/US Dollar Exchange Rates

Model[c]	**Mean Squared Erros**		**Percentage Mean Absolute Error**	
	1 Step Ahead	*5 Step Ahead*	*1 Step Ahead*	*5 Step Ahead*
Random Walk	0.004932	0.006536	2.90	3.11
Best AR Process	0.004797	0.006386	2.83	3.02
TARCH(1,1)	0.004867	0.006471	2.87	3.07
SETAR(2)	0.004614	0.006241	2.74	3.00
SETAR(2)-TARCH-M	0.004725	0.006232	2.81	3.03

a- Forecast period is between 4-August-2008 and 8-September-2008 and includes 26 daily observations.
b- Out of sample forecasts are obtained by estimating the models recursively.
c- GARCH(1,1) and SETAR(2)-TARCH-M models are estimated by using the Maximum Likelihood method. Other models are estimated with the OLS method.

volatility. Therefore, it was of interest to determine whether the intervention policy of the CBRT constrained the dynamics of the exchange rates that would have been otherwise expected under the free float exchange rate regime.

Our empirical search revealed that the random walk model fails to support as the best description of the exchange rate behavior in Turkey. Following this conclusion we proceeded to estimate non-linear specifications of the exchange rates. To this end we first estimated a GARCH-M model with asymmetric effects of the residuals from the mean equation on the conditional volatility (the TARCH-M model) and then extended the mean equation with a SETAR specification. We found significant asymmetric responses of the conditional volatility of the exchange rates to the innovations in the mean equation for both type of specifications. However, we also found that these asymmetric responses are regime depended as the negative and positive innovations have quite different effects in size and direction below and above the thresholds values for both the Euro and the US Dollar exchange rates. Given the different structures both in the mean and variance equations we concluded that the exchange rates have followed different dynamics that depend on the level of the exchange rates during the full fledged Inflation Targeting regime in Turkey.

In the final section of the study the robustness of the above conclusion is checked by conducting within and out of sample forecasts exercises. The results show that the performance of the SETAR models again depends on the specific regime. In the upper regime (values above the threshold) none of the models were able to produce superior forecasts than the Random Walk model. However the SETAR specifications have produced superior forecasting performance in the lower regime (values below the threshold) for both the Euro and the US dollar.

To conclude, it can be argued that the single threshold specifications with two regimes are more appropriate for modeling the dynamics of the daily exchange rates than the models that assume a single linear process during the inflation targeting regime in Turkey. Furthermore, we also found that the exchange rate dynamics have become more predictable below the estimated threshold levels compared to the dynamics observed above these threshold levels for both the Turkish lira/Euro and the Turkish lira/US dollar exchange rates. Thus, it appears that the *de jure* exchange rate policy of floating in Turkey might actually be close to a *de facto* of implicit target zone exchange rate regime, as the dynamics of the exchange rates seems to be constrained at the low levels of the exchange rates. However, this is not in conflict with the CBRT's FX policy that aims at reducing the anticipated excess volatility in the FX market, as it is also one of the main motivations of adopting the target zone regime. Neither is it in conflict with the Inflation Targeting regime, as it gives enough flexibility to the monetary policy makers to focus on the stabilization of the inflation rates around the target level and, at the same time, it reduces the volatility in exchange rates.

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APPENDIX – Non-Linearity Tests

We performed the following non-linearity test to assess the presences of non-linear structures in the Turkish lira/Euro and the Turkish lira/ US Dollar rates;

1- The McLeod-Li test is introduced by McLeod and Li (1983) and it is a test for detecting non-linearity in series. Let;

$$Q(m) = \frac{n(n+2)}{n-k}\sum_{k=1}^{m} r_a^2(k)$$

where,

$$r_a^2(k) = \frac{\sum_{t=k+1}^{n} e_t^2 e_{t-k}^2}{\sum_{t=1}^{n} e_t^2} \quad \text{and} \quad k=0,1,........n-1$$

e is the residuals from a fitted model and r^2 is the autocorrelations of the squared residuals. The null hypothesis is that e_t is IID. It is distributed as $Q(m) \approx \chi^2(m)$.

2- The BDS test introduced by Brock, Dechert and Scheinkman (1987) is used to test the independence of the residuals that are obtained from the estimation of the above models. The BDS test is a powerful test for time based dependence in a series. This test relies on the correlation dimensions, which are constructed for a sequence of scalar observations. The distribution of the BDS statistic can be written as fallows,

$$W_{m,T}(\varepsilon) = \frac{\left[C_{m,T}(\varepsilon) - C_{1,T}(\varepsilon)^m\right]}{\sqrt{\sigma_{m,T}^2(\varepsilon)} \Big/ \sqrt{T}}$$

where $W_{m,T}(\varepsilon)$ is known as the BDS statistic and it is asymptotically distributed $N(0,1)$ for a iid time series, $x_t : t = 1,2,........,T$, for which correlation integral $C_{m,T}(\varepsilon)$ is constructed within a (Euclidian) distance ε (Grassberger and Procaccia 1983). $\sigma_{m,T}^2(\varepsilon)$ is an estimate of the variance of the term in the numerator of the above equation under the null hypothesis of iid. The BDS test is extensively applied to the high frequency financial data. There are also some studies that apply the BDS test to the daily exchange rates (Chappell 1995).