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ORIGINAL PAPER

"New" monetary policy instruments and exchange rate volatility

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Abstract Turkish economy has been suffering from rises in financial flows since the last two decades that these flows have raised financial stability challenges across emerging economies including Turkey. Regarding the ability of the central banks to decrease the financial risks including volatile exchange rate, the Central Bank of the Republic of Turkey has designed and implemented a new policy mix. In this study, we investigated the effect of new policy instruments (IRC, RRR and ROM) on the volatilities of US dollar, euro, British pound and basket rate for Turkish economy between January 2, 2002 and December 9, 2014 by using ARMA-GARCH, ARMA-EGARCH and SWARCH models. From the estimation results, we could not reach enough evidence that the IRC and RRR instruments could decrease the volatilities of exchange rates under investigation while the ROM instrument was successful, especially on US dollar and basket rate. We also found strong evidence in favour of asymmetric volatility, indicating that the positive shocks led to greater exchange rate volatility than negative ones.

Keywords Reserve option mechanism · Volatility models · SWARCH · Turkish economy

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1 Introduction

There has been a significant increase in financial flows since the last two decades and many emerging economies have been suffering from these capital movements. Although the most of the crises regarding capital movements historically were country or region specific due to the fragile macroeconomic structures of these economies, the nature of capital movements has changed for these economies during the last decade. In the aftermath of the rock-bottom interest rates in industrialised nations combined with the Fed's quantitative easing (QE) programme, trillions of speculative hot money flew to the developing world in search of better returns. Rising demand for domestic assets in emerging markets caused sharp reductions in borrowing costs in these countries, which ended in rapid credit growth and external debt accumulation. Although inflation targeting (IT) has had greater successes in stabilizing both inflation and output since 90s, many macroeconomists have been arguing that it may not be successful in small-open economies due to the changing structure of capital flows throughout the world. Critics of IT in small-open economies have suggested that although the short-term interest rates may meet price stability objectives, it may not prevent dangerous build-ups of financial risks in terms of current account deficits, credit growth, debt accumulation and international short-term capital flows.[1] Since financial risks have crucial effects on domestic inflation rates via the high volatility of the nominal exchange rates and credit growth rates, short-term policy rates may not achieve and maintain low and stable prices in open economies.

In terms of the debates on the role and ability of the central banks to affect to financial stability, emerging economies either have employed quantity-based capital flow measures as Brazil and Colombia did or implemented some macro-prudential policies as in Turkey. Although the capital flow restriction measures have potential to reduce the financial risks on theoretical base, there are some uncertainties in empirical ground where the effectiveness of such policies are found neutral.[2] Because of the difficulties in practical ground, some economists suggested macro-prudential policies which are potentially more practical and effective.

In Turkey, the Central Bank of the Republic of Turkey (CBRT) has designed and implemented a new policy suggesting to decrease financial risks and to secure financial stability. This new policy mix consists of the interest rate corridor (IRC), required reserve ratio (RRR) and reserve option mechanism (ROM) instruments to supplement conventional short-term interest rates (IR).[3] While the former two policy instruments (IRC and RRR) are intended to control domestic credit growth

[1] Since the policy rate required ensuring price stability is generally different from the interest rate needed to preserve financial stability, policy rate may not be a sufficient instrument to achieve and maintain price stability. For detailed information please see Kara (2011).

[2] For details, please see Bruno and Shin (2013).

[3] The overnight borrowing rate of the CBRT was the policy rate before May 2010; whereas since May 2010, the CBRT has adopted the weekly repo funding rate as its primary policy rate and the margin between the overnight lending and borrowing rates of the CBRT is defined as the interest rate corridor.

and to reduce the volatility of the exchange rate by discouraging short-term capital inflows, the purpose of the latter (ROM) is to decrease the volatility of the exchange rate through an automatic stabilizer mechanism. Understanding whether or not this policy mix can reduce exchange rate volatility may provide a new inflation-targeting framework which is not in conflict with the objective of achieving and maintaining price stability for open economies, especially small ones.

This paper examines the effect of policy mix on exchange rate volatilities of US dollar, euro, British pound and basket rate for the Turkish economy by using ARMA-GARCH, ARMA-EGARCH and SWARCH volatility models covering about the whole flexible exchange rate period starting from January 2, 2002 to December 9, 2014. The presence of such an effect indicates that inflation-targeting central banks of small-open economies may be able to secure financial stability by reducing exchange rate volatility.

The Turkish economy is important in the following ways. First, Turkey is an IT country and a good example of a small-open economy. Second, although the CBRT has achieved and maintained relatively low and stable inflation since the adoption of IT regime in 2002, the inflation rate still remains higher in Turkey than in many other world economies. Thirdly, Turkish economy has been increasingly exposed to capital flows for the last decade than many of emerging economies which made domestic currency more vulnerable to capital movements. Fourthly, one of the main reasons for the deviation of the inflation rate from its official target is the high volatility of exchange rates.[4] Therefore, understanding the effects of new policy approach on exchange rate volatilities is crucial for IT central banks of medium and small-open economies. Our empirical analysis based on daily data on exchange rates of the major currencies such as US dollar, euro and British pound plus a basket rate suggests that the ROM instrument could decrease the volatilities of exchange rates, especially of US dollar and basket rate while we could not reach enough evidence in favour of the IRC and RRR instruments. We also found strong evidence in favour of asymmetric volatility, indicating that the positive shocks led to greater exchange rate volatility than negative shocks.

The remainder of this paper is organized as follows. Section 2 presents theoretical perspective of IRC, RRR and ROM in addition to the literature on volatility of exchange rate; Sect. 3 introduces ARMA-GARCH, ARMA-EGARCH and SWARCH models; Sect. 4 describes the data and presents the empirical results, and Sect. 5 concludes.

2 Theoretical perspective and literature

When the present figures are compared to past ones, one can easily accept that inflation rates around the world have been low and stable over the last two decades generally thanks to IT regime although some shocks hit the economies. IT regime,

[4] Many authors modelling inflation for Turkish economy add the exchange rate as an explanatory variable to the models and find positive relationship between the movements of exchange rate and inflation rate although the pass-through has been decreasing. For detailed information, please see Şen (2009), Kara and Öğünç (2011), Çiçek (2012), Çiçek and Akar (2013), Çiçek and Boz (2013).

however, has been criticized by many macroeconomists who argue that medium and small-open economies are more likely to suffer from the changing structure of international short-term capital flows, current account deficits and volatile exchange rates.

In the aftermath of the rock-bottom interest rates in industrialised nations combined with the Fed's QE programme, trillions of speculative hot money flew to the developing world including Turkey in search of better returns. These capital flows have brought important challenges for financial stability in emerging economies as well as in Turkey. Although the current account deficit recovered quickly just after the global financial crisis, the composition of the current account deficit largely turned into portfolio investments in Turkey unlike the pre-crisis period as shown in Fig. 1.

2.1 Theoretical perspective of new policy mix

IT theory makes an argument favouring flexible exchange rates through interest rate parity, implying that the expected return on domestic assets will equal the exchange rate-adjusted expected return on foreign currency assets. Since it is not possible to earn arbitrage profits by borrowing in one country and lending in another because of interest rate parity, central banks do not need to intervene in the exchange rate or capital movements and central banks should concentrate strictly on short-term interest rates. Conversely, researchers such as Engel (1996) and Bansal (1997) found strong evidence against interest rate parity and revealed that the currencies of the countries with high interest rates appreciated rather than depreciated. This invalidity of interest rate parity may indicate that the instrument of short-term interest rate has potential to create dangerous build-ups of financial risks even though it may help to ensure price stability. Indicating this characteristic of the short-term policy rate together with the changing structure of capital flows, the CBRT decided to adopt a new policy framework to contain financial risks.

The premise of new monetary policy framework is that the equilibrium rates of interest for internal and external balances are different in a small economy.[5] New policy mix theory argues that the policy rate required to achieve price stability may not be same as the interest rate needed to ensure external balance. For example, while the policy rate should be increased in boom periods which are driven by domestic factors such as productivity shocks, an increase in policy rate may encourage and attract capital inflows and may accumulate financial risks regarding revaluation of domestic currency, current account deficits and exchange rate volatility. Central banks, thus, should use more than one instrument to ensure external (current account) balance in addition to internal (output gap) balance. In line with these theoretical explanations, the CBRT started using the policy instruments of IRC and RRR beginning in mid-2010. Kara (2011) indicates that these two instruments help to improve the quality of capital account, limiting maturity mismatches and avoiding exchange rate misalignments by reducing incentive for carry trade and lengthening the maturity of capital inflows.

[5] For detailed information, please see Başçı (2010).

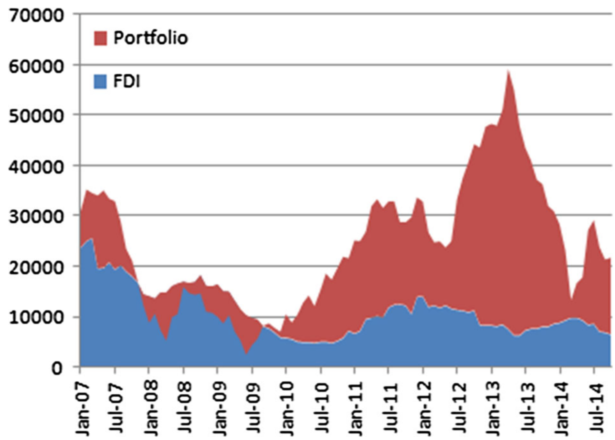

Fig. 1 Main sources of current account deficit (12-months cumulative, Billion $). *Source*: CBRT

RRR of varying degrees across maturities is an unconventional policy instrument which helps to withdraw liquidity from banking system in order to control the amount of liquidity, to moderate rapid credit growth and to sustain internal balance during boom periods (Fig. 2). In order to compensate for the liquidity withdrawn through an increase in RRR, banks instinctively turn to central bank funding but the central bank funding may not be a perfect substitute for deposits because of its very short term and the associated interest rate risk; therefore, it limits the amount of liquidity of banks and so does the credit growth rate. In order to compensate for the liquidity withdrawn by RRR, banks may resort to carry trade which may increase capital inflows. In order to discourage capital inflows, the CBRT used another policy instrument: IRC (Fig. 3).

IRC is a corridor in which the upper and lower limits are determined by overnight borrowing and lending rates while the short-term policy rate (1-week repo auction rate) is determined by the CBRT within this corridor besides short-term overnight (o/n) interest rate which is determined at Istanbul Stock Exchange Market. Widening the corridor between overnight borrowing and lending rates in the periods of acceleration in capital inflows may bring in some volatility in short-term o/n interest rates, especially in swap markets, and discourage short-term capital inflows by reducing the expected return-to-risk ratios from carry trades. As a result, the RRR and IRC both have potential to reduce the volatility of exchange rate by discouraging short-term speculative inflows (and credit growth rate by affecting liquidity amount of banks) through the unpredictable behaviour of short-term o/n interest rate.[6]

Although the CBRT tries to discourage short-term capital inflows through alternative policy instruments while controlling the domestic growth rate through policy rate, it may not be successful in preventing massive capital inflows since

[6] For detailed information about the implementation of this policy mix, please see Kara (2011) and Mimir et al. (2012).

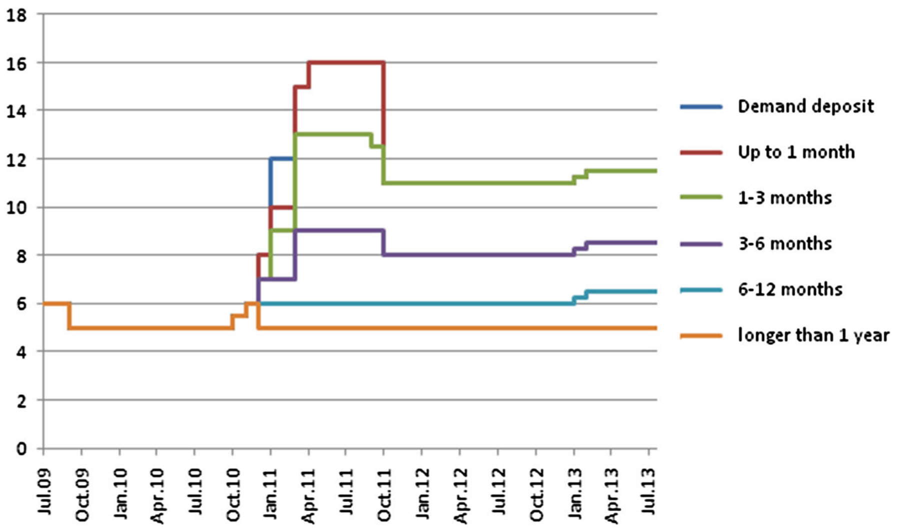

Fig. 2 Required reserve ratios. *Source*: CBRT

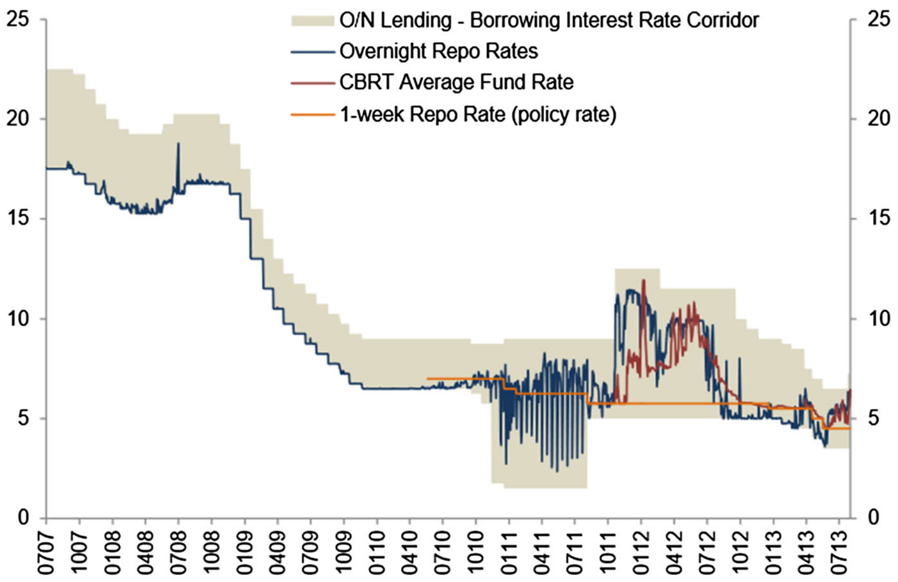

Fig. 3 Overnight lending/borrowing IRC, policy rate, and O/N repo rates. *Source*: CBRT

capital flows are sensitive to many other push or pull factors and may cause a volatile domestic currency. The CBRT, then, designed a new policy tool to decrease the volatility of nominal exchange rate, ROM. Alper et al. (2013a) indicates that ROM allows banks to keep a certain ratio of their domestic reserve requirements in foreign exchange and/or gold at the central bank. The fraction of domestic currency required reserves that can be held in foreign exchange is set by the reserve option ratio (ROR). The amount of foreign currency or gold that can be held per unit of domestic currency is called the reserve option coefficient (ROC) and up to what fraction banks will use the ROM depends on the relative cost of foreign currency to domestic currency funding.

The construction of ROM for foreign exchange started in September 2011 by setting the upper limit of the ROR at 10 %; since then it has gradually increased, and has remained at 60 % since August 2012. Different ROC values have been determined for some tranches since June 2012. Current ROC values are 1.4 for the first 40 % tranches, 1.4 for between 40 and 45 %, 1.8 for between 45 and 50 %, 2.1 for between 50 and 55 %, 2.5 for between 55 and 60 %. Figure 4 illustrates the construction of ROM for foreign exchanges in eight steps in Turkey.[7]

ROM can be seen as an automatic stabilizer. Each bank can determine its own ROC value according to its relative funding cost. Taking the period of acceleration in capital inflows as an example, one can see that the foreign exchange funding cost is lower than the domestic currency funding cost. When the relative cost of borrowing in foreign exchange decreases, the threshold ROC value tends to increase because banks' profit maximization behaviour stimulates the banks to hold a higher ratio of domestic currency reserve requirement liabilities in foreign exchange. What is most important here is that a fraction of the foreign exchange inflows can be withdrawn from market and placed in the central bank accounts of the banks as reserve requirements thanks to "voluntary" behaviour of banks and this process causes both the domestic currency to appreciate less than lack of ROM and restricts the conversion of the foreign exchange inflows into bank lending. Even though some domestic currency liquidity is injected into the system because of ROM in the period of acceleration in capital inflows, they can be withdrawn via sterilization and sterilization costs will be lower than they would be in the case of direct foreign purchase by the central banks, as long as ROC is higher than 1, as indicated by Alper et al. (2013b).

2.2 Literature on exchange rate volatility

Although many empirical studies have been conducted on exchange rate volatility, the empirical literature on the effect of new monetary policy tools on the volatility of exchange rate has remained scant for the Turkish economy since CBRT has designed three monetary policy tools to reduce the volatility of nominal exchange rate and to contain other financial risks.[8]

Ermişoğlu et al. (2013) investigated the effectiveness of ROM on the volatility of Turkish Lira (TL) by employing Generalized Autoregressive Conditional Heteroskedastic (GARCH) model and found strong evidence in favour of decreasing the volatility of Turkish lira in the sample period between October 2010 and

[7] For detailed information about ROM and its construction in Turkey, please see Alper et al. (2013a, b).

[8] For studies regarding exchange rate volatility in Turkey but regardless of ROM, please see: Güloğlu and Akman (2007), Domaç and Mendoza (2004), Guimarez and Karacadağ (2004), Çağlayan and Dayıoğlu (2009), Oduncu (2011) and Uysal and Özşahin (2012).

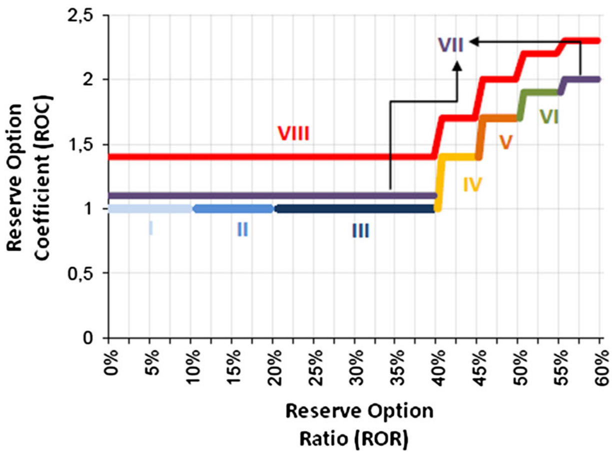

Fig. 4 Construction of ROM for foreign exchange in eight steps in Turkey. *Source*: Alper et al. (2013b), p 6

October 2012. Although this study enlightens us about the change in volatility of exchange rate regarding ROM, this study could not capture the possible asymmetric behaviours of exchange rate volatility since GARCH model cannot model the non-linearities in error terms.

For these reasons, the first goal of our paper is to capture the possible asymmetric behaviour of exchange rate volatility by using ARMA Exponential GARCH (ARMA-EGARCH) model, besides estimating ARMA-GARCH model. At the same time, GARCH type of models including ARMA-GARCH and ARMA-EGARCH we applied, do not allow any structural changes in the volatility process and force us to use explanatory or dummy variables to capture a change in variance. In order to allow structural changes in the variance equation, we also estimated the same equation with structural break dummies. Additionally, to allow structural change in variance without using any dummy variable, or in other words, to capture the regime shifts in exchange rate volatility through its own dynamics during the sample period, we also applied Switching ARCH (SWARCH). Although Ermişoğlu et al. (2013) have provided evidence that ROM has decreased the volatility of the exchange rate, it does not tell anything about the effect or the IRC and RRR on the volatility. Hence, we investigated almost whole flexible exchange rate period starting from January 2, 2002 rather than October 2010.

3 Volatility models

3.1 ARMA-GARCH and ARMA-EGARCH

Understanding the behaviour of exchange rates has always been important in economics since the exchange rate has a crucial role in monetary policy despite a flexible exchange rate regime. In order to model the volatility of exchange rate, Auto Regressive Conditional Heteroskedasticity (ARCH) type models have been widely used, one of the most of which is the Generalized ARCH (GARCH), originally proposed by Bollerslev (1986). ARCH-type models need to specify both mean equation and variance equation. Consider the mean equation of GARCH model follows autoregressive moving average process [ARMA (p, q)] as indicated in the following equation.

$$e_t = \beta_0 + \sum_{i=1}^{p} \beta_i e_{t-i} + \sum_{i=1}^{q} \theta_i u_{t-i} + u_t \quad u_t = \sqrt{h_t}\varepsilon_t \tag{1}$$

where e_t represents logarithmic change of exchange rate at time t, β_0 is a constant term, β_i is the ith autoregressive (AR) coefficient, θ_i is the ith moving average (MA) coefficient and u_t is the error term which is assumed to be student-t distributed. Error term of u_t has the changing variance over time and is modelled as in Eq. (1). h_t is conditional variance of e_t and ε_t is an independent and identically distributed (iid) sequence. p and q are called the orders of AR and MA terms. In order to determine orders of AR and MA process, the autocorrelation and partial autocorrelation functions (ACF and PACF, respectively) are basic instruments besides Akaike and Schwarz information criteria (AIC and SIC, respectively). We also purify the residuals from autocorrelations. The conditional variance equation of the model is shown in Eq. (2).

$$h_t = \vartheta_0 + \sum_{i=1}^{m} \vartheta_i h_{t-i} + \sum_{i=1}^{n} \gamma_i u_{t-i}^2 + \omega_1 D_{ROM} + \omega_2 D_{IRC/RRR} \tag{2}$$

In this notation, the error term u_t is said to follow a GARCH process of orders n and m, denoted by GARCH (n, m) and D_{ROM} and $D_{IRC/RRR}$ are dummy variables specified as in Eqs. (3) and (4) which represent the ROM and IRC/RRR periods in the sample, respectively.[9]

$$D_{ROM} = \begin{cases} 0, & \textit{before } 30.09.2011 \\ 1, & \textit{otherwise} \end{cases} \tag{3}$$

$$D_{IRC/RRR} = \begin{cases} 1, & \textit{between } 15.10.2010 \textit{ and } 30.09.2011 \\ 0, & \textit{otherwise} \end{cases} \tag{4}$$

Although the ARMA-GARCH specification of conditional variance in Eq. (2) helps us to observe the effect of the ROM and IRC/RRR instruments on foreign exchange rate volatilities, it ignores the asymmetric responses to the negative and positive changes in u_t. One of the most commonly used asymmetric volatility models is Exponential GARCH (EGARCH) that is proposed by Nelson (1991). In order to capture asymmetric impact of positive and negative shocks on volatility, we designed and applied the ARMA-EGARCH specifications of exchange rates. Although the

[9] Since the amount of FX reserves held in place of Turkish lira reserve requirements is not publicly accessible in daily basis, we have used dummy variables to see the effects of instruments.

mean equation of ARMA-EGARCH is the same as ARMA-GARCH one, conditional variance equation is different and expressed as logarithmic in Eq. (5).

$$\ln(h_t) = \vartheta_0 + \sum_{i=1}^{m} \vartheta_i \ln h_{t-i} + \sum_{i=1}^{n} \left[\delta_i \left| \frac{u_{t-i}}{\sqrt{h_{t-i}}} \right| + \gamma_i \left[\frac{u_{t-i}}{\sqrt{h_{t-i}}} \right] \right] + \omega_1 D_{ROM} + \omega_2 D_{IRC/RRR} \tag{5}$$

where ϑ_i is the lag coefficient and δ_i and γ_i are return and leverage-effect coefficients, respectively. Whether γ_i is positive and negative decides the asymmetric effects on volatilities. While the contribution of $(u_{t-i}/\sqrt{h_{t-i}})$ to the conditional variance is $(\delta_i + \gamma_i)$ in the case of $u_{t-i} > 0$, the contribution changes to $(\delta_i - \gamma_i)$ if $u_{t-i} < 0$. Therefore, the interpretation of asymmetric effect depends upon the sign of γ_i and the asymmetric effect exists in the condition of that γ_i coefficient is significantly different from zero (Akar 2006).

3.2 Structural breaks in unconditional variance

Substantial shifts in exchange rate volatility have occurred in the last decade, particularly after the global financial crisis due to change in the composition of the financial sources of current account deficits. Allowing for breaks in unconditional variance may provide different volatilities in the models. A failure to account for such breaks could yield spuriously high or low estimates of exchange rate volatility. Therefore, a key aspect of our approach is to allow for structural breaks in the unconditional variance equation and to re-estimate the coefficients under investigation.

One of the most useful methods to detect the breaks in the unconditional variance is iterated cumulative sum of squares (ICSS) algorithm which was proposed by Inclán and Tiao (1994). Although ICSS algorithm has been commonly used in the literature, it does not consider the non-mesokurtosis and heteroscedastic conditional variance processes. To correct these problems Sansó et al. (2004) developed new tests named κ_1 and κ_2. While κ_1 takes into account non-mesokurtosis, κ_2 considers both non-mesokurtosis and heteroscedastic conditional variance. In this study, κ_2 test is used to find the changes in the unconditional variance.

For the κ_2 test, Sansó et al. (2004) make some assumptions about the sequence of random variables $\{\varepsilon_t\}_{t=1}^{\infty}$.

a. $E(\varepsilon_t) = 0$ and $E(\varepsilon_t^2) = \sigma^2 < \infty$ for all $t \geq 1$
b. $sup_t E(|\varepsilon_t|^{\psi+\varepsilon}) < \infty$ for some $\psi \geq 4$ and $\varepsilon > 0$
c. $\omega_4 = \lim_{T\to\infty} E\left(T^{-1}\left(\sum_{t=1}^{T}(\varepsilon_t^2 - \sigma^2)^2\right) < \infty\right.$ exists
d. $\{\varepsilon_t\}$ is a mixing with coefficients α_j which satisfy $\sum_{j=1}^{\infty} \alpha_j^{(1-2/\psi)} < \infty$

In these assumptions, ω_4 represents a long run fourth moment of ε_t. After making these assumptions, Sansó et al. (2004) propose the following test statistic.

$$\kappa_2 = \sup_k \left| T^{-1/2} G_k \right| \tag{6}$$

where $G_k = \hat{\omega}_4^{-\frac{1}{2}}\left(C_k - \frac{k}{T}C_T\right)$, $\hat{\omega}_4$ is a consistent estimator of ω_4 and $C_k = \sum_{t=1}^{k} \varepsilon_t^2, k = 1, 2, \ldots, T$ is the cumulative sum of squares of ε_t. Under above four assumptions, the limit distribution of the statistic can be written as;

$$\kappa_2 \Rightarrow \sup_r \left| W^*(r) \right| \tag{7}$$

where $W^*(r) = W(r) - rW(1)$ is a Brownian Bridge, $W(r)$ is standard Brownian motion and $\Rightarrow$ shows weak convergence of the associated probability measures. Sansó et al. (2004) also provide critical values for κ_2.[10]

After detecting break points, we rewrite the conditional variance equations of ARMA-GARCH and ARMA-EGARCH models (Eqs. 2 and 5) as follows.

$$h_t = \vartheta_0 + \sum_{i=1}^{m} \vartheta_i h_{t-i} + \sum_{j=1}^{n} \gamma_j u_{t-j}^2 + \sum_{l=1}^{s} \varphi_l D_{BREAK,l} + \omega_1 D_{ROM} + \omega_2 D_{IRC/RRR} \tag{8}$$

$$\ln(h_t) = \vartheta_0 + \sum_{j=1}^{m} \vartheta_j \ln h_{t-j} + \sum_{i=1}^{n} \left[\delta_i \left| \frac{u_{t-i}}{\sqrt{h_{t-i}}} \right| + \gamma_i \left[\frac{u_{t-i}}{\sqrt{h_{t-i}}} \right] \right] + \sum_{l=1}^{s} \varphi_l D_{BREAK,l} + \omega_1 D_{ROM} + \omega_2 D_{IRC/RRR} \tag{9}$$

where $D_{BREAK,l}$ denotes the dummy variables taking the value of 1 from each break point to end of sample and zero otherwise.

3.3 SWARCH

Traditional ARCH and GARCH-type models are successful in modelling volatility, but Hamilton and Susmel (1994) indicated that these types of models tend to overestimate volatility. Lamoureux and Lastrapes (1993) pointed out that the persistence is higher because traditional models do not consider the regime shifts. Thus, in addition to traditional models, we use alternative specifications which allow the structural changes, in other words regime shifts, during the sample period for the robustness of the results. Furthermore, without using any dummy or exploratory variables in the model, we determine the decreasing foreign exchange volatility effect of ROM by estimating unobserved state variables which show their own volatility dynamics of the data. For this purpose, we use the Switching ARCH (SWARCH) model proposed by Hamilton and Susmel (1994) and Cai (1994).[11]

$$e_t = \mu_t + z_t \tag{10}$$

[10] For detail information about the ICSS algorithm, κ_1 and κ_2 test, please see Inclan and Tiao (1994) and Sansó et al. (2004).

[11] The mean equations of switching models are not specified as ARMA process for simplicity.

$$z_t = u_t\sqrt{[g(s_t)]} \tag{11}$$

$$u_t = \sqrt{h_t}\varepsilon_t \quad \varepsilon_t \approx \text{student} - t \tag{12}$$

$$h_t = \vartheta_0 + \sum_{i=1}^{n} \gamma_i u_{t-i}^2 \tag{13}$$

where μ_t is the conditional mean, z_t is the serially uncorrelated deviation term and follows the ARCH process with h_t, conditional variance. ε_t is assumed to be student-t distributed. s_t is the unobserved state variable, $s_t \in \{1, 2\}$, which represents the low and high volatility states. $g(s_t)$ is a constant variance factor that scales the ARCH process. For a two-state Markov process, state transition probabilities can be written as;

$$\begin{aligned} &P(s_t = 1|s_{t-1} = 1) = p_{11} \\ &P(s_t = 2|s_{t-1} = 1) = 1 - p_{11} = p_{12} \\ &P(s_t = 2|s_{t-1} = 2) = p_{22} \\ &P(s_t = 1|s_{t-1} = 2) = 1 - p_{22} = p_{21} \end{aligned} \tag{14}$$

where p_{ij} is the probability that state i, is followed by state j. The persistence problem of classical volatility models can be eliminated by the SWARCH model.

4 Data and empirical results

4.1 Data

Our data set consists of the daily foreign exchange rates of US dollar (*USD*), euro (*EUR*), British pound (*POU*) and exchange rate basket (*BAS*) covering the almost whole flexible exchange rate period from January 2, 2002 through December 9, 2014. The data were obtained from the CBRT through Electronic Data Delivery System (EDDS). In order to calculate the percentage changes in exchange rates, we have used the logarithmic change of each foreign exchange as expressed in Eq. 15.

$$e_t^j = 100 * \left[\ln\left(ER_t^j\right) - \ln\left(ER_{t-1}^j\right)\right] \tag{15}$$

where ER_t^j is the value of exchange rates at working day t and $j = usd$, eur, pou and bas. The exchange rate basket was computed as in Eq. 16;

$$ER_t^{bas} = \left(\rho_t^{usd} * ER_t^{usd}\right) + \left(\rho_t^{eur} * ER_t^{eur}\right) + \left(\rho_t^{pou} * ER_t^{pou}\right) \tag{16}$$

where ρ_t^{usd}, ρ_t^{eur} and ρ_t^{pou} are the yearly shares of US dollar, euro and British pound in foreign trade, respectively. The yearly shares of foreign currencies in foreign trade were derived from the foreign trade data obtained from Turkish Statistical Institute (TurkStat).

Table 1 Summary statistics and unit root tests

	e_t^{usd}	e_t^{eur}	e_t^{pou}	e_t^{bas}
Mean	0.014	0.023	0.016	0.017
Median	−0.017	0.000	0.000	0.000
Maximum	7.039	5.451	5.014	5.425
Minimum	−11.936	−6.769	−4.904	−8.873
Standard deviation	0.833	0.816	0.806	0.767
Skewness	0.001	0.553	0.506	0.383
Kurtosis	20.548	9.026	7.317	13.424
ADF test statistic	−56.199*	−42.589*	−42.186*	−55.971*
PP test statistic	−56.233*	−56.042*	−54.792*	−56.029*
KPSS test statistic	0.153	0.045	0.067	0.047

The null of unit root is tested with ADF and PP. The null of stationary is tested with KPSS test statistic. All tests performed with intercept

* Significance at 1 % level

4.2 Sample statistics and unit root tests

Table 1 presents the mean, median, maximum, minimum, standard deviation, skewness and kurtosis statistics for the daily exchange rates besides traditional unit root or stationary test results. The mean rate of exchange rates in Table 1 are generally low; diverging from 0.014 (for e_t^{usd}) to 0.023 (for e_t^{eur}). Although the means are quite low, the standard deviations are rather high, ranging between 0.883 (for e_t^{usd}) and 0.767 (for e_t^{bas}). A higher standard deviation of US dollar means that the series are more dispersed throughout the sample period than other currencies against Turkish lira. Since the share of the US dollar is high in foreign trade of Turkish economy, the volatility of US dollar may remarkably have potential to affect the trade volume of Turkey. The skewness and kurtosis measures indicated that our dependent variables are not likely drawn from normal distributions. In general, the kurtosis measure is much higher than the value of 3 associated with normal distribution, indicating that the distribution is leptokurtic, in other words the distributions had fat tails.

Traditional unit root or stationary test results clearly show that the series are stationary. According to the results which are presented in Table 1, univariate unit root tests present evidence that our exchange rate series do not have a unit root process in daily data for the period from January 2, 2002 through December 9, 2014. The ADF test and PP tests reject unit root null at 1 % level and the KPSS test also accepted stationary null at 1 % level.

4.3 Estimation results from GARCH and EGARCH models

We now focus on the volatility estimations in Table 2. The estimated values of AR and MA terms in the mean equations (β_1 and θ_1, respectively) are significant at 1 %

Table 2 Estimation results for ARMA-GARCH and ARMA-EGARCH models

	ARMA-GARCH (1, 1)				ARMA-EGARCH (1, 1)			
	e_t^{usd}	e_t^{eur}	e_t^{pou}	e_t^{bas}	e_t^{usd}	e_t^{eur}	e_t^{pou}	e_t^{bas}
Mean equation								
β_0	−0.007 (0.544)	0.001 (0.948)	−0.003 (0.817)	−0.002 (0.649)	0.020*** (0.071)	0.026** (0.014)	0.019*** (0.078)	0.025* (0.004)
β_1	0.052* (0.003)	−0.441* (0.010)	−0.376** (0.028)	−0.446* (0.006)	0.060* (0.001)	−0.424* (0.005)	−0.378** (0.024)	−0.428* (0.003)
θ_1	–	0.516* (0.001)	0.454* (0.007)	0.523* (0.001)	–	0.506* (0.000)	0.457* (0.005)	0.514* (0.000)
Variance equation								
ϑ_0	0.020* (0.000)	0.029* (0.000)	0.026* (0.000)	0.020* (0.000)	−0.163* (0.000)	−0.173* (0.000)	−0.165* (0.000)	−0.206* (0.000)
ϑ_1	0.132* (0.000)	0.147* (0.000)	0.121* (0.000)	0.169* (0.000)	0.961* (0.000)	0.958* (0.000)	0.959* (0.000)	0.958* (0.000)
γ_1	0.848* (0.000)	0.819* (0.000)	0.846* (0.000)	0.810* (0.000)	0.073* (0.000)	0.082* (0.000)	0.067* (0.000)	0.080* (0.000)
δ_1	–	–	–	–	0.197* (0.000)	0.206* (0.000)	0.195* (0.000)	0.245* (0.000)
ω_1	−0.011* (0.000)	−0.015* (0.000)	−0.015* (0.000)	−0.011* (0.000)	−0.033* (0.026)	−0.035* (0.000)	−0.035* (0.000)	−0.036* (0.000)
ω_2	−0.001 (0.995)	−0.003 (0.487)	−0.005 (0.407)	−0.006 (0.188)	−0.030* (0.004)	−0.026* (0.005)	−0.030* (0.000)	−0.044* (0.000)
Log-likelihood	−3563.58	−3540.46	−3592.22	−3204.30	−3576.08	−3560.37	−3586.67	−3200.61

p values are in parenthesis

*, ** and *** indicates that the coefficients are significant at 1, 5 and 10 %, respectively

level and similarly, the ARCH, GARCH and EGARCH terms in the conditional variance equations (ϑ_1, δ_i and γ_1) are statistically significant.[12]

The estimated values of w_1 and w_2 coefficients provide significant details about the effect of new policy mix on exchange rate volatility process. The negative signs of w_1 suggest negative effect of the ROM on exchange rate volatility that arise from the voluntary behavior of commercial banks, while the negative signs of w_2 similarly indicate negative effect of the IRC/RRR on exchange rate volatility that arise from the liquidity compensation behavior of banking system. Table 2 revealed that the coefficients of ROM dummy, w_1, are negative, range from -0.011 to -0.015 in ARMA-GARCH models and from -0.033 to -0.036 in ARMA-EGARCH models plus statistically significant at the level of 1 % for all series regardless of exchange rate series in our volatility regression specifications. These findings point out that the exchange rate volatilities decreased during the ROM period since September 2011 in Turkey although there was again an increase in the volatilities at the end of 2013 where the capital flows from the United States to emerging economies slowed down because of the announcement of tapering the bond-buying program by the US Fed. However, the effects of the IRC/RRR policies on exchange rate volatilities are unclear. While the estimated values of w_2 are not significant and have negative values where range from -0.001 to -0.006 in ARMA-GARCH models, they are significant at the level of 1 % and range from -0.026 to -0.044 in ARMA-EGARCH models accepting the notion that the IRC/RRR instruments decreased the exchange rate volatility since October 2010.

As aforementioned, while the ARMA-GARCH model have just concentrated on a symmetric value in the equation regardless of whether the shocks are positive or negative that hits the exchange rates, our ARMA-EGARCH model allow us to capture the possible asymmetries in variance equation. The estimated values of γ_1 coefficients capture possible asymmetric effects of new policy instruments on the exchange rate volatilities for the periods under investigation. Positive signs of γ_1 suggest that positive shocks in exchange rates lead to more volatile exchange rate than negative ones. Table 2 revealed evidence of asymmetry in variance equation. Positive shocks to the exchange rates led to more exchange rate volatility (asymmetry coefficients are ranging from 0.067 to 0.082) than negative ones. Figure 5 shows the asymmetric effects of shocks (z) on conditional variance equation (h) which is called news impact curves. When we look at the Fig. 5, we can see that the dynamic behaviors of exchange rates under investigation are asymmetric. The effects of negative shocks ($z < 0$) on conditional variances are low but in case of positive exchange rate shocks, the impacts become stronger on conditional variances in our models.

The primary reason behind of this asymmetry might be precaution motive of economic agents. Since the Turkish economy has been increasingly exposed to capital flows for the last decade, the costs of foreign loans were cheaper than the costs of Turkish lira credits. Accessibility of cheap bank loan led many firms,

[12] Diagnostic tests for mean and variance equations are performed. But they are not reported to save space. According to the test results, mean equations are purified from autocorrelations and ARCH effect is eliminated from conditional variance equations.

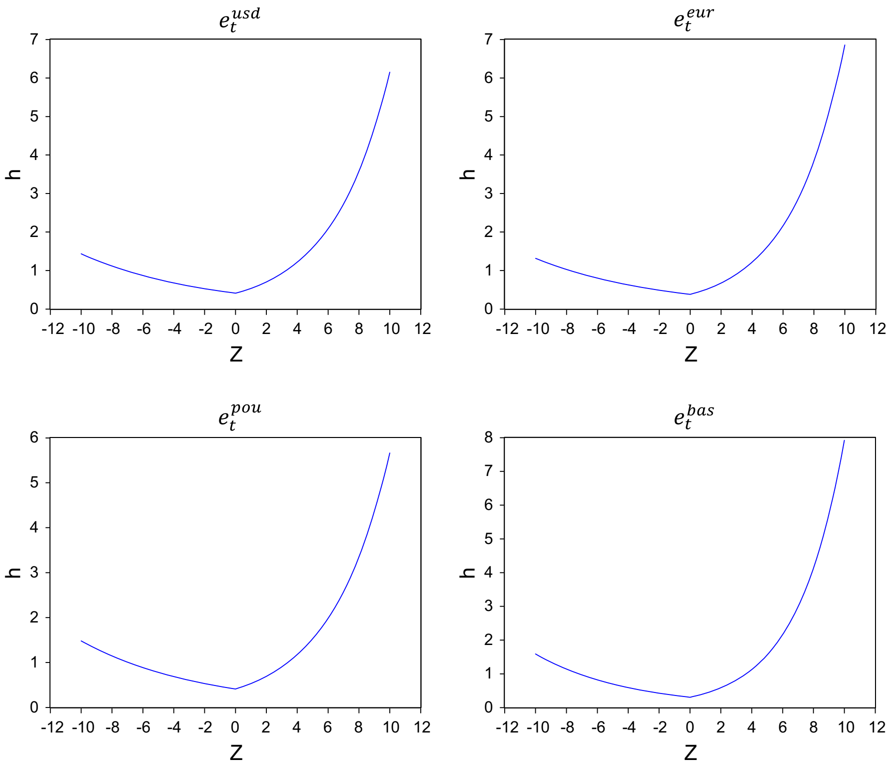

Fig. 5 News impact curves

especially non-financial corporations, to borrow in foreign currencies. Recently, 85 % of short-term debt of private sector which will be due in next year is in foreign currencies in Turkey.[13] Therefore, when a positive shock hits the exchange rate, private sector prefers to buy foreign exchange with precautionary reasons in order to avoid an insolvency situation which leads to conditional variance to increase more. Another reason might be the speculation motive of economic agents. In a less volatile environment, economic agents may prefer to invest alternative assets such as stocks or Treasury bonds which may provide higher returns. But when a positive shock hits the exchange rate, these investors may immediately sell their assets and buy foreign exchange in order to limit their losses arise from the depreciation. But the speed may not be the same in the appreciation periods. Therefore, the behavior of economic agents may differ in a positive and negative shock terms.

4.4 Allowing for structural breaks

As we mentioned previously, the amount of FX reserves held in place of Turkish lira reserve requirements is not publicly accessible in daily basis, hence we had to

[13] Çiçek (2014).

use a dummy variable (D_{ROM}) in order to capture the effect of ROM on exchange rate volatility. Although this dummy variable searches for a break in the data, we wanted to take also other break points into account since substantial shifts in exchange rate volatility have occurred in the last decade, particularly in the aftermath of the rock-bottom interest rates in industrialised nations and the global financial crisis due to change in the composition of the financial sources of current account deficits. Allowing for breaks in unconditional variance may provide different volatilities in the models. In order to detect the breaks in the unconditional variance, we employed κ_2 test proposed by Sansó et al. (2004). The data gave us some break points throughout the sample period which are listed in Table 3 and presented in Fig. 6.

After detecting break points, we rewrite the conditional variance equations of ARMA-GARCH and ARMA-EGARCH models by extending with the break dummies and re-estimated the coefficients. Estimation results are obtained by using the same methodology as described in Sect. 3.2 and presented in Table 4.

Our findings indicate that the structural break results have some considerable implications. All structural break dummies are statistically significant and there are some changes in the coefficients and significance levels of our instrument variables in the models. Although the ARMA-GARCH models showed that the ROM instrument still can explain the decreases in the volatility of the exchange rate of US dollar and basket rate at 1 % level and of British pound at 5 % level except for euro which has lost its significance, the RRR/IRC instrument has gained an explanatory power in euro rate due to small *p* values while the others has not. When the pre-break results are compared to post-break ones for ARMA-EGARCH models, one can see that the findings are parallel in line with the ARMA-GARCH model. Regarding with *p* values of US dollar, British pound and basket rate, we can say that the ROM instrument still has explanatory power on our dependent variable with relatively high but still significant *p* values. The RRR/IRC instruments have not significant effect on the exchange rate volatility in the models besides insignificance of the ROM instrument on the volatility of euro due to higher *p* values. These findings imply that the CBRT has rather taking the volatility of US dollar (and, therefore, basket rate) into account than euro because of that the foreign exchange reserves the CBRT held are mainly denominated by US dollar and it has higher standard deviation against Turkish lira than euro throughout the sample period as previously shown in Table 1 which may arise from global financial crisis. It should be noted that we could not find clear evidence in favor of that the RRR/IRC instruments have caused exchange rate volatility to reduce.

When we look at the asymmetry coefficients, we can see that there are no considerable changes in their significance levels conversely tiny increases in the values of the coefficients. News impact curves in Fig. 7 show that the effect of positive shocks on conditional variance gets larger while the negative shocks still have relatively smaller effects on conditional variance. Hence, we can point out that the data provides much more asymmetric behavior when the all breaks are taken into account and these findings are in parallel with our findings from models without breaks.

Table 3 Break dates in unconditional variance equations in ARMA-GARCH and ARMA-EGARCH models

e_t^{usd}	e_t^{eur}	e_t^{pou}	e_t^{bas}
20.07.2007	30.10.2003	30.10.2003	10.04.2003
15.05.2009	26.10.2005	03.05.2006	31.05.2005
	25.02.2008	25.02.2008	03.05.2006
	20.05.2009	04.06.2009	11.05.2009

Dates are determined by κ_2 test

4.5 Estimation results from SWARCH models

So far, we employed ARMA-GARCH and ARMA-EGARCH models in order to capture the effects of new monetary policy instruments on the exchange rate volatility. As we have mentioned before, these models can capture the regime shifts in exchange rate volatilities by adding some explanatory variables into the model. Since the amount of FX reserves held in place of Turkish lira reserve requirements is not publicly accessible in daily basis, we have used dummy variables to see the effects of instruments. However, in this section, we will employ SWARCH model over the full sample period using daily data. This method might be more accurate capturing the regime shifts in exchange rate volatilities through its own dynamics. The specification which allows the structural changes give us a robustness check of the results of Tables 3 and 4 where we have used dummy variables to capture a change in the variance. Table 5 presents the results for both mean and variance equations.[14]

The estimated values of p_{11} and p_{21} provide significant details about the regime shifts where p_{11} indicates the probability that a day of low volatility will be followed by a low volatility regime while p_{21} shows the probability of shifting low volatility state from a high volatility state. The probabilities that a day of low volatility will be followed by a low volatility regime, p_{11}, are estimated by 0.980, 0.976, 0.984 and 0.973 and the probabilities shifting low volatility state from a high volatility state, p_{21}, are estimated by 0.062, 0.064, 0.043 and 0.056 for US dollar, euro, British pound and basket rate, respectively, in Table 5. The expected duration of each state, expressed in number of days, is;

$$\textit{Expected duration} = \frac{1}{1 - p_{ij}} \tag{17}$$

where p_{ij} is the probability that state i, is followed by state j. The expected numbers of days staying in the low volatility regime (calm period) are computed as 50, 42, 63 and 37 days while the expected numbers of days staying in the high volatility (turbulent period) regime similarly are computed as 16, 16, 23 and 18 days for US dollar, euro, British pound and basket rate, respectively. These findings imply that the calm periods last longer than the turbulent periods in Turkey. One of the reason of this result might be that the CBRT uses various instruments including ROM, IRC,

[14] We compare the in-sample forecasting performance of GARCH, EGARCH and SWARCH models upon the request of anonymous referee. The results show that SWARCH model performs better than the other models to forecast the exchange rate. But the results are not reported to save the integrity of the study.

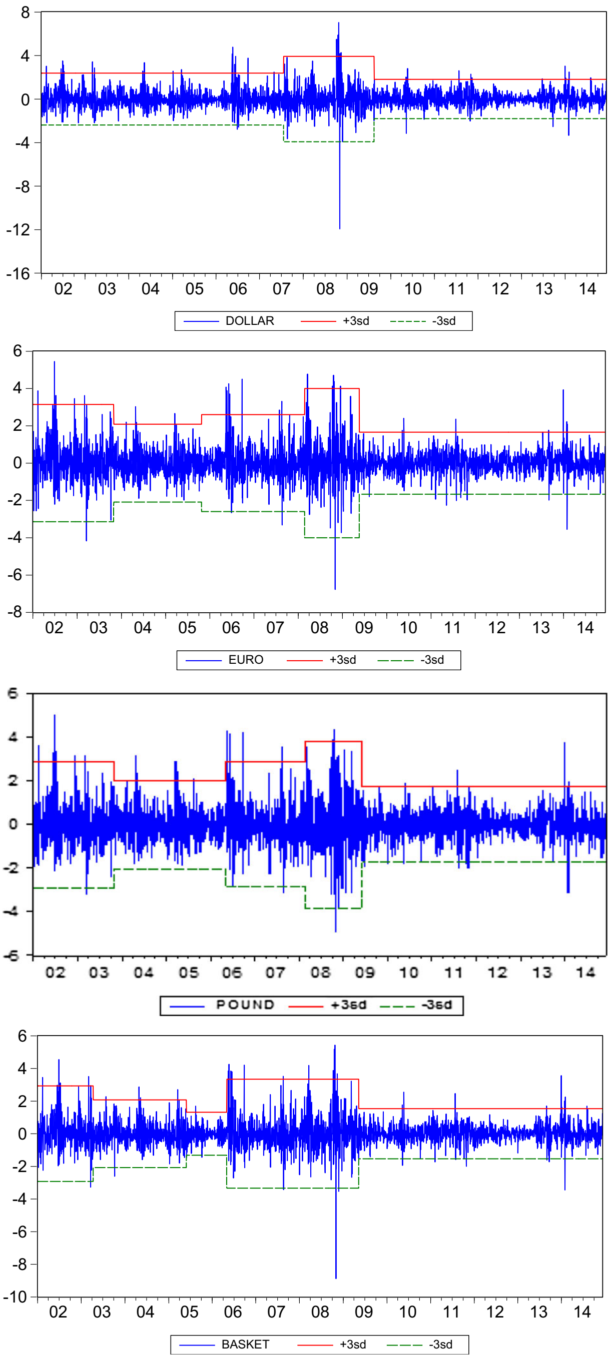

Fig. 6 Break points in variance equations

Table 4 Estimation results for ARMA-GARCH and ARMA-EGARCH models with breaks

	ARMA-GARCH (1,1)				ARMA-EGARCH (1,1)			
	e_t^{usd}	e_t^{eur}	e_t^{pou}	e_t^{bas}	e_t^{usd}	e_t^{eur}	e_t^{pou}	e_t^{bas}
Mean equation								
β_0	−0.009 (0.394)	0.001 (0.952)	−0.004 (0.724)	−0.004 (0.649)	0.015 (0.183)	0.024*** (0.099)	0.017 (0.311)	0.020** (0.021)
β_1	0.050* (0.005)	−0.448* (0.010)	−0.386** (0.023)	−0.445* (0.005)	0.058* (0.001)	−0.444* (0.005)	−0.364** (0.034)	−0.451* (0.002)
θ_1	–	0.522* (0.000)	0.464* (0.005)	0.524* (0.000)	–	0.522* (0.006)	0.444* (0.000)	0.532* (0.000)
Variance equation								
ϑ_0	0.025* (0.000)	0.097* (0.000)	0.060* (0.000)	0.066* (0.000)	−0.199* (0.000)	−0.162* (0.000)	−0.155* (0.000)	−0.199* (0.000)
ϑ_1	0.139* (0.000)	0.147* (0.000)	0.120* (0.000)	0.170* (0.000)	0.941* (0.000)	0.911* (0.000)	0.933* (0.000)	0.919* (0.000)
γ_1	0.821* (0.000)	0.767* (0.000)	0.819* (0.000)	0.770* (0.000)	0.078* (0.000)	0.095* (0.000)	0.079* (0.000)	0.094* (0.000)
δ_1	–	–	–	–	0.215* (0.000)	0.213* (0.000)	0.193* (0.000)	0.252* (0.000)
ω_1	−0.010* (0.010)	−0.004 (0.219)	−0.008** (0.041)	−0.005* (0.010)	−0.021** (0.026)	−0.010 (0.327)	−0.017*** (0.085)	−0.015*** (0.100)
ω_2	0.006 (0.403)	0.015** (0.025)	0.007 (0.342)	0.004 (0.466)	−0.008 (0.590)	0.021 (0.155)	−0.001 (0.967)	−0.011 (0.496)
Log-likelihood	−3548.90	−3540.46	−3578.29	−3157.25	−3555.55	−3529.04	−3570.49	−3156.99

p values are in parenthesis

All break dummies are statistically significant. But these are not reported

*, ** and *** indicates that the coefficients are significant at 1, 5 and 10 %, respectively

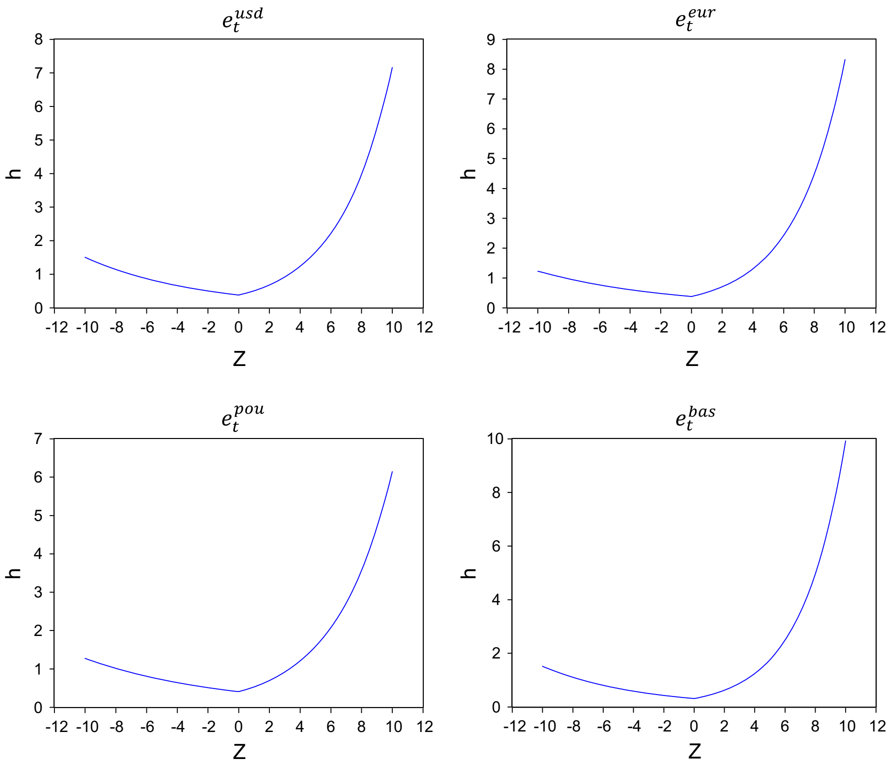

Fig. 7 News impact curves with breaks

Table 5 Estimation results for SWARCH models

	e_t^{usd}	e_t^{eur}	e_t^{pou}	e_t^{bas}
Mean equation				
μ	−0.027** (0.013)	−0.011 (0.304)	−0.013 (0.247)	−0.018** (0.041)
Variance equation				
ϑ_0	0.244* (0.000)	0.232* (0.000)	0.258* (0.000)	0.155* (0.000)
γ_1	0.123* (0.000)	0.069* (0.002)	0.127* (0.000)	0.126* (0.000)
p_{11}	0.980* (0.000)	0.976* (0.000)	0.984* (0.000)	0.973* (0.000)
p_{21}	0.062* (0.000)	0.064* (0.000)	0.043* (0.000)	0.056* (0.000)
$g(s_t = 2)$	7.427* (0.000)	7.268* (0.000)	5.483* (0.000)	8.367* (0.000)
Log-likelihood	−3604.24	−3545.46	−3624.22	−3223.04

p values are in parenthesis

* and ** indicates that the coefficients are significant at 1 and 5 %, respectively

policy rate, and foreign exchange intervention in order to restrict the volatility of exchange rate in turbulent times, otherwise doing nothing. Finally, $g(s_t = 2)$ values point out that the high volatility states are 7.427, 7.268, 5.483 and 8.367 times more

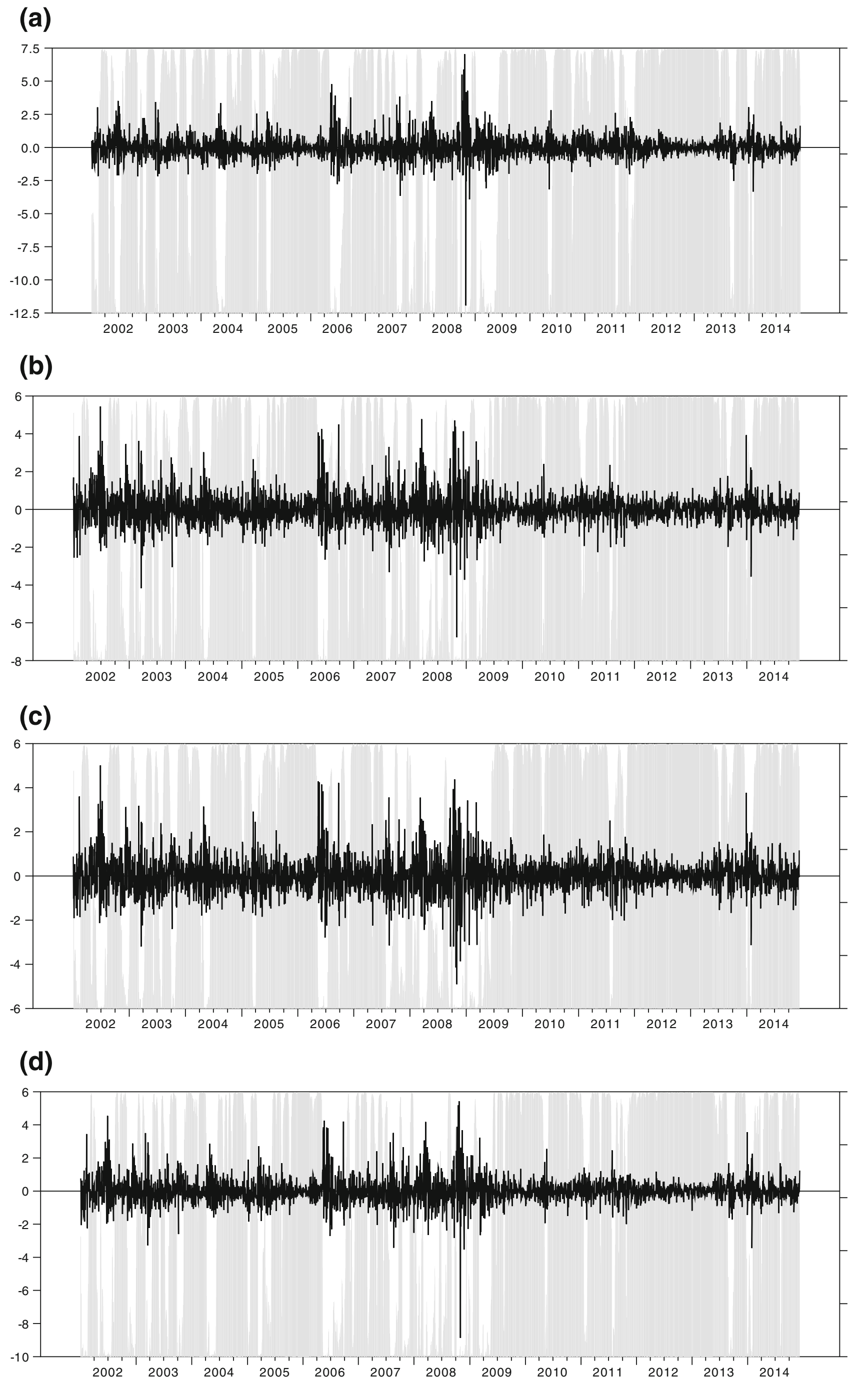

Fig. 8 Foreign exchange logarithmic change and probability of low volatility state for SWARCH model. **a** US Dollar, **b** Euro, **c** British pound, **d** Basket

volatile than the low volatility states for US dollar, euro, British pound and basket rate, respectively. For a better interpretation of the results, Figs. 8 may be instructive.

In Fig. 8, the left hand side gives the levels of volatilities for currencies while the right hand sides show the probabilities of being in low volatilities and the shaded areas indicate where the variable is in low volatility period. All four figures demonstrate that the exchange rate volatility has been significantly lower since September 30, 2011 where the ROM instrument has been started by the CBRT. Although there are some rises in volatilities in the end of 2013 and at the beginning of 2014, it can easily be seen from the figures that the volatilities quickly could return to low volatility regime. In other words, the turbulent periods are short-lived. But we should express that the CBRT had rigorously used various instruments such as foreign exchange interventions and policy rate increases (at the beginning of 2014) other than the ROM instrument. Hence, it might not be correct to say that ROM solely could decrease the exchange rate volatility. If we take the IRC/RRR instruments into account, we can see that from the figures, there are important rises in volatilities during 2011. Therefore, it might be a compelling review that IRC/RRR instruments have caused the exchange rate volatilities to decrease.

5 Conclusion

Although the policy instrument of short-term interest rates (IR) may be an effective instrument for the pursuit of price stability objective in inflation targeting (IT) regime, some macroeconomists insist that it may not be able to prevent dangerous build-ups of financial risks due to the changing structure of capital flows throughout the world. Regarding the ability of the central banks to affect to financial stability, the Central Bank of the Republic of Turkey (CBRT) has designed and implemented a new policy mix which consists of the interest rate corridor (IRC), required reserve ratio (RRR) and reserve option mechanism (ROM) instruments to supplement conventional instrument of short-term interest rates. In this study, we investigated the effect of new policy instruments on the volatilities of US dollar, euro, British pound and basket rate for Turkish economy by using ARMA-GARCH, ARMA-EGARCH and SWARCH models.

The results from the data covering the period from January 2, 2002 to December 9, 2014 provide some evidence that the ROM instrument could decrease the volatilities of exchange rates, especially of US dollar and basket rate, while we could not reach enough evidence in favour of the IRC and RRR instruments in our ARMA-GARCH and ARMA-EGARCH specifications. In addition, we found strong evidence in favour of asymmetric volatility, indicating that the positive shocks led to greater exchange rate volatility than negative shocks. The primarily reason behind of this asymmetry might be precaution motive of economic agents. Since the Turkish economy has been increasingly exposed to capital flows for the last decade, the costs of foreign loans were cheaper than the costs of Turkish lira credits. When a positive shock hits the exchange rate, private sector prefers to buy foreign exchange with precautionary reasons in order to avoid an insolvency situation which leads to conditional variance to increase more. Another reason might be the speculation motive. In a less volatile environment, economic agents may prefer to invest alternative assets such as stocks or Treasury bonds which may provide higher returns. But when a positive shock hits the exchange rate, these investors may immediately sell their assets and buy foreign exchange in order to limit their losses arise from the depreciation.

We also allowed for other structural breaks since substantial shifts in exchange rate volatility have occurred in the last decade, particularly in the aftermath of the rock-bottom interest rates in industrialised nations and the global financial crisis due to change in the composition of the financial sources of current account deficits. When the pre-break results are compared to post-break ones for ARMA-EGARCH models, we can say that the ROM instrument still has explanatory power but he RRR/IRC instruments have not significant effect on the exchange rate volatility in the models besides insignificance of the ROM instrument on the volatility of euro. These findings imply that the CBRT has rather taking the volatility of US dollar (and, therefore, basket rate) into account than euro because of that the foreign exchange reserves the CBRT held are mainly denominated by US dollar and it has higher standard deviation against Turkish lira than euro.

Since the amount of FX reserves held in place of Turkish lira reserve requirements is not publicly accessible in daily basis, we employed SWARCH model which is more accurate capturing the regime shifts in exchange rate volatilities through its own dynamics. The probabilities that a day of low (high) volatility will be followed by a low (high) volatility regime provided that the expected numbers of days staying in the low volatility regime (calm period) are computed as 50, 42, 63 and 37 days while the expected numbers of days staying in the high volatility (turbulent period) regime similarly are computed as 16, 16, 23 and 18 days for US dollar, euro, British pound and basket rate, respectively. These findings imply that the calm periods last longer than the turbulent periods in Turkey.

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