An Analysis Of Central Bank Interventions: Evidence From Turkey

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ABSTRACT

This paper investigates the characteristics of the foreign exchange operations of the CBRT during the period following the Turkish economic crisis in February 2001. Using time series based econometric models, we estimate the parameters of the FOREX market, along with the degree of effectiveness of the interventions of the monetary authority and the inflation targeting framework it employs. The results indicate that the CBRT interventions are inefficient and are mainly influenced by the uncertainties inherent in the economic environment, and cannot decrease the volatility of the exchange markets.

INTRODUCTION

Central bank interventions in foreign exchange (FOREX) markets are of crucial importance when a monetary authority develops a policy framework to maintain financial stability and achieve a target inflation rate. As Turkey, a developing country, emerged from an economic crisis in February 2001, the Central Bank of the Republic of Turkey (CBRT) was restructured as an independent entity and given authority to smooth the volatility of FOREX rates and implement policies impacting wages and domestic prices. Thus, it is warranted to examine the Turkish experience to determine the *ex-ante* reasons and *ex-post* consequences of the policy decisions in the area of FOREX market interventions by the CBRT and to shed light on the effectiveness and efficiency of such actions.

We first consider the policies developed immediately after the February 2001 crisis using the official reports published by the CBRT. Following the establishment of the floating exchange rate regime in Turkey in 2001, the *ex-ante* expectations of the CBRT's monetary policy and FOREX market interventions have been to eliminate the problems in the payments system and to maintain stability in the financial markets. Within this framework, the CBRT provided the required liquidity through quotations and open market operations in the form of direct FOREX purchases and by supplying Turkish liras to the inter-bank money market.

To bring functionality to the banking system and to end the bottlenecks in at the payments system, the CBRT actively intervened in the markets, lowered the short term interest rates, and implemented policies to provide an efficient allocation of liquidity to the system. The maturities of the overdue loans of the state controlled banks and the banks supported by the Saving Deposits Insurance Fund (SDIF) were renewed to eliminate the liquidity demands exerted on these banks and the system (CBRT, 2001, November: 19). In addition, ceiling values were set for the net domestic assets and base money items that appear on the CBRT's balance sheet, along with floor values of the changes that can periodically be realized in the net international reserves. However, in a major departure from a traditional monetary targeting framework, the restriction on the base money supply was not used as a performance criterion, but was used to indicate a ceiling value (CBRT, 2001, November: 3). This departure from tradition would stay in force until the prerequisites for the CBRT's inflation targeting regime were met and was necessary because the economic crisis of 2001 and rapid structural changes in financial markets led to structural changes in the money demand and base money estimations (CBRT, 2002, April: 18).

Following the lead of the CBRT and to rehabilitate the financial structure, the Treasury provided new T-bills to the aforementioned banks, of which, a considerable amount was purchased directly by the CBRT. This liquidity enabled state banks and fund banks to close their overnight borrowing windows with other banks and their customers.

Any excess liquidity created by these transactions and due to the use of external financing provided from the IMF was eliminated by the CBRT through FOREX sales, reverse repurchase agreements, and inter-bank transactions. In this manner, the impact of these operations on domestic credit expansion and monetary aggregates was controlled by the CBRT. In addition, the base money targets set by policy were maintained, limiting their inflationary consequences (CBRT, 2001, November: 19-21).

In this financial and monetary policy framework, the CBRT based its exchange rate policy on free market principles and let the supply and demand conditions determine the rates. Foreign exchange operations wee restricted and the CBRT intervened in the FOREX markets only to prevent excessive rate fluctuations. When required, the CBRT used transparent methods to increase foreign exchange reserves in compliance with its established floating exchange rate policy, but only after ensuring that long term trend of the exchange rate and its natural equilibrium point would not be distorted. Consequently, the CBRT conducted regular FOREX sale auctions in order to smooth the effects of short term, temporary exchange rate fluctuations without affecting the long run equilibrium level. In this manner, the CBRT sterilized the excess liquidity in the market caused by the use of external IMF financing in the very early phases of the program throughout 2001 (CBRT, 2001, November: 24). Subsequent phases witnessed FOREX purchase auctions to accumulate reserves and to strengthen the confidence in the markets, in the medium and long run (CBRT, 2002, April: 19).

In addition to the FOREX policy, the CBRT used the short term interest rates to provide price stability and manage the macroeconomic variables affecting future inflation. Thus, the CBRT cut its short term interest rates whenever indicated by developments in the domestic economy, such as the appreciation of the Turkish lira, lack of domestic demand which reduces inflation, domestic price movements that are within year-end inflation targets, convergence of inflation expectations towards year-end targets, and low volatility in financial markets (CBRT, 2002, July: 25; CBRT, 2002, October: 20-21). Naturally, the reverse of the developments listed above would lead the CBRT to implement restrictive monetary policies.

After a four-year period of implementing and experimenting with these policies, the CBRT announced that monetary policy will be used to maintain the price stability achieved by the second quarter of 2005. This policy will focus on the developments in capital, money, and exchange rate markets, as well as the developments in aggregate supply and demand equilibrium, productivity, employment, unit wage costs, public and private sector pricing behavior, changes in inflation expectations, and risk considerations resulting from exogenous shocks in international markets (TCMB, 2005, July: 27-30).

Thus, endogenous characteristics seem to have a dominant role in the *ex-ante* CBRT policy formation process. In addition it is clear that the CBRT will consider developments in external political factors and in Turkish foreign policy to determine increases in the risk premium of market interest rates, declaring that it will try to guide policy by acting more prudently when indicated by political developments. Indeed, Özdemir and Turner (2005) warn that policy makers should pay attention to the importance of fiscal discipline to ensure that the disinflation process is sustained and the high Turkish budget deficit is reduced. They conclude that, tight fiscal policies should be mixed with either monetary or debt management policies to avoid the long term monetary contraction that results when real demand for money increases with the disinflation process. As of the second quarter of 2005, no changes were planned in short term interest rates.

DYNAMICS OF CBRT's FOREX INTERVENTIONS

The February 2001 Turkish economic crisis reduced real incomes and introduced a great deal of volatility into financial markets, resulting in large scale poverty. Following the crisis, the CBRT announced that the primary goal of monetary policy and FOREX intervention was not to meet strict targets for financial indicators, but to smooth and limit volatility in markets. Pursuing targets might lead to unacceptable *ex-post* consequences given the huge level of government debt and the sensitivity of financial indicators to domestic interest rates. Thus, the monetary policy took a moderately accommodative stance since no policy choices that would increase the risk premium in financial markets could be accepted. In addition, the CBRT announced that it would respond to shocks in exchange rates, wages, and domestic prices to ensure that a target annual inflation rate was achieved (CBRT, 2002, April: 70). Thus, the CBRT acknowledged that the inflationary pressures in Turkish economy had their origins in non-monetary factors such as shocks that led to sharp exchange rate depreciations, adjustments in the public sector prices, and inflationary inertia.

Using the aforementioned policy proposals, the CBRT started to intervene in the FOREX markets. During the early phases, all interventions were sale transactions. During the period between March 29, 2001, and November 30, 2001, FOREX sales totaled $6553 million. Starting in April 2002 and up to June 2005, all interventions were purchase transactions. The first phase of these purchases occurred between April 1, 2002, and June 27, 2002, with $795 million being bought by the CBRT. The second phase of purchases amounted to $5652 million and was conducted between May 6, 2003, and October 22, 2003. Next, during the period beginning January 2004 and ending March 2005, the FOREX market witnessed two other episodes of buying interventions. The first one occurred between January 23, 2004, and April 26, 2004, with $3782 million being purchased, while the second one occurred between December 22, 2004, and March 1, 2005, with $2072 million being purchased. Thus, the CBRT purchased approximately $12301 through FOREX interventions since the exchange rates were permitted to float.

LITERATURE REVIEW

Given the promise by the CBRT of limited post-crisis period FOREX interventions and the goal of preventing excessive rate fluctuations, it is warranted to explore how successful the CBRT has been in this endeavor. Using the Turkish economy as a case study, Ağcaer (2003); Domaç and Mendoza (2004); Selçuk and Ardıç (2005); Selçuk (2005: 295-312); Ardıç and Selçuk (2005); Guimarães and Karacadağ (2004); Herrera and Özbay (2005); Akıncı, Çulha, Özlale and Şahinbeyoğlu (2005a); and Akıncı, Çulha, Özlale and Şahinbeyoğlu (2005b) analyze how the foreign exchange market responses to central bank interventions in a floating exchange rate system. In addition, Sarno and Taylor (2001: 839-868); Canales-Kriljenko, Guimarães and Karacadağ (2003); and Ağcaer (2003) consider the policy issues and surveys of methodologies dealing with foreign exchange interventions and give international evidence on the effectiveness of such interventions.

Ağcaer (2003) estimates that the CBRT's interventions are generally effective in reducing exchange rate volatility. Specifically, while large interventions in small numbers are shown to manage the level of exchange rates well, several small sell interventions are shown to be effective in reducing exchange rate volatility. Akıncı, Çulha, Özlale and Şahinbeyoğlu (2005a) investigate the impact of the foreign exchange interventions from several perspectives. They find that high volatility in exchange markets leads to a high probability of intervention, and high a depreciation (appreciation) trend in the Turkish lira leads to a high probability of sale (purchase) interventions. In addition, they demonstrate that interventions in the foreign exchange markets signal the future course of monetary policy, leading to changes in the volatility of the foreign exchange markets.

A detailed investigation of central bank interventions indicates that purchase interventions are more effective in controlling the volatility of exchange rates than sale interventions. Akıncı, Çulha, Özlale, and Şahinbeyoğlu (2005b) support these findings showing that purchase-based interventions are successful specially after the financial markets are stabilized, and propose a policy where the CBRT intervenes in the FOREX markets with large purchases. They also find that the interest rate parity process operates in an unconventional manner, in that, a decrease in the secondary market interest rates leads to the appreciation of the Turkish lira because it signals a decrease in the perceived risk to foreign investors.

Domaç and Mendoza (2004) demonstrate that whenever the FOREX markets perceive the presence of central bank operations, domestic currency appreciates, making purchase operations more effective than sale operations in controlling the mean level of the exchange rates. In contrast, interventions through sale operations reduce the volatility of exchange rates. In addition, as a monetary policy instrument, an increase in overnight interest rates also leads to decreases in volatility. They conclude that if the foreign exchange interventions are carried out with finesse and the central bank does not engage in the defense of a particular exchange rate, FOREX sale and purchase transactions can play a useful role within an inflation targeting framework and contain the adverse effects of temporary exchange rate shocks on inflation and financial stability.

Selçuk and Ardıç (2005), Selçuk (2005: 295-312), and Ardıç and Selçuk (2005) analyze the dynamics of exchange rates in Turkey after February 2001, when exchange rates were allowed to float. Their findings generally point out that the central bank policies are effective in taming the volatility of exchange rates, especially through selling auctions. In addition, they show that unexpected increases in interest rates raise exchange rate volatility, while unexpected interest rate cuts reduce volatility. They conclude that their findings are in line with the official CBRT arguments proclaiming that intervention policies are not aimed at the level or the direction of the exchange rates but rather the goal is to contain volatility.

Herrera and Özbay (2005) find that foreign exchange interventions during the free float period were not effective in altering the exchange rate level, but had a positive and marginally significant effect on the exchange rate volatility. Their results show that while foreign exchange sales have a positive and marginally significant effect on the conditional variance of exchange rates, purchase based interventions have no statistically significant effect on the volatility of exchange rate. In addition, foreign exchange interventions by the CBRT have no significant effect on the conditional mean of the exchange rates. They conclude that, during the free float period, the CBRT achieved its objective of allowing the market determine the level of exchange rates, and intervene only during periods of heightened volatility.

However, foreign exchange interventions laed to higher, not lower, volatility. Using Turkey as a test case, Guimarães and Karacadağ (2004) find that neither foreign exchange sales nor purchases have a significant effect on the exchange rate level. They also find that foreign exchange sales (but, not purchases) reduce volatility in the short term and increase it in the long term. Thus, they conclude that the results do not support the claim that intervention is a useful tool in reducing FOREX volatility.

PURPOSE

The analyses of the monetary and FOREX intervention policies of the CBRT during the period following February 2001 indicate that it is warranted to examine the determinants, effectiveness, and consequences of these transactions. In addition, given the depth and breadth of research addressing the determinants and consequences of FOREX interventions by central banks, it is important to use a double verification approach to ensure that the research findings are internally consistent and can be generalized. Finally, the research period used must be long enough to ensure that the results are robust and better represent the realities of the Turkish economy than the results of prior studies that they may contradict.

METHODOLOGY AND RESULTS

To achieve the above stated purpose, the first step is to apply the generalized autoregressive conditional heteroskedasticity (GARCH) methodology (Bollerslev, 1986: 307-327) to reveal the effects of FOREX interventions on the level and volatility of exchange rate returns. Next, unrestricted vector autoregression techniques (VARs) inspired by Ardıç and Selçuk (2005), Selçuk (2005: 295-312), and Selçuk and Ardıç (2005) are used to reveal the dynamic relationships between applied FOREX interventions and their *ex-post* results. The aim is to determine if the findings of the two models are consistent with each other, ensuring that the conclusions are robust.

Data and Variable Specification

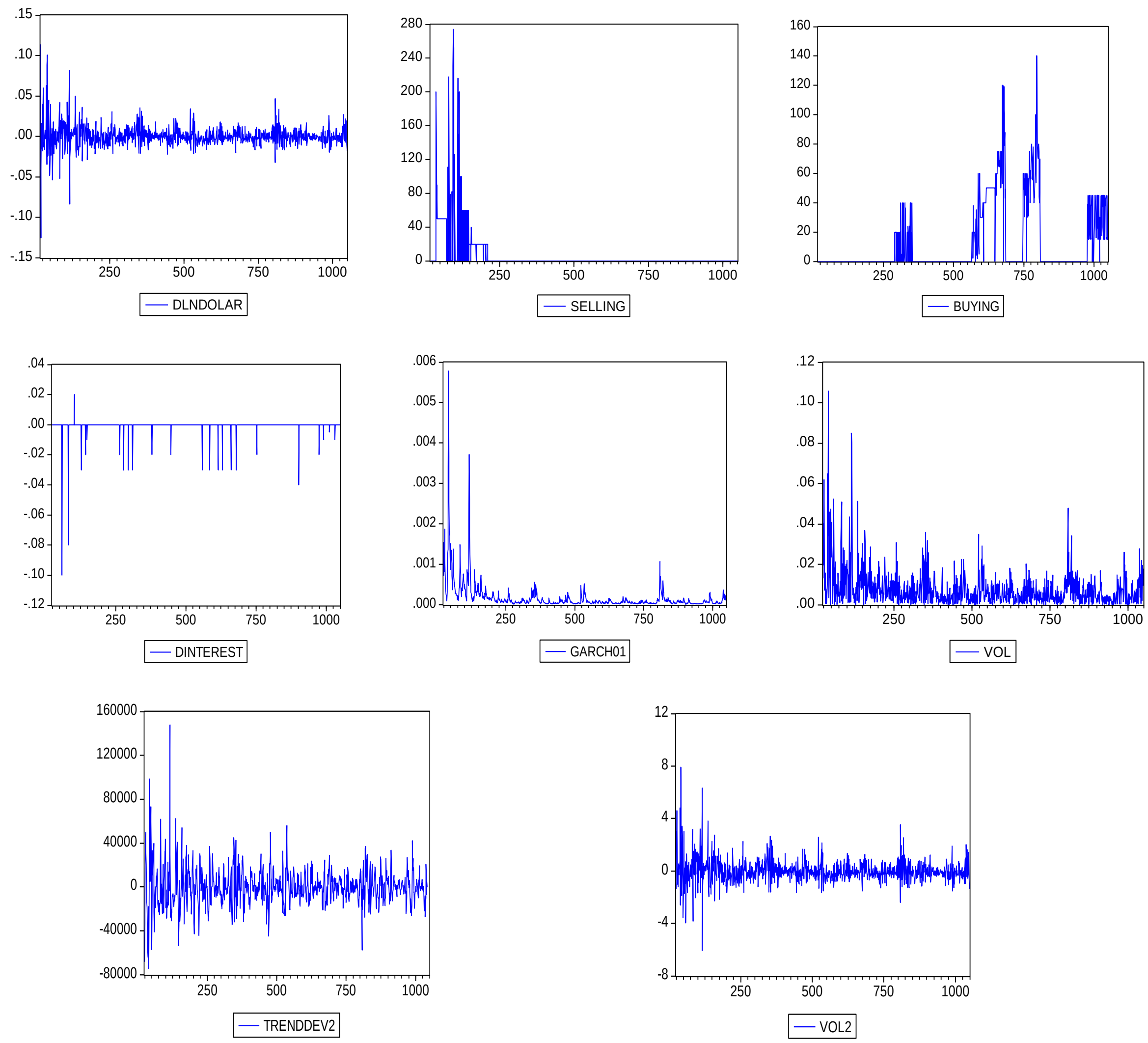
Daily time series data used in this study covers the period of 2/23/2001 - 04/01/2005 and consists of 1034 business days. The variables used are the log difference of the TL/US$ exchange rate return (DLNDOLAR), daily total amount sold by the CBRT in US$ selling auctions in millions of US$ (SELLING), daily total amount bought by the CBRT in US$ buying auctions in millions of US$ (BUYING), change in central bank overnight interest rates (DINTEREST), absolute value of exchange rate return as a measure of exchange rate volatility (VOL), conditional variance of the exchange rate estimated through using GARCH methodology as a measure of volatility (GARCH01), and deviation of exchange rate from its 15-day moving average as a measure of volatility (TRENDDEV2), following Akıncı, Çulha, Özlale and Şahinbeyoğlu (2005).

The latter is calculated as,

$$(TL/US)_i \ (1/15)\sum_{t=i-7}^{k=i+7} (TL/US\$)_i \qquad (1)$$

In addition, an exchange rate pressure index (VOL2), calculated as the difference of daily percent change in the exchange rate from its mean value, is considered as a measure of volatility. This measure indicates when the CBRT will possibly intervene in the market. Following Özatay (1999: 327-352), this pressure index is weighted by the inverse of its standard deviation. A preliminary investigation (not reported here to save space), found that all of the variables considered are stationary. Likewise, a brief analysis of Figure 1 below points out that all of the variables used in this study have stationary characteristics.

Figure 1: Time Series Used In The Study



Research Model for the Level and Volatility of FOREX Returns and Results

To address econometric/methodological issues and provide the explanations below concerning model specifications, *Eviews 5 User's Guide* by QMS (2004: 585-587) is used. First, dealing with the volatility analysis in a standard GARCH(1,1) specification given below, we can consider that,

$$y_t = x_t'\gamma + \varepsilon_t \quad (2)$$

$$\sigma_t^2 = \varpi + \alpha\varepsilon_{t-1}^2 + \beta\sigma_{t-1}^2 \quad (3)$$

Equation (2) is the mean equation written as a function of exogenous variables $x_t's$ and an error term. In equation (3), σ_t^2 is the conditional variance and provides the one period ahead forecast variance based on past information. This conditional variance equation is a function of three terms, the mean term ϖ, the ARCH term ε_{t-1}^2 which represents the volatility from the previous period measured as the lag of the squared residual from the mean equation, and the GARCH term σ_{t-1}^2 which is the forecast variance of the previous period. The (1,1) in GARCH(1,1) refers to the presence of a first order GARCH term and a first order ARCH term. Higher order GARCH models denoted as GARCH*(p,q)* can be chosen by selecting either *p* or *q* greater than 1.

An ordinary ARCH model is a special case of a GARCH specification in which there are no lagged forecast variances in the conditional variance equation. Introducing the conditional variance into the mean equation, we get the ARCH-in-Mean (ARCH-M) model (Engle, Lilien and Robins, 1987: 391-407),

$$y_t = x_t'\gamma + \sigma_t^2 + \varepsilon_t \quad (4)$$

If we consider that,

$$v_t = \varepsilon_t^2 - \sigma_t^2 \quad (5)$$

and substituting for the variances in the variance equation and rearranging terms, we can write the model in terms of the errors as,

$$\varepsilon_t^2 = \varpi + (\alpha + \beta)\varepsilon_{t-1}^2 + v_t - \beta v_{t-1} \quad (6)$$

The squared errors follow a heteroskedastic ARMA(1,1) process. The autoregressive root which governs the persistency of volatility shocks is the sum of α and β. An estimated value close to unity means that shocks die out rather slowly, which is often observed in high frequency financial data.

Table 1 reports the effects of foreign exchange interventions on the level and volatility of exchange rate through GARCH(1,1) analysis presented in equation (2) and equation (3) and allows the conditional variance affect the mean equation as expressed in equation (4). Potential model misspecification are dealt with by calculating robust *t*-ratios using the quasi maximum likelihood method suggested by Bollerslev and Wooldridge (1992: 143-172) so that parameter estimates will be unchanged but the estimated covariance matrix will be altered. The mean and the variance are specified by the equations (7) and (8) below, respectively,

$$DLNDOLAR_t = \alpha_1 + \alpha_2\sigma_t^2 + \alpha_3 BUYING_t + \alpha_4 SELLING_t + \alpha_5 DINTEREST_t + \varepsilon_t \quad (7)$$

$$\sigma_t^2 = \beta_1 + \beta_2\varepsilon_{t-1}^2 + \beta_3\sigma_{t-1}^2 + \beta_4 BUYING_t + \beta_5 SELLING_t + \beta_6 DINTEREST_t \quad (8)$$

The output of the ARCH estimation process (Table 1) is divided into two sections. The upper part provides the results of implementing the mean equation (7) and the lower part, labeled "Variance Equation," contains the coefficients, standard errors, z-statistics and p-values for the coefficients of the variance equation (8). The ARCH parameters correspond to α and the GARCH parameters to β in equation (3) above.

Table 1: GARCH Estimation Process Of The Exchange Rate Volatility

Dependent Variable: DLNDOLAR
Method: ML-ARCH (Marquardt)
Sample: 02-06-2001 to 04-01-2005
Included observations: 1033 after adjusting endpoints
Bollerslev-Wooldridge robust standard errors & covariance
Cariance backcast: ON

Variable	Coefficient	Std.Error	z-Statistic	Probability
GARCH	-1.094203	2.265796	-0.482922	0.6292
C	-0.000763	0.000307	-2.487646	0.0129 (*)
BUYING	9.24E-06	8.56E-06	1.079149	0.2805
SELLING	7.84E-05	2.76E-05	2.843507	0.0045 (*)
DINTEREST	-0.002155	0.008733	-0.246785	0.8051
		Variance Equation		
C	5.68E-06	1.76E-06	3.222482	0.0013 (*)
ARCH(1)	0.353505	0.072648	4.865975	0.0000 (*)
GARCH(1)	0.623016	0.063500	9.811236	0.0000 (*)
BUYING	1.91E-08	5.98E-08	0.320015	0.7490
SELLING	1.20E-06	5.56E-07	2.150713	0.0315 (*)
DINTEREST	0.000495	0.000172	2.887384	0.0039 (*)
AIC	-6.495061			
SC	-6.442455			
Q(20)	24.493	Prob.	0.222	
Q(36)	34.031	Prob.	0.563	
$Q^2(20)$	7.985	Prob.	0.992	
$Q^2(36)$	13.801	Prob.	0.998	

(*) means that the results are statistically significant

The standard GARCH(1,1) procedure used in Table 1 reveals that selling auctions have a significant and positive impact on the level of exchange rate return. Thus, selling auctions in the foreign exchange market increase the exchange rate return, rather than decreasing it. Since the selling auctions were implemented just after the crisis period of February 2001 lasted for the entire year, the interventions might have been perceived by market participants as a sign of increasing uncertainty in the market leading them to require higher prices for exchange rates. Buying interventions and interest rate cuts did not have a statistically significant impact on the change in exchange rate levels during the same period. Finally, the impact of the conditional variance on the exchange rate returns is not significant.

The results of using the variance equation show that, selling auctions tend to increase the volatility of the FOREX market. Given that the sum of the ARCH and GARCH terms is close to one (0.977), the volatility shocks are persistent and the forecasts of the conditional variance converge to the steady state quite slowly. While buying interventions do not affect the volatility of the exchange rate returns, changes in overnight interest rates, such as interest rate cuts, have a positive and dampening effect on volatility.

To ensure that autocorrelations do not distort the results, correlogram-Q statistics was used. The test for the presence of autocorrelation in the standardized residuals and in the squares of standardized residuals cannot reject the null (no autocorrelation) at conventional levels ($\alpha < 0.05$). Thus, no residual serial correlation in the mean equation is detected and also the mean and variance equations are correctly specified since Q-statistics are not significant. In addition, the GARCH model is re-estimated by including additional ARCH and GARCH terms in the variance equation, such as GARCH(1,2), GARCH(2,1), and GARCH(2,2) estimation processes, with no change in the results presented above.

Research Model for the Consequences of FOREX Interventions and Results

Next, the research approach used by Ardıç and Selçuk (2005), Selçuk (2005: 295-312), and Selçuk and Ardıç (2005) is employed to examine the dynamic relationships between FOREX interventions and their *ex-post* consequences. The aim is to discover if the research findings reported above are verifiableand can be duplicated by another inquiry, leading to robust conclusions. The methodology employs contemporaneous vector autoregression (VAR) estimation techniques such as Granger causality and impulse response analyses.

Followong Johnston and Dinardo (1997: 287-301), Greene (2000: 740-747), and QMS (2004: 708-716), and assuming first an *AR(p)* process, we obtain

$$y_t = m + \alpha_1 y_{t-1} + \alpha_2 y_{t-2} + ... + \alpha_p y_{t-p} + \varepsilon_t \quad (9)$$

Next, a column vector of *k* different variables is considered,

$$y_t = [y_{1t}\ y_{2t}\ ...\ y_{kt}]' \quad (10)$$

and modeled in terms of the past values of the vector as a VAR. The VAR*(p)* process would thus be,

$$y_t = m + A_1 y_{t-1} + A_2 y_{t-2} + ... + A_p y_{t-p} + \varepsilon_t \quad (11)$$

The A_i are *kxk* matrices of coefficients, *m* is a *kx1* vector of constants and ε_t is a vector of white noise process, with the properties,

$$E(\varepsilon_t) = 0 \text{ for all } t \quad E(\varepsilon_t, \varepsilon_s') = \begin{cases} \Omega, & s=t \\ 0, & s \neq t \end{cases} \quad (12)$$

where the Ω covariance matrix is assumed to be positive definite. Under these circumstances, when *A* is *nxn* and symmetric, which is the matrix whose transpose *A´* equals to *A*, *A* is positive definite if $\delta' A \delta > 0$ for all *nx1* vectors $\delta \neq 0$. Thus, ε's are not serially correlated but may be contemporaneously correlated. Some of the basic features of VARs can be demonstrated by considering a simple case where *k=2* and *p=1*. This would result in,

$$y_t = \begin{bmatrix} y_{1t} \\ y_{2t} \end{bmatrix} = \begin{bmatrix} m_1 \\ m_2 \end{bmatrix} + \begin{bmatrix} a_{11} & a_{12} \\ a_{21} & a_{22} \end{bmatrix} \begin{bmatrix} y_{1,t-1} \\ y_{2,t-1} \end{bmatrix} + \begin{bmatrix} \varepsilon_{1t} \\ \varepsilon_{2t} \end{bmatrix} = m + Ay_{t-1} + \varepsilon_t \quad (13)$$

Thus, as in all VARs, each variable is expressed as a linear combination of the lagged values of itself and lagged values of all other variables in the system. In such a system of VARs, the behavior of the *y*'s will depend on the properties of the *A* matrix. For simplicity, the deterministic time trends and other exogenous variables are ignored in this demonstration.

Sometimes one may wish to test whether a specific variable or group of variables plays any role in the determination of other variables in the VAR. Granger causality is inferred when lagged values of a variable y_{2t} have explanatory power in a regression of a variable y_{1t} on lagged values of y_{1t} and y_{2t}. In this case a two-variable VAR, as in equation (13), is specified as,

$$y_t = \begin{bmatrix} y_{1t} \\ y_{2t} \end{bmatrix} = \begin{bmatrix} a_{11} & 0 \\ a_{21} & a_{22} \end{bmatrix} \begin{bmatrix} y_{1,t-1} \\ y_{2,t-1} \end{bmatrix} + \begin{bmatrix} \varepsilon_{1t} \\ \varepsilon_{2t} \end{bmatrix} \quad (14)$$

Here the lagged value of y_2 plays no role in the determination of y_1. Thus, y_2 is said to not cause y_1 within the context of Granger causality. The hypothesis that y_2 does not cause y_1 could be tested simply by running the regression of y_1 on the lagged values of y_1 and y_2 and examining whether the coefficient of the latter variable is significantly different from zero. More generally, the y vector might be partitioned into two sub-vectors: y_1 of order k_1x1 and y_2 of order k_2x1. The hypothesis that the block y_2 does not Granger cause y_1 is tested by estimating the first k_1 equations of the VAR and testing whether the coefficients of the lagged y_2 vectors differ significantly from zero.

Following Johnston and Dinardo (1997: 287-301), Greene (2000: 740-747), and QMS (2004: 708-716), and to examine the nature of short run dynamic interactions among the variables used, a two- variable VAR system such as equation (13) is considered. Continuing with the above example,

$$y_{1t} = m_1 + a_{11}y_{1,t-1} + a_{12}y_{2,t-1} + \varepsilon_{1t} \quad (15)$$

$$y_{2t} = m_2 + a_{21}y_{1,t-1} + a_{22}y_{2,t-1} + \varepsilon_{2t} \quad (16)$$

A perturbation in ε_{1t} has an immediate and one-for-one effect on y_{1t}, but no effect on y_{2t}. In period $t+1$, the perturbation in y_{1t} affects $y_{1,t+1}$ through the first equation and also affects $y_{2,t+1}$ through the second equation. These effects work through to period $t+2$, and so on. Thus, a perturbation in one innovation ε_t in the VAR sets up a chain reaction over time in all VAR variables. Impulse response functions are used to calculate these chain reactions. The path whereby the variables return to a state of equilibrium is called the impulse response of the VAR (Greene, 2000: 745).

A shock to the *i-th* variable not only directly affects the *i-th* variable but is also transmitted to all of the other endogenous variables through the dynamic lag structure of the VAR. An impulse response function traces the effect of a one-time shock to one of the innovations ε_t on current and future values of the endogenous variables. If the innovations ε_t are not contemporaneously correlated, interpretation of the impulse response is straightforward. The *i-th* innovation $\varepsilon_{i,t}$ is simply a shock to the *i-th* endogenous variable $y_{i,t}$. Innovations ε_t, however, are usually correlated, and may be viewed as having a common component which cannot be associated with a specific variable. In order to interpret the impulses, it is common to apply a transformation to the innovations ε_t so that they become uncorrelated. In this paper, generalized impulses as described by Pesaran and Shin (1998: 17-29) are applied to construct an orthogonal set of innovations ε_t that does not depend on the VAR ordering. The generalized impulse responses from an innovation ε_t to the *j-th* variable are derived by applying a variable specific Cholesky factor computed with the *j-th* variable at the top of the Cholesky ordering.

At this stage, an unrestricted VAR model is constructed using daily observations discussed above to examine the possible *ex-post* consequences of the FOREX interventions of the CBRT. A preliminary analysis reveals that the appropriate lag length for this VAR model is the maximum chosen lag. This choice is not sensitive to the use of either the most popular minimized Akaike information criterion (AIC) or the sequential modified likelihood ratio (LR) statistics. The latter model starts with the maximum lag and decreases the lag one at a time until the null hypothesis is rejected. Since the VAR model lag length is found to be the maximum lag length, given the chosen maximum lag order, lag order 7 and lag order 14 are applied to different VAR model considerations. The aim is to examine whether the estimated results are sensitive to the lag specification in the chosen VAR model.

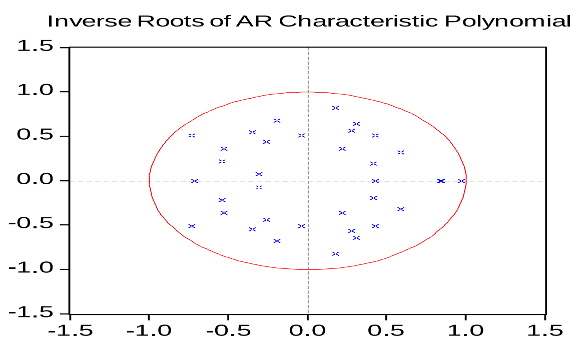
The first VAR model considered consists of the variables DLNDOLAR, SELLING, BUYING, DINTEREST, and VOL. Using a 7-day horizon in Table 2 and Figure 2, the pair-wise Granger causality block is subjected to the Exogeneity Wald test and generalized impulse response estimation results are employed with 1000 Monte Carlo repetitions of plus/minus two standard deviations. For the pair-wise Granger causality tests in which each equation is represented by columns (probabilities are in parentheses), we test whether an endogenous variable can be treated as exogenous under the null hypothesis. For each equation in the VAR, we consider χ^2 (Wald) statistics for the joint significance of each of the other lagged endogenous variables in that equation. The statistic in the last row *(All)* is the χ^2 statistic for the joint significance of all other lagged endogenous variables in the equation.

Table 2: VAR Pair-Wise Granger Causality/Block Exogeneity Wald Test

Dependent Variable	DLNDOLAR	BUYING	SELLING	DINTEREST	VOL
DLNDOLAR	2.619580	2.433216	30.47749	24.38588	
	(0.9178)	(0.9320)	(0.0001)	(0.0010)	
BUYING	13.50970		1.688114	9.139504	4.722947
	(0.0606)	(0.9751)	(0.2428)	(0.6937)	
SELLING	64.51202	1.094934		69.83159	92.43232
	(0.0000)	(0.9931)		(0.0000)	(0.0000)
DINTEREST	45.43129	4.761942	1.587395	52.75629	
	(0.0000)	(0.6890)	(0.9791)	(0.0000)	
VOL	14.30572	14.30572	18.53709	33.00779	
	(0.0460)	(0.0460)	(0.0098)	(0.0000)	
All	152.0358	17.47707	29.29508	127.1752	177.2429
	(0.0000)	(0.9386)	(0.3977)	(0.0000)	(0.0000)

Pair-wise Granger causality test results reveal that buying auctions, selling auctions, changes in the CBRT overnight interest rate, and the absolute value of the exchange rate return as a measure of exchange rate volatility separately and jointly cause changes in the exchange rate return. While Granger causality factors exist for buying auctions, the exchange rate volatility has a casual association with only selling auctions. Also, while the exchange rate return, selling auctions, and the exchange rate volatility cause changes in overnight interest rates, buying auctions show no such effect. As to the main subject of interest, the exchange rate volatility, the daily log-returns on exchange rates, the selling auctions, and changes in interest rates have Granger causality with changes in the exchange rate volatility, but the same effect on volatility does not exist for buying auctions.

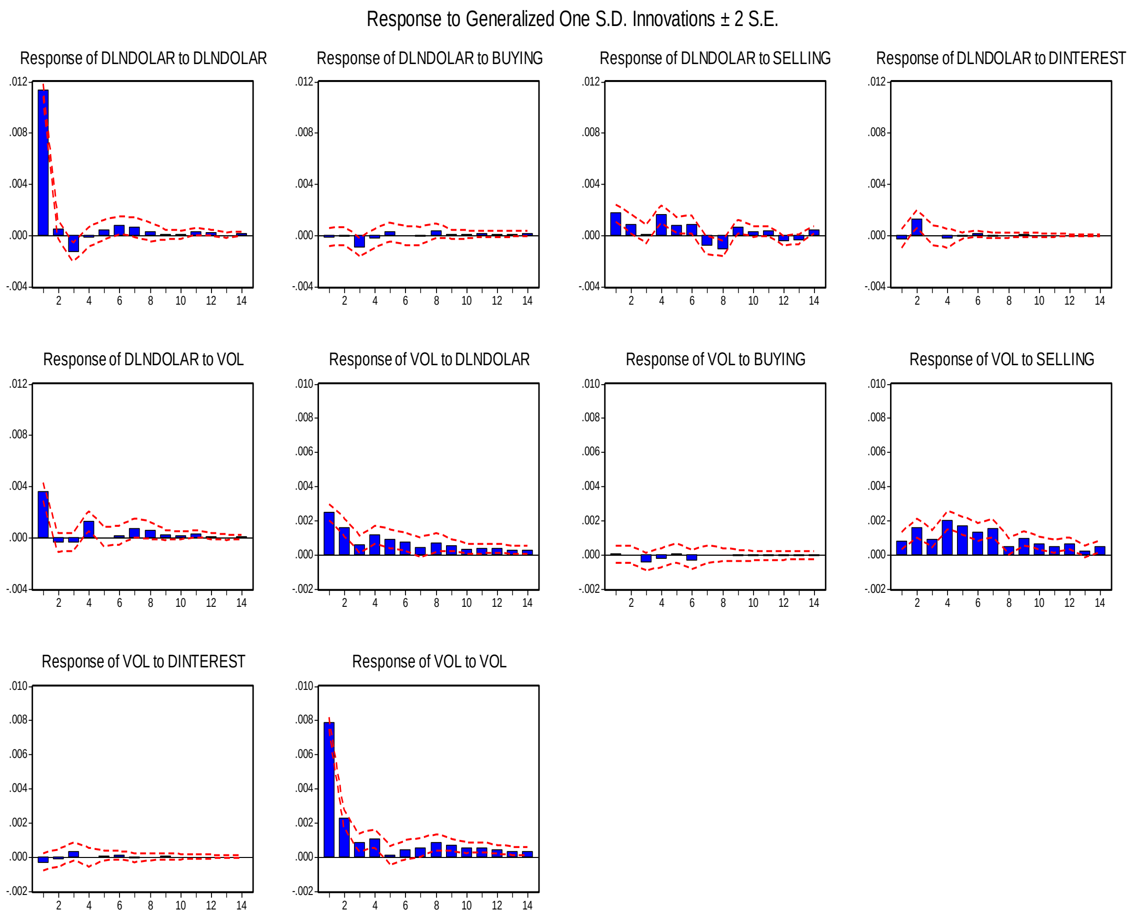
Figure 2: Inverse Roots of AR Characteristic Polynomial



As can be seen in Figure 2, all reported inverse roots of the AR polynomial have roots with modulus less than one and lie inside the unit circle, indicating that the estimated VAR is stable (stationary). This is a very favorable result because if the VAR were not stable, certain results, such as impulse response standard errors, would not be valid making the model results and conclusions suspect.

The estimated generalized impulse responses shown in Figure 3 that deal with the exchange rate return and exchange rate volatility in the VAR system, report that a positive shock to the selling auctions leads to a positive and statistically significant response of the log-return of the exchange rate. Further, this effect carries on for 6 days, while some negative responses to the exchange rate returns occur much later, in days 7 and 8. Thus, contrary to the findings of the studies discussed in the Literature Review section, FOREX market selling auctions by the CBRT do not decrease the return on exchange rates through supply-side effects. The main explanation for the rejection of the conclusions of prior studies is that the CBRT's interventions are perceived by market participants as a sign of increasing uncertainty in the FOREX markets, leading them to require a higher price for the exchange rates. Thus, the VAR model results support the findings of the GARCH analysis presented in the previous section.

Figure 3: Generalized Impulse Responses – Lag 7



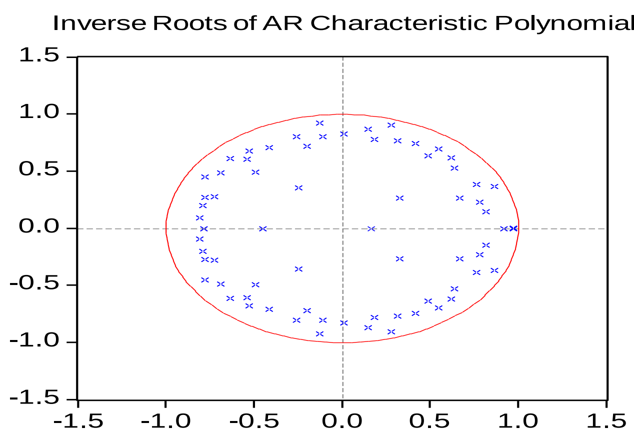
As is in the case of selling auctions, a positive shock to the exchange rate return has a positive and significant effect on exchange rate volatility. While, a one standard deviation positive shock to selling auctions increases the volatility rather than decreasing it, the model reports no statistically significant effect resulting from shocks to buying auctions as well as shocks to changes in overnight interest rates.

The results of lag specification 14 reported in Table 3, Figure 4, and Figure 5 support the lag specification results, with two exceptions. First, buying auctions do not show Granger causality with the log-return of exchange rates. Second, changes in the overnight interest rates do not show Granger causality with the exchange rate volatility.

Table 3: VAR Pair-wise Granger Causality/Block Exogeneity Wald Test

Dependent Variable	**DLNDOLAR**	**BUYING**	**SELLING**	**DINTEREST**	**VOL**
DLNDOLAR	8.333594	25.70078	68.04969	47.29288	
	(0.8712)	(0.0282)	(0.0000)	(0.0000)	
BUYING	16.56155	2.062199	14.95408	10.07507	
	(0.2803)		(0.9999)	(0.3813)	(0.7567)
SELLING	84.45803	3.096862		70.28040	106.5102
	(0.0000)	(0.9989)	(0.0000)	(0.0000)	
DINTEREST	29.99355	12.44549	11.67182		12.74256
	(0.0076)	(0.5706)	(0.6326)		(0.5469)
VOL	45.36032	8.960818	37.44055	45.33081	
	(0.0000)	(0.8336)	(0.0006)	(0.0000)	
All	179.5104	31.06952	87.47845	192.9907	201.9330
	(0.0000)	(0.9972)	(0.0045)	(0.0000)	(0.0000)

Figure 4: Inverse Roots of AR Characteristic Polynomial



Next, the conditional variance of the exchange rate is estimated as a measure of volatility using GARCH methodology (GARCH01) with a lag length of 7. Table 4, Figure 6, and Figure 7 report approximately the same results through pair-wise Granger causality analysis and a VAR model that satisfies the stability condition. All the endogenous factors have Granger causality with the exchange rate log return. While the volatility factor is the main determinant of the selling auctions, no explanatory factor is found for buying auctions. Change in the overnight interest rate is affected by selling auctions and the log return of the exchange rate. The estimation results support the above findings since the log return of the exchange rate and selling auctions affect the exchange rate volatility. Also, buying auctions have no determining effect on the exchange rate volatility. Generalized impulse response analysis reveals that a one standard deviation shock to selling auctions significantly increases both the log return of the exchange rate and its volatility. Finally, a negative shock to the change in the overnight interest rate has a significant and immediate positive effect on the exchange rate volatility. As reported in Table 5, Figure 8, and Figure 9 below, similar results are obtained using lag length 14.

Figure 5: Generalized Impulse Responses – Lag 14

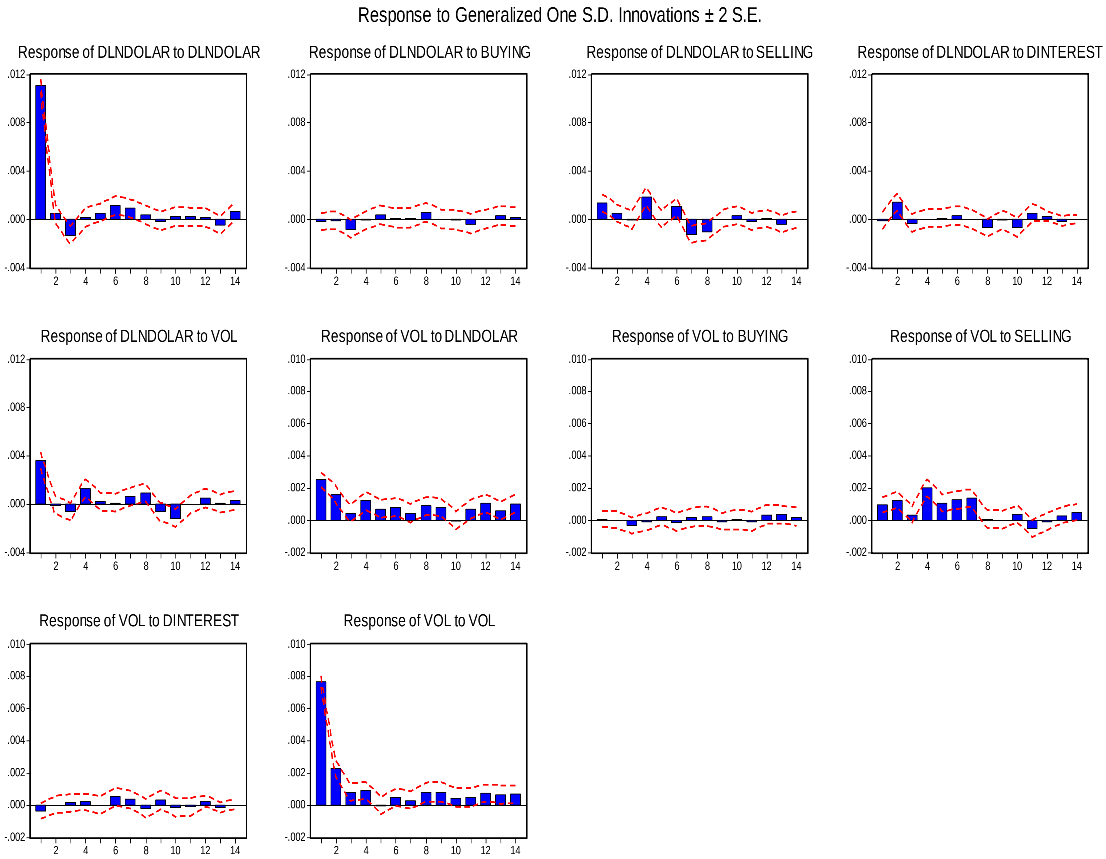


Table 4: VAR Pair-wise Granger Causality/Block Exogeneity Wald Test

Dependent Variable	DLNDOLAR	BUYING	SELLING	DINTEREST	GARCH01
DLNDOLAR		3.747718	4.415460	22.10821	139.1395
		(0.8083)	(0.7309)	(0.0024)	(0.0000)
BUYING	13.94647		1.337573	8.934134	1.085469
	(0.0521)	(0.9874)	(0.2574)	(0.9933)	
SELLING	67.12186	0.445050		73.97637	142.9727
	(0.0000)	(0.9996)		(0.0000)	(0.0000)
DINTEREST	59.81711	4.361800	6.290156		66.93845
	(0.0000)	(0.7373)	(0.5063)	(0.0000)	
GARCH01	15.76561	0.971986	21.57710	8.551121	
	(0.0273)	(0.9953)	(0.0030)	(0.2865)	
All	153.6959	10.10577	32.36753	100.4673	430.5292
	(0.0000)	(0.9992)	(0.2598)	(0.0000)	(0.0000)

Figure 6: Inverse Roots of AR Characteristic Polynomial

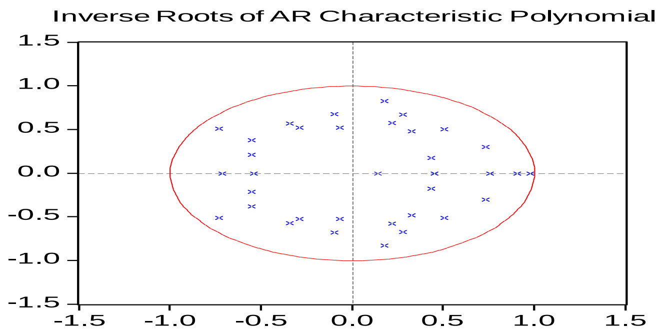


Figure 7: Generalized Impulse Responses – Lag 7

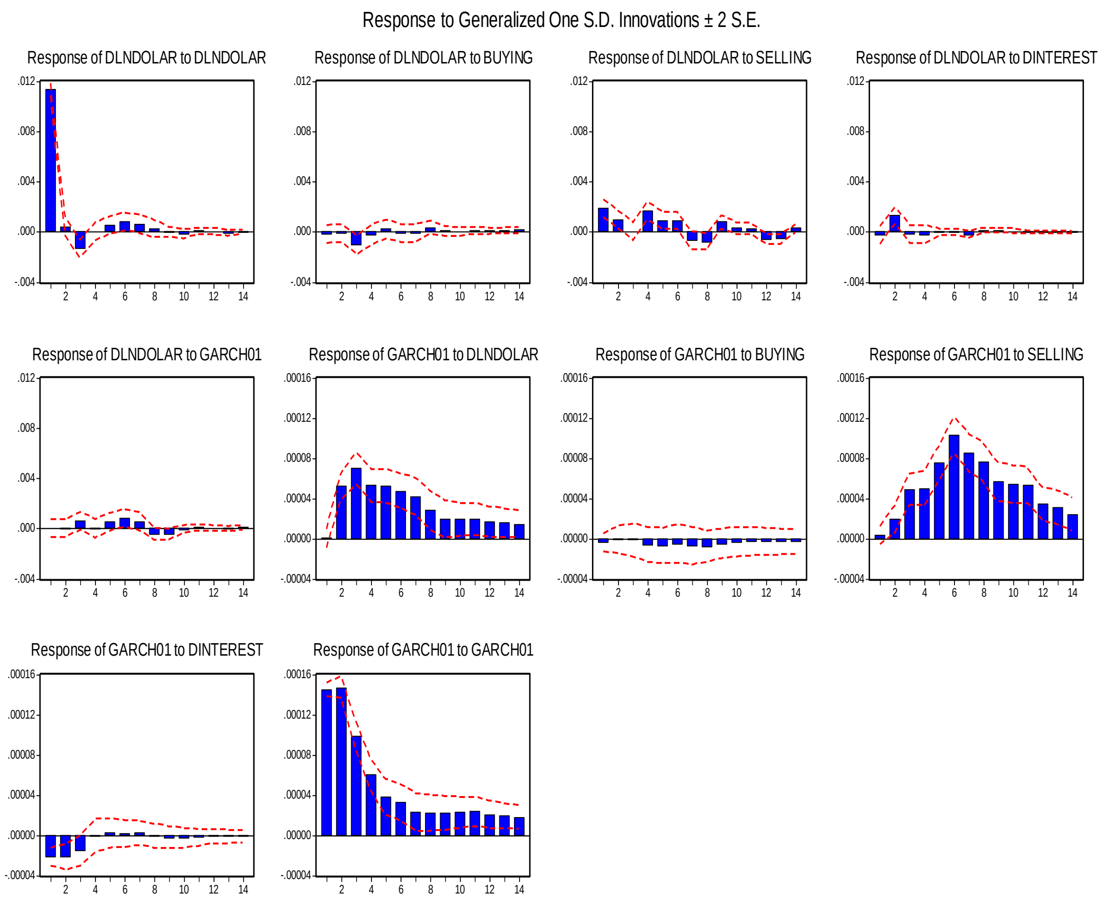
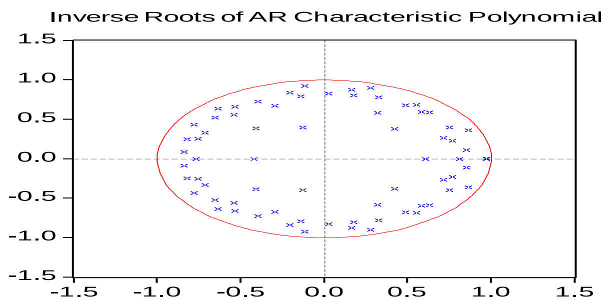


Table 5: VAR Pair-wise Granger Causality/Block Exogeneity Wald Test

Dependent Variable	DLNDOLAR	BUYING	SELLING	DINTEREST	GARCH01
DLNDOLAR		11.77236	29.78674	61.95797	190.2212
		(0.6246)	(0.0082)	(0.0000)	(0.0000)
BUYING	17.26636		1.534865	13.99405	3.905364
	(0.2423)		(0.9999)	(0.4502)	(0.9960)
SELLING	88.08698	1.660445		70.78547	162.7704
	(0.0000)	(0.9999)		(0.0000)	(0.0000)
DINTEREST	37.96512	11.26576	13.55461		12.8900
	(0.0005)	(0.6650)	(0.4834)		(0.5352)
GARCH01	65.21251	2.122748	35.33034	20.24509	
	(0.0000)	(0.9999)	(0.0013)	(0.1226)	
All	202.0436	24.07347	85.26109	164.1760	455.7644
	(0.0000)	(0.9999)	(0.0071)	(0.0000)	(0.0000)

Figure 8: Inverse Roots of AR Characteristic Polynomial



As a third step in analyzing volatility, the variable GARCH01 is replaced in the VAR model with TRENDDEV2. Since the results above are not found to be sensitive to the lag length, only lag length 7 is used in the remainder of the paper. Granger causality analysis results reported in Table 6, Figure 10, and Figure 11 point out that selling auctions and the volatility variable TRENDDEV2 have Granger causality with the changes in the exchange rate. Verifying the results above, buying auctions have an exogenous relationship with other system variables. While the exchange rate return and TRENDDEV2 have a determining effect on selling auctions, selling auctions rather than buying auctions affect the changes in the overnight interest rate. Similarly, selling auctions have Granger causality with the exchange rate volatility and the generalized impulse response analysis in Figure 11 points out that the direction of this causality is positive, that is, selling auctions lead increases in the exchange market volatility.

Finally, the exchange rate pressure index VOL2 is used as a measure of volatility. Using VAR lag length 7, Table 9, Figure 12, and Figure 13 show that the exchange rate volatility and the log return of the exchange rate are found have Granger causality with selling auctions, but no feedback effects are found with buying auctions. The change in the overnight interest rate is affected by every endogenous factor except buying auctions. However, buying auctions are found to have Granger causality with the exchange rate volatility, along with selling auctions and the change in the overnight interest rates. Thus, generalized impulse response analysis results support the earlier findings that selling auctions, rather than buying auctions, significantly affect both the log return of the exchange rate and the exchange rate volatility. A one standard deviation shock to selling auctions leads to increasing volatility.

Figure 9: Generalized Impulse Responses – Lag 14

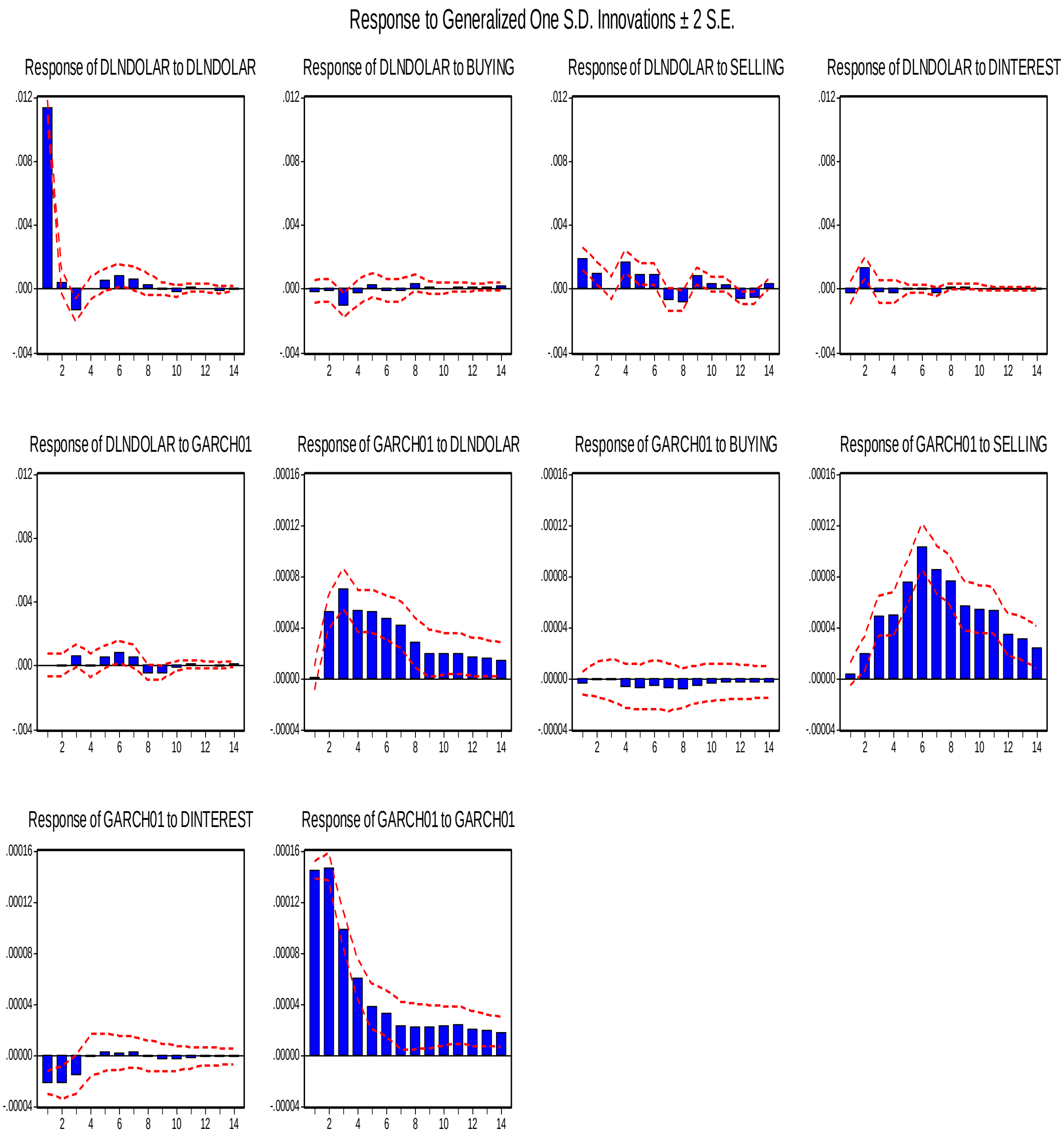


Table 6: VAR Pair-wise Granger Causality/Block Exogeneity Wald Test

Dependent Variable	DLNDOLAR	BUYING	SELLING	DINTEREST	TRENDDEV2
DLNDOLAR	(0.2633)	8.854476 (0.0003)	27.16577 (0.0445)	14.40138 (0.0000)	136.9088
BUYING	8.473136 (0.2927)		4.207224 (0.7556)	9.352320 (0.2283)	8.725117 (0.2730)
SELLING	60.35885 (0.0000)	0.487994 (0.9995)		71.71246 (0.0000)	60.31199 (0.0000)
DINTEREST	9.809485 (0.1996)	9.338401 (0.2293)	1.893284 (0.9655)		6.85990 (0.4436)
TRENDDEV2	747.6878 (0.0000)	7.919316 (0.3398)	47.44817 (0.0000)	6.496983 (0.4831)	
All	908.6137 (0.0000)	21.92823 (0.7846)	59.38276 (0.0005)	98.58022 (0.0000)	224.6742 (0.0000)

Figure 10: Inverse Roots of AR Characteristic Polynomial

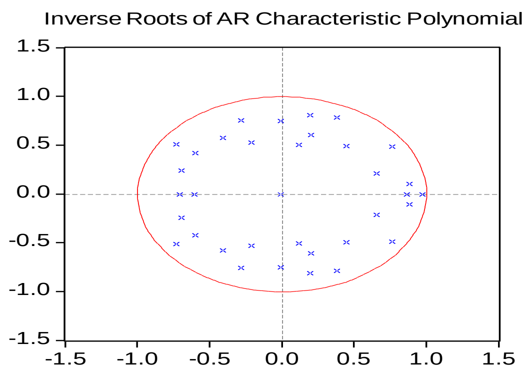


Table 7: VAR Pair-wise Granger Causality/Block Exogeneity Wald Test

Dependent Variable	DLNDOLAR	BUYING	SELLING	DINTEREST	VOL2
DLNDOLAR		1.098303 (0.9931)	27.11284 (0.0003)	33.74448 (0.0000)	7.912001 (0.3404)
BUYING	14.28547 (0.0463)		2.048747 (0.9571)	8.914921 (0.2588)	14.16098 (0.0484)
SELLING	68.02196 (0.0000)	0.434990 (0.9997)		75.16314 (0.0000)	70.00650 (0.0000)
DINTEREST	46.84324 (0.0000)	4.380085 (0.7351)	3.606373 (0.8238)		47.70550 (0.4436)
VOL2	8.821967 (0.2657)	1.134337 (0.9924)	27.63508 (0.0003)	33.23323 (0.0000)	
All	145.8000 (0.0000)	10.26962 (0.9991)	38.49012 (0.0895)	127.4214 (0.0000)	147.9204 (0.0000)

Figure 11: Generalized Impulse Responses – Lag 7

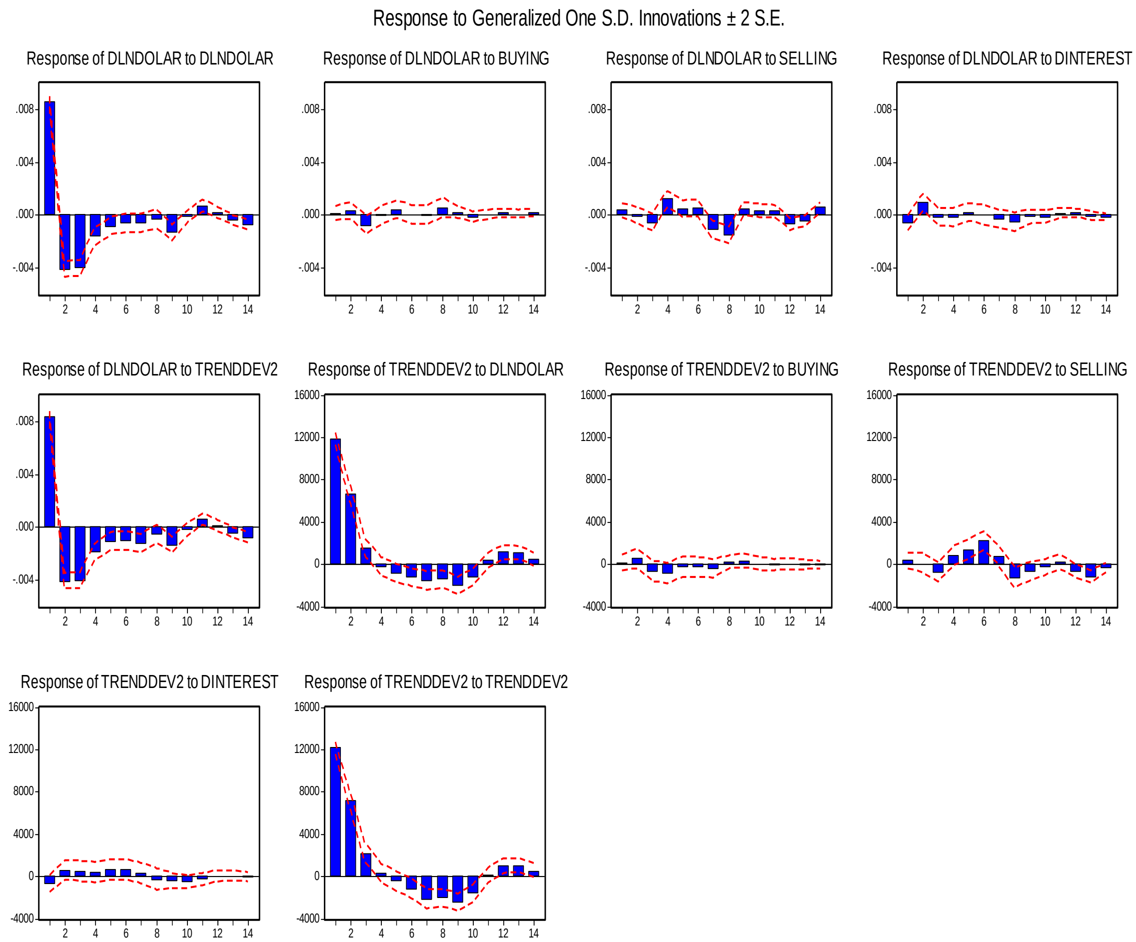


Figure 12: Inverse Roots of AR Characteristic Polynomial

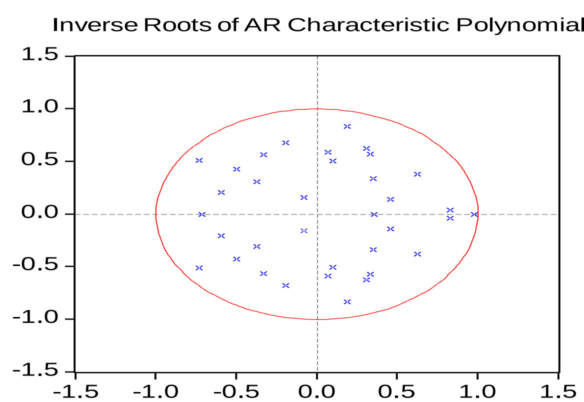
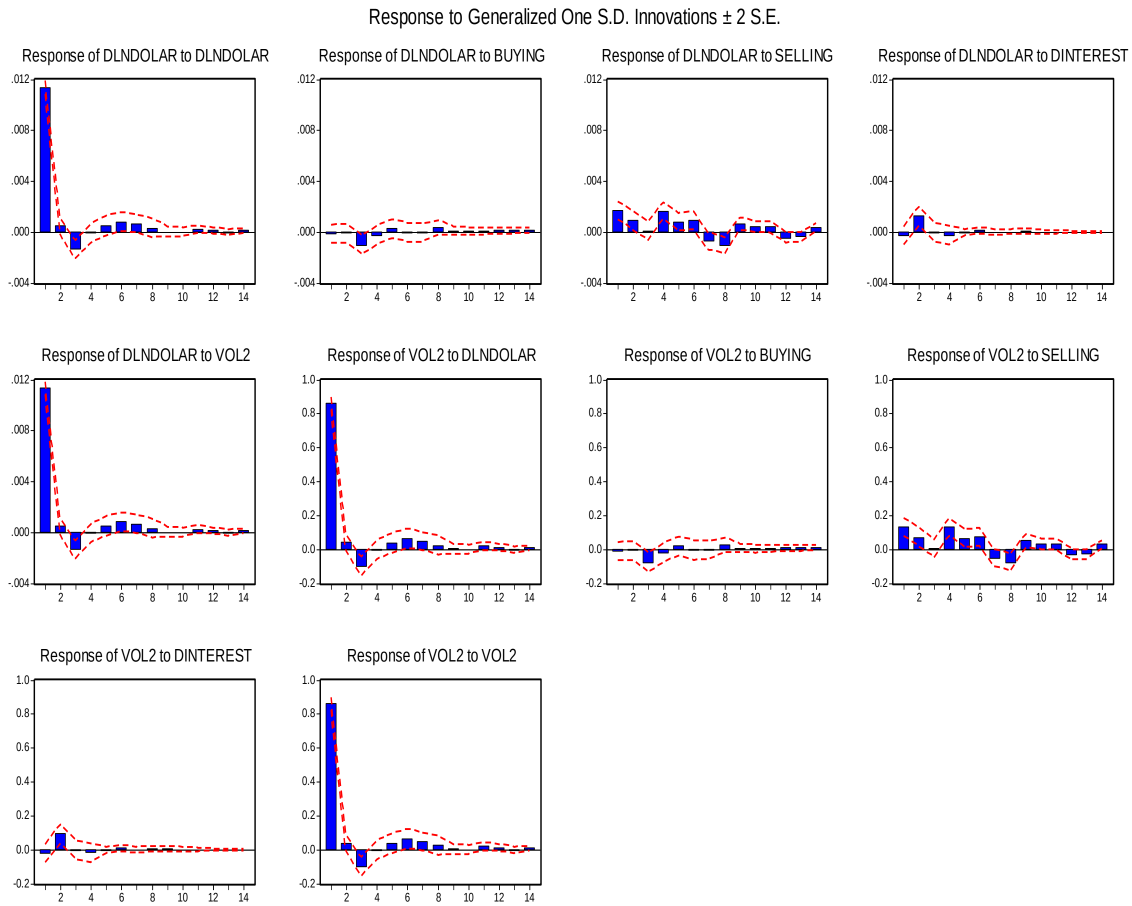


Figure 13: Generalized Impulse Responses – Lag 7



CONCLUSIONS AND RECOMMENDATIONS

This study investigates the factors that affect and are affected by the FOREX operations of the CBRT for the Turkish post-crisis period of February 2001 – March 2005. First, both the course of the monetary policy stance of the CBRT and its intervention policies are examined. Next, time series econometrics that make use of generalized autoregressive conditional heteroskedasticity (GARCH) methodology and unrestricted vector autoregression techniques (VARs) are employed to reveal the dynamic relationships between the CBRT interventions and their *ex-post* consequences. The aim is to discover the degree of effectiveness of the CBRT interventions within the implied inflation targeting framework and to ensure that the findings are robust, verifiable, internally consistent, and lead to policy conclusions that can be generalized.

Based on the results of both models, the main policy conclusion is that the CBRT interventions are under the control of uncertainties and exogenous variables in the Turkish economic environment. Rather than decreasing the volatility of the exchange market, interventions are shown to be ineffective and inefficient. Analyzing the direction of these interventions, sale auctions rather than the buy auctions are found effective in conduct of the CBRT's monetary policy. While these results are contrary to the findings of previous studies, the dual verification methodology and the length of time period used in this study ensures that our conclusions better represent the reality of the Turkish economy.

SUGGESTIONS FOR FUTURE RESEARCH

Future studies can analyze the impact of interventions on the level and the volatility of domestic inflation rates. In addition, the study period can be lenghten to include pre-crisis data to compare and contrast the effectiveness of interventions in reducing volatility at time periods with different characteristics. This study can be extended to include an analysis of the dominant monetary transmission mechanism present in the Turkish economy, to obtain more accurate policy implementation recommendations for the CBRT. In addition, future studies may be conducted in countries other than Turkey to examine if the lack of effectiveness observed in FOREX interventions in Turkey is common to other developing countries. Finally, future studies may use our methodology and determine if our results can be duplicated to ensure the accuracy of our findings that are contrary to the results of previous studies by Agcaer (2003); Akinci, Culha, Ozlale, and Sahinbeyoglu (2005b); and others.

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