DAILY VOLATILITY

IN THE TURKISH FOREIGN EXCHANGE MARKET

Cem Aysoy

Ercan Balaban

Çigdem Izgi Kogar

Cevriye Ozcan

THE CENTRAL BANK OF THE REPUBLIC OF TURKEY

Research Department

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Abstract

The primary objective of this paper is to assess daily changes in the Turkish foreign exchange market within the framework of volatility and day of the week effect. Upon detection of heteroscedastic errors in the model (autoregression with deterministic daily seasonality), Generalized Autoregressive Conditional Heteroscedasticity (GARCH) model is applied to let exchange rate variances change through time. Empirical results verify that volatility of the Turkish foreign exchange market is low except instability and crisis periods. Moreover, day of the week effects are present in US dollar and German mark return series for the period January 1988 to December 1995. Potential sources of heteroscedastic errors in the foreign exchange rates are discussed and possible effects of the 1994 economic crash on variance function are measured. Implications for option pricing and hedging decisions are briefly addressed.

Cem Aysoy, Ercan Balaban, Çiğdem İzgi Koğar, and Cevriye Özcan

Key words: Seasonal effects, heteroscedastic errors, ARCH/GARCH models.

JEL Classification: G12, G14.

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I. INTRODUCTION

It has been well documented in finance literature that any predictable pattern in returns may be exploitable and judged as evidence against informational efficiency of markets. One statistically significant pattern in exchange rates stems from seasonality. As such, these effects in currency markets have attracted much interest and numerous researchers have studied daily seasonal anomalies for developed financial markets. However, it seems more difficult to find empirical studies for currency markets of developing countries. Although daily developments in foreign exchange provide useful information for domestic and foreign investors holding portfolios of Turkish financial assets, empirical characteristics of daily returns on foreign currencies seem to remain almost unknown to market participants as well as policy makers. The primary aim of this paper is to present empirical evidence for daily volatility by examining seasonal anomalies in the foreign exchange market of Turkey, a high-inflationary developing country. There has been little work using high frequency data from foreign exchange market of Turkey. To our best knowledge, recent studies employing such data are Abaan (1995), Aysoy and Balaban (1996), and Balaban and Kunter (1996).

In finance, variance of return is important for forecasting about portfolio decisions. Many time series showing high volatility do not have a constant mean and variance whereas econometric models generally assume constant variance. There are models with serially uncorrelated process having nonconstant variances conditional on the past and constant unconditional variances. In this case, conditional variance plays an important role because of time-varying structure and modeling is difficult by standard approaches since the assumptions of linear regression are violated due to misspecifications arising from wrong functional form. To deal with this difficulty, Autoregressive Conditional Heteroscedasticity (ARCH) model is recommended. This approach provides modelling volatile data since forecast variance may change over time and is predicted by past forecast errors (Engle, 1982). Various ARCH models capture changing short-run behaviour due to randomness associated with different forecast periods. Moreover, the models using variance as a measure of risk are also tested with conditional variance.

This paper is a pioneering one in modeling daily changes in foreign currencies of Turkey. In addition, to our best knowledge, this is a first attempt to employ ARCH methodology with the daily Turkish data. The rest of the paper is organized as follows: Section II is devoted to the introduction of foreign exchange markets in Turkey. Data and methodology are introduced in Section III. Empirical results are summarized in Section IV. Section V discusses potential sources and implications of low volatility.

II. FINANCIAL MARKETS IN TURKEY

Starting from the 1980s, Turkey entered a new era in the sense that structural adjustments, liberalization attempts and institutional changes made possible reorganization of the economic system. The capital market, the Istanbul Stock Exchange and the interbank money market became operational in 1986. Number of banks actively trading in the market was 52 and transactions heavily occurred in overnight. Overnight funds and interest rates showed significant fluctuations even in the same day. Transaction limits in the interbank money market set for banks according to the Government bond and Treasury bills that deposited at the Central Bank as a collateral. Finally, foreign exchange deposits were introduced. In 1987, the introduction of institutional changes were furthered by the beginning of public auctions for government securities on weekly basis (CBRT, Annual Report, 1986).

The beginning of 1988 was marked with an instability in the financial markets due to excess liquidity. To adjust this instability, some measures were taken on interest rates. Foreign exchange market started its operations on August 1988, with daily fixing sessions so that exchange rates would be determined by the market. 2.2 billion dollars worth of total 6382 operations including fixing were realized. In 1989, the foreign exchange market led to overvaluation of the domestic currency in real terms. In 1990, real interest rates were above the rates of 1989 on average. The Central Bank announced the monetary program and implemented successfully. Real appreciation of the Turkish Lira continued. Restrictions on foreign exchange were removed to a great extent, and the transfer of the Turkish lira to foreign currencies became possible by a decree. This development was considered as a step toward the convertibility of the Turkish currency.

1991 was a difficult year with regard to monetary policy implementation. Large deposits were withdrawn from the Turkish banking system due to the Gulf War. Since foreign exchange rates were unstable due to the elections and the Gulf War, the Central Bank sold foreign exchange in the market in order to meet liquidity requirements. Monetary expansion together with uncertainty led to an increase in inflationary expectations and interest rate. Therefore, a monetary program was announced in January 1992. Despite the real interest rates, the growth of foreign exchange deposits was above the growth of deposits denominated in the Turkish Lira and the Turkish lira was devaluated in real terms. The volume of transactions in the interbank money market was below the level of 1991. Quotation limit lowered and the Central Bank preferred to be supplier. Generally, 1992 was a liquid year for the markets. The number of the banks increased in 1993. In the foreign exchange market, the volume of transactions increased because of the increase in banking sector's demand for foreign currency. Due to the inability of rolling the maturing government securities and the rise in dollar-mark parity, excess liquidity increased, and the Central Bank was the net purchaser. Short-term foreign capital inflow was realized via banks as foreign exchange credits.

In 1994, the volume of interbank transactions increased significantly compared to 1993 although the number of banks in the market fell due to the termination of banks as a result of the financial crisis. After the crisis, overnight interest rates reached 350 percent in March, and went down 250 percent in the following months, then radically declined and remained below the auction rates. Participating banks were required to keep government securities at least 50 percent of the amount borrowed. The Central Bank tried to stabilize the foreign exchange market by direct foreign exchange sales and followed tight monetary policy for the most of 1994. However, the continued volatility in the foreign exchange market led to an increase in margin between the market rates and the Central Bank rates. After the Stabilization Program in April, the demand for foreign currency was reduced by guaranteed deposits in banks, high short-term interest rate on deposits and government securities. The depreciation of the Turkish lira against the US dollar was 168 percent annually in 1994. The changes in the compulsory foreign exchange and foreign currency transfer policy and the revision in the method of determining the Central Bank official foreign exchange rates were effective in decreasing the volatility of foreign exchange rates. The official TL-dollar rate was determined by taking the average of buying-selling quotas of 10 banks that have the highest foreign exchange volume in the market. As of May 1994, the foreign exchange rate which was announced to the market by the Central Bank perceived as an indicator in the foreign exchange market and in the parallel markets.

In 1995, one sided volume of the interbank money market reached 68 percent of GNP. Interest rates in the market tended to rise by the last quarter of the year. The excess liquidity was withdrawn by the Central Bank via net purchases. In the foreign exchange market, the volume reached 20.6 billion US dollars in 1995. Demand for foreign exchange rose because banks tried to reduce their short positions. Elections and inflationary expectations also played an important role. As a new instrument in the Turkish financial system, foreign exchange futures were temporarily used in the second half of 1995 in order to reduce volatility and high expectations about the depreciation of the Turkish lira via announcement effect. The rate of increase in the foreign exchange was behind the inflation rate throughout 1995.

III. DATA AND METHODOLOGY

We employ daily Turkish foreign exchange data obtained from the Central Bank of the Republic of Turkey for the period from January 4, 1988 to December 29, 1995. Daily returns ($R_{i,t}$) of the free market selling rates ($FX_{i,t}$) on currency i, US dollar and German mark, on day t are calculated as the logarithm of exchange rate relatives:

$R_{i,t} = \log (FX_{i,t} / FX_{i,t-1})$ (1)

We estimate the following pth order autoregressive, AR(p), model with deterministic daily seasonality for each currency:

$R_{i,t} = \quad k_j R_{t-j} + \quad b_s D_s + e_t$ (2)

where $D_1 = 1$ if day is Monday and 0 otherwise; $D_2 = 1$ if day is Tuesday and 0 otherwise; and so on. The order of autoregression, p, is chosen as three so that no serial correlation problem arises. The coefficients b_1 to b_5 of deterministic seasonal dummies are the mean returns on currency i for Monday through Friday upon removal of serial correlation.

We test whether our models have heteroscedasticity in error terms. If one detects such effects, (Generalized) Autoregressive Conditional Heteroscedasticity (G)ARCH modeling is one way to deal with this problem. Note that following Engle's 1982 introduction of ARCH models and their extension by Bollerslev (1986) to include GARCH models, numerous researchers have successfully applied these models for financial data. Bollerslev *et al*. (1992) provide an excellent review of the theory and empirical work on ARCH modeling in finance. Upon detection of heteroscedasticity, we rerun the model (Eq. 2) by defining a time-varying variance function (h_t) which can be expressed as follows:

$e_t \sim N(0, h_t)$ (3)

$h_t = a_0 + \; a_i \, e^2_{t-i}$ (4)

$h_t = a_0 + \; a_i \, e^2_{t-i} + \; c_j \, h_{t-j}$ (5)

The first variance function (Eq. 4) shows an ARCH(p) model. The second (Eq. 5) is a GARCH (p, q) model. When ARCH models do not fit very well, then GARCH model is used by incorporating lagged variable of h_t into variance function model. Note that similar work has also been done by Milhoj (1987), Hsieh (1988), Baillie and Bollerslev (1989), and Copeland and Wang (1994), among others, for daily exchange rates. As it has been well documented in the literature of this field, shifts in variance due to exogenous structural breaks can lead to spurious ARCH effects (see, for example, Lamoureux and Lastrapes (1990)). As such, one explanation for the high degree of ARCH in our samples may be the presence of a structural break associated with the financial crisis of 1994. Then, GARCH model provides to deal with the presence of a structural break by incorporating a crisis dummy (DC) into the variance function of GARCH (p, q) model and we rerun the original model with the following conditional variance function:

$h_t = a_0 + \; a_i \, e^2_{t-i} + \; c_j \, h_{t-j} + d \, DC$ (6)

Regression model with ARCH may include exogenous and lagged endogenous variables with disturbances e_t. To estimate unknown parameters, log likelihood function can be maximized via iterative scoring algorithm as

$L_t = -1/2 \log h_t - (1/2 \, e_t^2) / h_t$ (7)

If the disturbances are conditionally heteroscedastic, maximum likelihood estimator is nonlinear and more efficient than least squares.

IV. EMPIRICAL RESULTS

According to descriptive statistics and ARCH diagnostics for the returns on the US dollar and the German mark in Table 1, there is strong appearance of heteroscedasticity.

Table 1

Summary Statistics and ARCH Diagnostics

	US Dollar	**German Mark**

Maximum	0.19237	0.17435
Minimum	-0.16089	-0.15138
Mean	0.0019894	0.0020384
Standart Deviation	0.01207	0.012505
Skewness	1.7093	1.4031
Kurtosis	69.7219	48.5846
Coeficient of Variation	6.0669	6.235
ARCH(1) (*) LM-Test	445.8094	426.265
F-Test	571.186	539.3581
ARCH(4) (*) LM-Test	446.7909	430.9015
F-Test	151.336	136.5031
ARCH(8) (*) LM-Test	470.9722	441.6497
F-Test	76.4006	70.295
ARCH(12) (*) LM-Test	481.5324	451.5815
F-Test	52.3324	48.1275
(*) All tests indicate significant ARCH effects		

After removal of autoregressive effects in exchange rates, there exist significant day of the week effects in exchange rates. For the period from January 1988 to December 1995, only Friday mean return on US dollar is statistically undistinguishable from zero. Other days have significant positive returns at the level of 5 percent. Among these, Tuesday has the highest daily mean return, 0.35 percent, which is more than twice larger than Thursday mean return, 0.14 percent. Unlike US dollar, Friday mean return on German mark is statistically significant (Table 2).

Table 2

Diagnostics of the Original Models

	Coefficients	**Standard Errors**	**t-Statistic**	**Significance Level**
US Dollar	**AR(3) with day dummies 1,2,3,4,5**			
D1	0.0025	0.000593	4.22	0.000023
D2	0.0035	0.000592	5.92	3.1E-09
D3	0.0022	0.000594	3.83	0.00012
D4	0.0014	0.000595	2.37	0.017
D5	0.00063	0.000597	1.06	0.28
R_{t-1}	0.137	0.0221	6.18	6.1E-10
R_{t-2}	-0.035	0.0223	-1.57	0.11
R_{t-3}	-0.147	0.0221	-6.66	2.6E-11
German Mark	**AR(3) with day dummies 1,2,3,4,5**			
D1	0.0024	0.000614	3.91	0.000089
D2	0.0036	0.000612	5.97	2.3E-09

D3	0.0025	0.000616	4.16	0.00003
D4	0.001	0.000617	1.69	0.09
D5	0.0012	0.000619	2.05	0.039
R_{t-1}	0.124	0.0221	5.61	0.000000019
R_{t-2}	-0.032	0.0223	-1.44	0.14
R_{t-3}	-0.163	0.0222	-7.38	1.5E-13

Although unconditional (or long run) variance seems constant, there are periods showing relatively high variance. In this case, results shown in Table 2 are inappropriate since homoscedasticity assumption is rejected. In determining lag order of ARCH by regressing et^2 on p lags, higher order seemed to be reasonable. However, some coefficients of the conditional variance became negative as the order increased. Then, ARCH(8) and ARCH(12) models were rejected (Table 3). This may be due to the presence of a structural break associated with the financial crisis of 1994.

Table 3

The Results From Different ARCH-GARCH Models

	a0	a1	a2	a3	a4	c1	d1	d2	FFV
US Dollar									
arch(1)	4E-05	0.546							8739.9
* t values	50.2*	30.4							
arch(4)	2E-05	0.465	0.22	0.1	0.11				8965.3
* t values	26.9	15	9.5	5.9	8.5				
garch(1,1)	1E-05	0.34				0.55			8942.2
* t values	22.8	15.8				36.4			
garch(1,1) with crisis dummy	5E-06	0.265				0.61	1E-05	0.044	8995.6
* t values	12.9	21.6				38	12.28	2.46	
German Mark									
arch(1)	4E-05	0.782							8608.2
* t values	43.8	23.4							
arch(4)	2E-05	0.339	0.4	0	0.11				8789.9
* t values	23.9	15.7	14.8	3.3	7.4				
garch(1,1)	9E-06	0.364				0.56			8796.2
* t values	15.5	18.6				33.4			
garch(1,1) with crisis dummy	1E-05	0.266				0.44	9E-07	0.24	8785.9
* t values	14.5	19.8				17.1	0.5	7.8	

Two models, ARCH(1) and ARCH(4) remained meaningful. The reason for selecting ARCH(1) model is the difficulty to satisfy nonnegativity and stationarity on the parameters. To ensure stability, it is necessary to restrict the parameters of et^2 between zero and one. When the parameters get closer to one as greater autoregressive parameter, there exists more persistence to any given change in the original dependent variable. If they are too large, the variance of the process will be infinite. In ARCH(1) model, for the US dollar, having equal but opposite signs in the parameters for the lag one and lag three model could be interpreted that the rebound in exchange rates follows the fall after two days. Point estimate of a_1=0.55 in ARCH(1) indicates an extreme amount of persistence since a large positive number for the parameter shows that successive observations will be dependent through higher-order moments (Engle, 1982). In this case, one can see a tendency for sustained movements in the variance using original model.

ARCH(4) model gives decreasing parameters in ARCH equation indicating that when a_1 is close to zero, unconditional variance of the rate of return is near to Gaussian white noise and small amount of dependence in higher moments. Moreover, individual values of autocorrelations with a value that is significantly different from zero are indicative of GARCH errors. The criteria in evaluating model performance are both the number of parameters to be estimated and the final functional value (FFV) as loglikelihood to be maximized. The values of FFV are greater for GARCH(1,1) and ARCH(4) model. Since GARCH(1,1) necessitates the estimation of only two parameters among different models, it is found to be the most appropriate model. The estimated parameters are positive and significantly different from zero (Table 4).

Under GARCH (1,1) model, Monday mean return on the US dollar turns out to be negative although it is insignificant. Tuesday and Wednesday mean returns decrease by approximately 50 percent. While Thursday mean return slightly increases, Friday mean return is one-third less and still insignificant. As in all cases, a_1= 0.34 implies that h_t is convergent. The parameter of h_{t-1}, a_2=0.55, is also highly significant indicating that variance of daily return is highly correlated. To compare the persistence implied by GARCH with ARCH model, it is useful to consider the sum of parameters of e_{t-1}^2 and h_{t-1}^2 in the conditional variance model realized as 0.89, which must be less than 1.0 for the volatility process to be stationary. The comparable estimates of b for ARCH(1) model is 0.54. In GARCH model, the parameter of h_{t-1}^2 is 0.55 warning for less risk averse behaviour.

Table 4

The Results from the Selected Models

	GARCH(1,1)			**GARCH(1,1)**	
	without crisis dummy			**with crisis dummy**	
	US Dollar	**German Mark**		**US Dollar**	**German Mark**
b1	-0.000098	0.001546	**b1**	0.001118	0.001356
	-0.0002	0.000233***		0.000227***	0.000254***
b2	0.001791	0.00249	**b2**	0.002052	0.002397
	0.00037***	0.000277***		0.000289***	0.000298***
b3	0.001067	0.001648	**b3**	0.001128	0.001615
	0.0003***	0.000298***		0.000274***	0.000304***
b4	0.001659	0.000936	**b4**	0.001394	0.000952
	0.00026***	0.000286***		0.000244***	0.000281***
b5	0.000227	0.000852	**b5**	0.000622	0.000772
	0.00027	0.000244***		0.000229	0.000312***

k1	0.062578	0.034626	**k1**	0.065519	0.066656
	0.02792***	0.022455		0.024171***	0.024299***
k2	0.080769	0.039413	**k2**	0.065355	0.075588
	0.02132***	0.020811*		0.018511***	0.019765***
k3	0.068017	0.027221	**k3**	0.016956	0.59854
	0.01649***	0.018211		0.015897	0.016262***
a0	0.00001	0.000009	**a0**	0.000005	0.000013
	0.0000004***	0.0000006***		0.0000004***	0.0000009***
a1	0.340872	0.364595	**a1**	0.265609	0.266283
	0.021467***	0.019548***		0.012276***	0.013421***
c1	0.553065	0.556775	**c1**	0.609828	0.436963
		0.016628***		0.016011***	0.025416***
			d1	0.000013	0.0000009
				0.000001***	0.000002
			d2	0.044022	0.240641
				0.017843***	0.030651***
(***)Significant values					

After dummy variable reflecting structural break due to the 1994 economic crisis is incorporated to GARCH(1,1) model, FFV increased remarkably compared to the other models. According to GARCH (1,1) model with a crisis dummy in variance function, all days have positive and significant mean returns on the US dollar. Significantly positive coefficient for the crisis dummy shows that there has been a structural break in volatility of US dollar returns (Table 4). Although the standard errors decreased, lag three is still insignificant but ignorable. It can be seen from the figures that the variability of ht is not too much (Figure 1 and 2). Except the 1988 instability period and the 1994 financial crash, the variability of predicted standard deviation, namely volatility in GARCH model, is low. This was proven by large value of the parameters of h_{t-1}^2 in conditional variance equation.

Mean returns on the German mark are significantly positive for all days. Similar to the US dollar, Tuesday and Thursday have the highest and the lowest mean returns, respectively. The interesting conclusion is to get the same results for the German mark in ARCH(8) and ARCH(12). In ARCH(1) model, parameter for e_{t-1}^2 is close to one. The estimated parameter of the ARCH equation of 0.78 implies that unconditional variance will be infinite with divergent h_t. Shocks to e_{t-1} increase the conditional variance so that there are periods of volatility. Under GARCH (1,1) model, although mean returns on all days became smaller compared to the original model, they are all positive and significant. FFV in GARCH(1,1) was the highest among the other models. Convergence was satisfied and parameters of conditional variance were highly significant. For that reason, GARCH(1,1) was selected in modelling German mark. The parameter of crisis variable is also significant. From Figure 2, the variability is low except 1988 and 1994 as in the US dollar.

Although many financial time series may exhibit a high degree of persistence in the variance of their univariate time series representations, this persistence is likely to be common among different series, so that certain linear combinations of the variables show no persistence. In that situation the variables are defined to be co-persistence in variance (Bollerslev *et al*., 1992).

V. SOURCES AND IMPLICATIONS OF CONDITIONAL HETEROSCEDASTICITY

In this study, it is found that the rates of returns in the US dollar and the German mark do not show volatile behavior except the 1988 instability and the 1994 financial crisis periods. Namely, volatility of the Turkish daily foreign exchange rates is low. This can be explained by the behaviour of economic agents who can anticipate the tendency of exchange rates during stable periods. The Central Bank intervention into the foreign exchange market is usually expected when fluctuations are high. Then, this decreases the volatility in the market. In this study, modeling of overnight interest rates was also tried but results were not successful. The aim to do this was to capture the transmission between exchange rates in the foreign exchange market and interest rate in the interbank money market in the case of low variability. It is the fact that during the volatile periods, as risk rises, risk-averse agents seek alternatives that are conditionally less risky. However, if policy makers in Turkey do not create instability in the financial markets, foreign exchange rates, namely the US dollar and the German mark do not show risky behaviour for the investors in the sense that volatility is low in the foreign exchange market. Our empirical results also show that seasonal effects, namely day of the week effects, exist in the foreign exchange returns.

Provide that our model is not misspecified, ARCH effects are present; i.e., volatility of the currency returns is time varying. To our knowledge, there has been no consensus on what causes ARCH effects. A very first reason may be model misspecification, a common problem in econometrics and time series analysis. Omitted variables and structural changes like breaks due to instability can be considered in this category. Another explanation is heteroscedasticity in information arrival. A more relevant explanation for the reported ARCH effects in our case can be associated with the behavior of monetary policymaker(s). Heteroscedasticity in frequency and volume in Central Bank intervention may induce the observed ARCH effects in daily exchange rates. If interdependence between foreign exchange and interbank money markets is considered, the possible effects of such an intervention may be well understood.

From another prospective, the most important determinant of option prices is the second moment of underlying asset. Note that there is a positive relationship between price volatility of underlying asset and option price. The conditional distribution of asset returns can also provide useful information for financial risk management. For example, as demonstrated by Hsieh (1993) and summarized in Hsieh (1995), estimation of conditional volatility can be used to calculate capital requirements for different levels of coverage probabilities of futures contracts for short and long positions.

Using rescaled range analysis, Aysoy and Balaban (1996) report that volatility in the Turkish foreign exchange is mean-reverting or anti-persistent. This is in contrast with the finding of volatility persistence in this paper. Although this contradiction may be due to differences in data, potential researchers should focus on this issue in the future.

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