CODEPENDENT VOLATILITY PATTERNS IN DAILY FOREIGN EXCHANGE AND INTEREST RATES: A CASE STUDY OF TURKEY

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ABSTRACT

In this paper, the main purpose is to detect the possible cross relationships between the volatilities of foreign exchange and interest rates in Turkey. In Turkey, it is seen that the volatilities of foreign exchange returns and daily interest yields are strongly correlated. This is because of the fact that Turkish financial markets are not deep enough to attract long term investors and this fact causes the short term foreign investors to speculate in Turkish markets leading to high levels of volatility in both foreign exchange and interest rates. For the foreign investors to acquire a more clear perception about the changing level of volatility and risk, it is necessary to estimate the time varying covariance matrix of the relevant assets. In order to do this, using the daily data between 1991, January 1st and 2000, December 31st, a multivariate GARCH(1,1)process augmented with various dummies for stabilisation programs, and financial crises will be estimated. Later on, it is intended to offer a specific criterion to foreign investors about the risk patterns in Turkish Financial Markets.

Keywords: codependent volatility patterns, multivariate GARCH processes, asymmetry

INTRODUCTION

As an emerging market and a developing country, Turkey, requires foreign capital. For such an economy in the age of a wide Globalisation process, the foreign capital can be considered as the fuel of that country's production system. This has been valid for Turkey since 1989, when the capital flows were let to be free. In this case, two risk factors are crucial for both policy authorities and financial agents: the foreign exchange and interest rates. In an open economy, these two economic indicators influence each other. In order to perceive the relationship between these two variables and to measure their risk levels within the time dimension, one has to examine their volatility dynamics. In what degree they correlate and how does this correlation fluctuates in time is a crucial problem for economic agents. The solution of the problem will enable them to evaluate their positions much clearly.

In this paper the main purpose is to estimate the relationship between the daily volatilities of interest and foreign exchange (FOREX) rates in Turkey between the years 1999 and 2000. The two-year period is chosen such that it can be convenient for analysing the effects of previous economic stabilisation program, in which their above mentioned relationship is clearly shown.

After a twenty-year history of high chronic inflation, the policy authorities in Turkey decided to apply an exchange rate based stabilisation program. This stabilisation program, starting from 2000,January 1st, and collapsing after 2001, February 19th, had mainly two pillars: First one was the exchange rate being set as the nominal anchor and the second one was the tight restriction on monetary base. The nominal anchor was set, because the main problem to overcome was to break the inflationary expectations, which have still been strongly influential since the early 80's. The monetary policy was tight implying a standard text book stabilisation policy. In the program, the flexibility and adjusting ability of the system to various shocks (e.g. political, external and domestic economic shocks) was proposed to be maintained by the fluctuations in the interest rates, which are the essential equilibrating variable. The capital flows were proposed to be determined by the interest rate differential. The effect of any monetary shock reflected in interest rates was then assumed to be omitted by a following capital in or out-flow. This mechanism would prevent a possible liquidity boom or crisis.

The operation mechanism of the program implied that the conditional volatility of daily interest rates would shift significantly by the start of the program, since all kinds of risks hitting the system could only be reflected in interest rates. Nevertheless, there was an open room for the exchange rate volatility, because the FOREX pillar of the program did not mention a strictly fixed exchange rate. On the other hand, the daily central bank (CB) FOREX rates were announced six months before their actual date, and the authorities let the free market adjust its rates to CB rates. Off course, the crucial assumption, here, was that the markets would be trustful to the program. Therefore, they expected the free market exchange rates would not show significant deviations from the CB rates. This was actually valid for exchange rate returns but not completely valid for their conditional volatility, especially for the periods of distrust and uncertainty. These can be seen in figure 1-a.

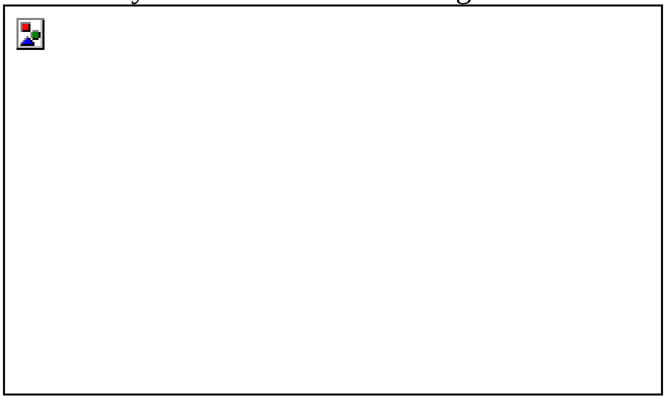

FIGURE 1

Figure 1 shows us the logarithmic returns of daily FOREX rates. Before the program, it can be seen that the returns are volatile and this implies that market rates reflect the FOREX risk. After the program, the big deviations in the return can not be seen and this issue can be addressed to the implication of the program. On the other hand, still, there exists some level of volatility and this level is seen to be persistent. For a more formal analysis, it is convenient to look at Table 1, which includes the summary statistics of FOREX returns during the sample period:

TABLE 1

ERET(%)	1999	2000
Mean	0.2731	0.0901
Standard Error	0.0285	0.0225
Median	0.2649	0.0910
St. Deviation	0.4022	0.3471
Sample Variance	0.1617	0.1205
Kurtosis	9.3344	1.6185
Skewedness	1.3242	-0.4706
Range	3.9920	2.6157
Min	-1.1372	-1.5975
Max	2.8548	1.0181
Sum	54.3448	21.5323
Number	199	239

In Table 1, we can see the daily percentage logarithmic FOREX returns between 1999 and 2000. In 1999, before the Program the unconditional mean of the daily returns was 0.2731% and this declined to 0.0901% in 2000 after the Program. This implies that after the program the pre-announced devaluation rate is lower than the actual depreciation rate before the program. The standard deviation does not show a significant shift, since it changes from 0.4022% to 0.3471% after the Program. This tells us that there is a persistency in the daily volatility process during the whole sample period. On the other hand, the values of higher order moments, skewedness and kurtosis, of daily FOREX returns show a large decline between 1999 and 2000. High values of kurtosis may be addressed to significant changes in the conditional volatility, whereas high values skewedness may be interpreted as a clue for possible existence of asymmetry in daily FOREX volatility.

Returning back to interest rates, the effects of the program can be seen more clearly. In Figure 2 we can see the percentage daily interest rates:

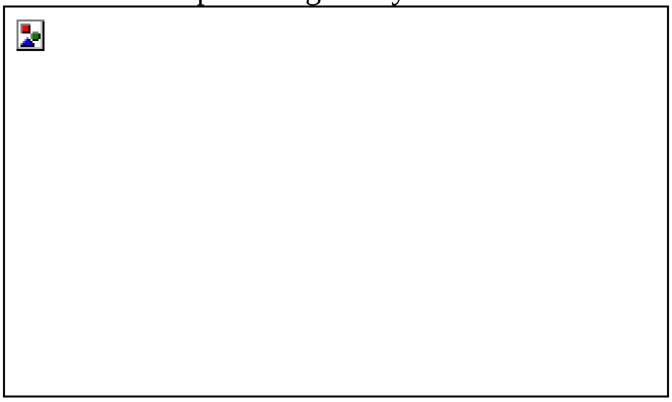

FIGURE 2

The mean of the interest rates shows a significant decline in 2000 after the Program. On the other hand it is clearly shown that, after the program, the interest rates become significantly more volatile. This is because of the fact that the largest amount of the risk was transmitted to the interest rates. For more accurate understanding let us look at Table 2.

TABLE 2

Interest Rates (%)	*1999*	*2000*
Mean	82,0356	47,7972
Standard Error	0,6662	2,7004
Median	79,7500	38,9050
Standard Deviation	9,3979	41,8340
Sample Variance	88,3197	1750,0861
Kurtosis	12,9405	93,5836
Skewedness	2,3127	8,4144
Range	81,1500	538,8900
Min	69,0100	16,6900
Max	150,1600	555,5800
Sum	16325,0800	11471,3250
Number	199	240

In Table 2, the summary statistics confirm the scene in Figure 2. While the mean of the interest rates was 82.04% in 1999, it declined to level of 47.79% in 2000 after the Program. This implies that the inflationary expectation decline sharply by the starting of the Program on January 2000, causing a sharp decline in interest rates. On the other hand the standard deviation of interest rates increase from 9.39% in 1999 to 41.83% in 2000 with declaration of Program. The higher moments show that after the declaration of Program the conditional volatility of interest rates and the degree of asymmetry in volatility pattern rise.

Conclusively, it can be said that, in the second moments, the interest rates and the FOREX returns are negatively correlated. Depending on this information, it is intended to search for the relationship between the conditional variances of interest and exchange rates. Nevertheless, before this, we have to identify and modify the data, in order to filter them from trend effects.

DATA

The raw data consist of daily market FOREX rates for Dollar in terms of Turkish Liras and repo interest rates between 4th January, 1999 and 26th December, 2000. In the sample period there are some days in which, one of the markets is closed while the other is open. This creates a time inconsistency problem. For that reason these dates are excluded from the sample set. The raw data for the FOREX rates have a strong time trend. Taking the logarithmic differences seem to terminate this effect, but the coefficient of the time trend is, then included in drift term of conditional mean returns. Therefore, it is decided to terminate this time trend. On the other hand, the interest rates do not show a time trend although they show a sharp decline by the declaration of the Program. This Program effect makes the data problematic. Taking the log differences do not solve the problem exactly, since the effect of sharp decline in interest rates on January 1^{st}, 2000 create excess volatility for a period of 1 month. Thus, from this fact, the necessity of removing the program effect from interest rate data appears.

For removing these effects in the mean level, we regress the raw FOREX rate data on a drift term and a time trend. Similarly, we regress the interest rate data on a drift term and a dummy representing the program effect. After that, the logarithmic differences of the detrendised FOREX and interest rates are taken as the sample data. The modified data set show a cycling behaviour around a zero mean. It can be seen in Figures 3-a and 3-b.

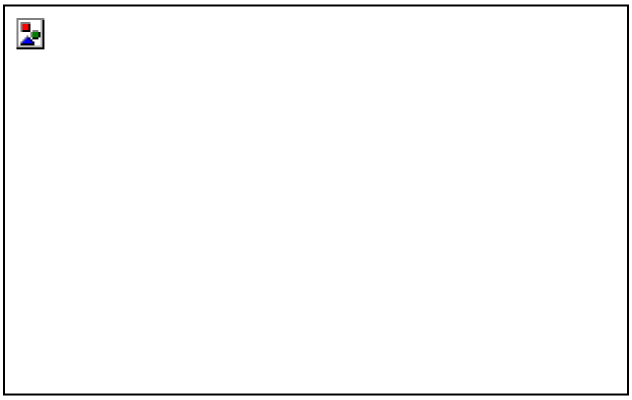

FIGURE 3-a

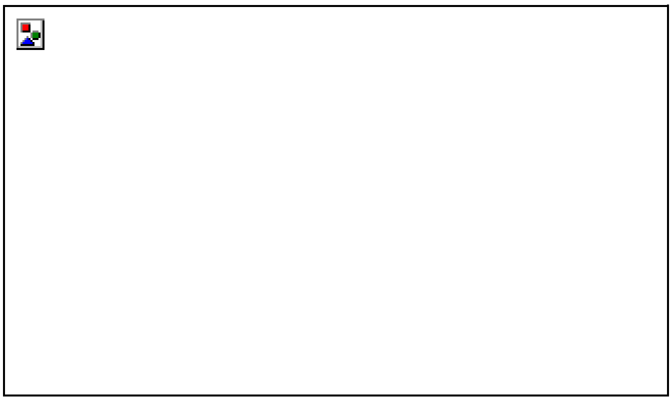

FIGURE 3-b

As our main concern is to explore the volatility linkages between FOREX and interest rates, these zero-meaned time series create no problem. Off course, if this study were mainly interested in mean returns, then it would be a problem. Consequently, during the estimation the estimates of mean return equation should be insignificant, implying a zero mean for both time series.

MODEL

Our aim, in this study, is to examine the relationship between the volatilities of FOREX and interest rates in Turkey. The time varying volatility is conventionally estimated by Generalised Autoregressive Conditional Heteroscedasticity (GARCH) models. GARCH models are the generalised versions of ARCH models, which are introduced by Engle (1982). Later on, Bollerslev (1986) introduced GARCH models. GARCH(p,q) processes are similar to an ARMA(p,q) process in the conditional variance. The idea is that the conditional variance of a random variable is determined by past variances and the past squared innovations. The multivariate GARCH processes are developed in order to estimate the conditional covariance matrix of residuals. They are similar to a VARMA(p,q) process in the conditional variance equation. Consider a system of *n* regression equations of the form

$$\mathbf{y_t} = \Pi \, . \, \mathbf{x_t} + \mathbf{u_t}$$

$$(nx1)\ (nxk)(kx1)\ (nx1)$$

where $\mathbf{x_t}$ is a vector of explanatory variables and $\mathbf{u_t}$ is a vector of white noise residuals. Let $\mathbf{H}_t$ denote (nxn) conditional covariance matrix of the residuals:

$$\mathbf{H}_t = E(\mathbf{u_t}.\mathbf{u'_t}|\mathbf{y_{t-1}},\mathbf{y_{t-2}},...,\mathbf{x_{t-1}},\mathbf{x_{t-2}},...)$$

Multivariate GARCH regressions are used for estimating the parameters of the conditional first and second moments and the conditional covariance matrix. In this paper, we will follow the approach of Bollerslev (1990), which assumes that the conditional correlations among the elements are of $\mathbf{u_t}$ are constant over time. Let $\sigma^2_{i,t}$ represents the conditional variance of the ith element of $\mathbf{u_t}$:

$$\sigma^2_{i,t} = E(u^2_{i,t} \mid \mathbf{y_{t-1}},\mathbf{y_{t-2}},...,\mathbf{x_{t-1}},\mathbf{x_{t-2}},...)$$

This conditional variance might be modelled with a univariate GARCH(1,1) process driven by the lagged innovation in variable i:

$$\sigma^2_{i,t} = \kappa_i + \delta_i\,\sigma^2_{i,t-1} + \alpha_i\,u^2_{i,t-1}$$

We might postulate n such GARCH specifications (i=1,2,3,...,n) one for each element of $\mathbf{u_t}$. The conditional covariance between $u_{i,t}$ and the $u_{j,t}$, or the row i, column j element of $\mathbf{H_t}$, is then taken to be a constant correlation ρ_{ij} times the conditional standard deviations of $u_{i,t}$ and $u_{j,t}$:

$$\sigma_{ij,t} = E(u_{i,t}\,u_{j,t} \mid \mathbf{y_{t-1}},\mathbf{y_{t-2}},...,\mathbf{x_{t-1}},\mathbf{x_{t-2}},...) = \rho_{ij}.\sigma_{i,t}.\sigma_{j,t}.$$

Maximum likelihood estimation of this specification turns out to be quite tractable; see Bollerslev (1990) for details. For other multivariate models, see Bollerslev, Engle, and Wooldridge (1988), Diebolt and Nerlove (1989), Engle, Ng,and Rotschild (1990), Engle and Kroner (1995).

In this study, there are two variables, of which covariance matrix is to be estimated: the daily interest and FOREX rates. We will use the modified data set, which are composed by removing the trend effects from raw data and which can be seen in Figures 3-a and 3-b. The relevant models should, then, shown as:

$e_t = a_0 + a_1 e_{t-1} + a_2\,r_{t-1} + u_{e,t};\ u_{e,t} \sim N(0, \sigma^2_{e,t})$ (1)

$\sigma^2_{e,t} = \kappa_e + \delta_e\,\sigma^2_{e,t-1} + \alpha_e\,u^2_{e,t-1} + \varepsilon_t\ \varepsilon_t \sim N(0,1)$ (2)

Equation (1) shows conditional mean equation and (2) shows the conditional variance equation for daily Dollar return. In equation (1) "e_t" represents the daily dollar exchange return at time period "t" and "e_{t-1}" and "r_{t-1}" represent the interest and FOREX returns in the previous day. For interest rates, there exist the following equations:

$r_t = b_0 + b_1 e_{t-1} + b_2\,r_{t-1} + u_{r,t};\ u_{r,t} \sim N(0, \sigma^2_{r,t})$ (3)

$\sigma^2_{r,t} = \kappa_r + \delta_r\,\sigma^2_{r,t-1} + \alpha_r\,u^2_{r,t-1} + \psi_t\ \psi_t \sim N(0,1)$ (4)

Equation (3) shows conditional mean equation and (4) shows the conditional variance equation for daily interest returns. The conditional co-variances are computed according to the approach developed in Bollerslev (1990). The relevant equation can be seen below:

$\sigma_{er,t} = \rho_{er}.\sigma_{e,t}.\sigma_{r,t}$ (5)

In equation (5), the correlation coefficient between interest and FOREX rates is assumed to be constant over time. The conditional standard deviations, representing the level of volatility, are obtained from the estimates of equations (1) – (4). For each period t, thus, there should be a different conditional covariance between these two return rates.

ESTIMATION RESULTS

The estimation results can be presented in two groups. One includes the regression results of FOREX rates and the other includes those of interest rates. For FOREX rates, the two equations, (1) and (2), are jointly estimated, by using Maximum Likelihood methodology. For interest rates, other two equations, (3) and (4), are estimated by using the same procedure. In Table 3, you can see the regression results for daily FOREX rates:

Table 3. The Regression Results for Daily FOREX Rates

	Estimate	**St.Deviation**	**t-value**	**Probability**
$\mathbf{a_0}$	0,000144	0,000258	0,556030	0,5780

a_1	0,052152	0,052553	0,992360	0,3220
a_2	-0,000365	0,001092	-0,333970	0,7390
κ_e	0,000015	0,000005	3,097000	0,0042
δ_e	0,257730	0,077565	3,322800	0,0038
α_e	0,383720	0,062052	6,183800	0,0015

The basic point, here, is that the parameters of the conditional mean equation, (1), are insignificant and very small estimates. This is because of the fact that we have terminated the trend effect before and, also, taken the logarithmic differences of the rates in order to obtain the daily return rates. This was mentioned before in the paper – see Figure 3-a. Certainly, we have no interest in the mean return equation, then, simply, these results are no problem for our purposes in this study. The regression test statistics for mean return rate equation, (1), are shown below in Box-1. Honestly speaking, these results are showing the characteristic behaviour of zero-meaned time series.

BOX-1 : Regression Test Statistics: Daily FOREX Rates

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*******************************************************************************
* R-Squared -.0052996 R-Bar-Squared -.013947 *
* S.E. of Regression .0061960 F-stat. F( 4, 465) *NONE* *
* Mean of Dependent Variable -.2964E-3 S.D. of Dependent Variable .0061533 *
* Residual Sum of Squares .017852 Equation Log-likelihood 1735.3 *
* Akaike Info. Criterion 1730.3 Schwarz Bayesian Criterion 1719.9 *
* DW-statistic 2.0386 *
*******************************************************************************
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The volatility parameters, on the other hand, are strongly significant at 95%. This shows us that although the modified FOREX return rates are zero-meaned series, their volatilitility patterns are significantly changing through time. At that point, we have to interprete what those estimates tell us. The ARCH parameter, "α_e", is greater than the GARCH parameter, "δ_e", and this means that the exchange rate volatility is influenced by random shocks for short periods, in other words, the volatility is shortly persistent to the random shocks.

Below, in Table 4, you can see the regression results for daily interest rates. Here, the same procedures of terminating the program effect and taking the logarithmic differences, maintain us a zero-meaned modified data set. Off course, this data set had to give us non-significant estimates for conditional mean return equation. We can see this fact below in Table 4. In addition to that, the regression test statistics for interest rates can be seen in Box 2.

BOX-2 : Regression Test Statistics: Daily Interest Rates

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*******************************************************************************
* R-Squared .039521 R-Bar-Squared .031276 *
* S.E. of Regression .29989 F-stat. F( 4, 466) 4.7936[.001] *
* Mean of Dependent Variable -.4484E-3 S.D. of Dependent Variable .30469 *
* Residual Sum of Squares 41.9098 Equation Log-likelihood 349.0912 *
* Akaike Info. Criterion 344.0912 Schwarz Bayesian Criterion 333.7041 *
* DW-statistic 2.3468 *
*******************************************************************************
```

Table 4. The Regression Results for Daily Interest Rates

	Estimate	St.Deviation	t-value	Probability
B_0	0,002530	0,003153	0,802430	0,4230
B_1	0,157590	0,054676	-1,762500	0,0790
B_0	-0,096368	0,624640	0,252290	0,8010
κ_r	0,000858	0,000247	3,470700	0,0034
δ_r	0,422590	0,088240	4,789100	-0,0027
α_r	0,415250	0,052595	7,892500	0,0008

The volatility parameters, in Table 4, are, converse the ones in Table 3, strongly significant. Also the GARCH parameter, "δ_e", is greater than the ARCH parameter, "α_e", implying that interest rate volatility is influenced by random shocks for a much longer time. In other words, the effects of random shocks on interest rate volatility are more persistent that those of exchange rates.

The estimated volatility patterns for FOREX and interest rates can be seen in Figures 4-a and 4-b.

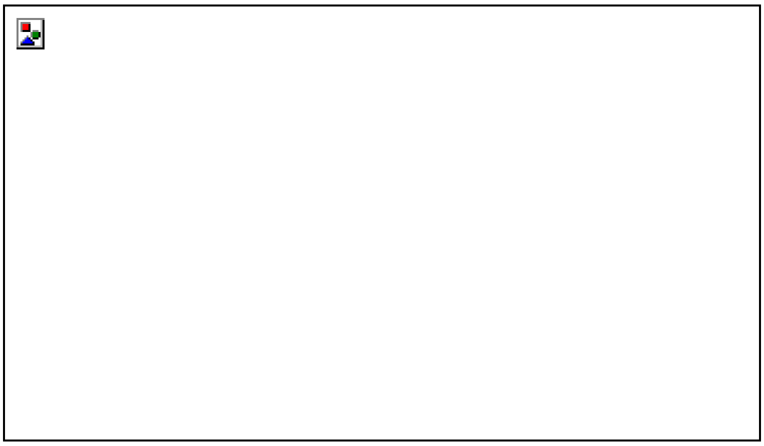

FIGURE 4-a: Daily FOREX volatility x10000

On Figure 4-a, you can see the estimated values of daily volatility. There are two dates, in which the volatility explodes. The first one is on April 25th, 1999, which can be addressed to the changes in the political environment after the general election on April 18th, 1999. The second is on 25th September, 2000, about which, the large inspection for the corruption in banking sector is started. CB, in these two crises, intervened and prevented the uncertainty in the FOREX market.

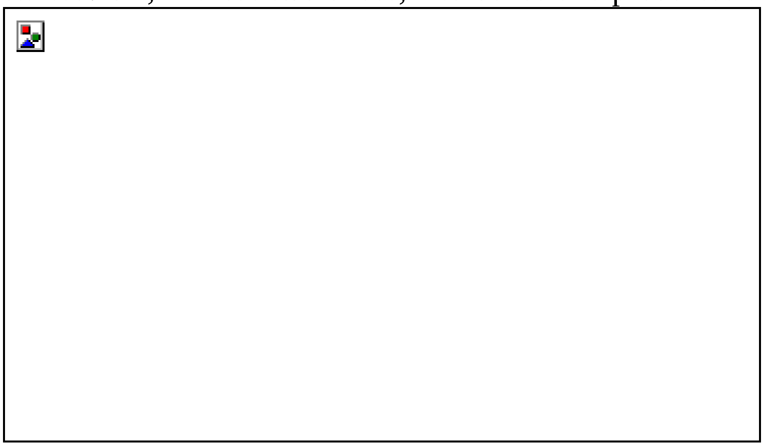

FIGURE 4-b: Daily interest rate volatility x10

In Figure 4-b, you can see the estimated volatility patterns for interest rates. Note that volatility rises significantly, when the exchange-rate-based stabilisation program has started. This confirms our propositions in the previous sections of this paper. Also, we have to note that at the end of 2000 the rise in interest rate volatility can be addressed to the effect of November Crisis.

The conditional covariances show us the volatility linkages between these two assets. In Figure 5, the conditional covariances between interest and FOREX rates are seen. Here, it is observed that the covariance structure changes drastically after the declaration of Program. As it is explained above in the previous sections of this paper, the rise in the covariances may appear because of the nature of exchange rate set as a nominal anchor. In that case, all the risk hitting the system can only be reflected in the fluctuations of interest rates, in other words interest rate volatility. Note that the covariances are high in absolute value but negative in sign. This means that a decline in the volatility of either assets cause a rise in the volatility of the other. In computing the covariance function values the fixed correlation rate is –0,0147, which is negative in value and significantly high at 95% level of significance.

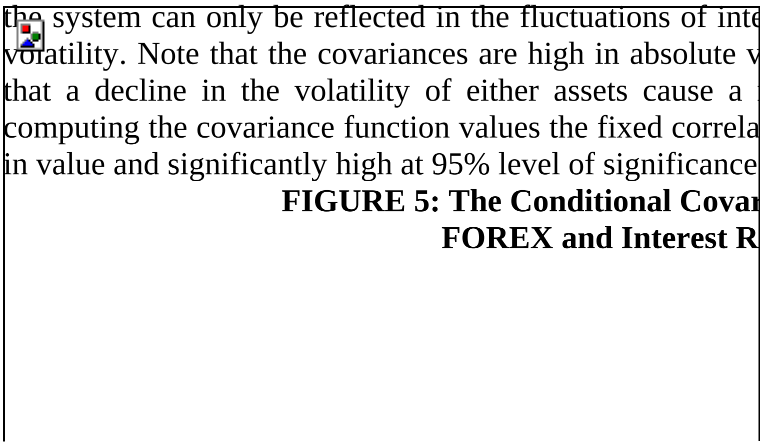

FIGURE 5: The Conditional Covariances Between FOREX and Interest Rates

CONCLUDING REMARKS

This study basicly intends to give specific intuition about the volatility linkages between the Dollar FOREX rates and repo interest rates on a daily basis. As there are high trend effects on the daily data and as our concern was not to examine the conditional mean return rates, we removed those trend effects from raw data and obtained a modified data set, which includes two zero-meaned time series. The observed volatility in those time series is seen to be non-stationary if you make a univariate analysis. On the other hand, a multivariate analysis gives us the opportunity to see the volatility linkages between the two relevant assets and maintains us stationary GARCH processes for the volatility of FOREX and interest rates. In addition to those claims, the observed asymmetry in a recet study (Demiröz (2000)) inherent in the FOREX rates in Turkey, is not seen as significant in this study, since most of the source of that asymmetry has seemed to come from co-dependency of interest and FOREX rates. In the literature, multivariate models for FOREX rates are generally used for examining the volatility linkages between different FOREX rates. In this study, we analyse the volatility linkages between the daily dollar FOREX rates and repo interest rates. Nevertheless, a more complex analysis including several FOREX rates and interest rates may be realised in future research. We also see that the intra-day volatility patterns may also be influential on daily volatilities and we are just in the research process of this topic. Another point may be examining the possible effects of dynamic hedging and speculation done by the private banks in Turkish money and FOREX markets. A last remark is that an analysis of FOREX and interest rate volatilities in lower frequencies, – such as weekly and monthly levels – which includes the capital flows and other macroeconomic variables, may maintain us a different perspective about the dynamic structure of FOREX and money markets. All these stuff shows us that there is a wide field of research that probably may give strong intuition to the financia agents and policy authorities interested in Turkish asset markets.

BIBLIOGRAPHY

Bollerslev, T., 1986, "Generalised Autoregressive Conditional Heteroscedasticity", *Journal of Econometrics*, 31: 307-27.

Bollerslev, T., R.F. Engle, and J. M. Wooldridge ,1988, "A Capital Asset Pricing Model with Time Varying Covariances", *Journal of Political Economy*, 96:116-31.

Bollerslev, T., 1990,"Modelling the Coherence in Short Run Nominal Exchange Rates: A Multivariate Generalised ARCH Model", *Review of Economics and Statistics*, 72: 498-505.

Demiroz, D. M., 2000, "Exchange Rate Volatility and News Effects: An Application with Turkish Daily Data", Unpublished MA Thesis, Marmara University, Institute of Social Sciences, Istanbul.

Diebolt, F. X. and M. Nerlove 1989, "The Dynamics of Exchange Rate Volatility: A Multivariate Latent Factor ARCH Model", *Journal of Applied Econometrics*, 4:1-21.

Engle, R.F, 1982, "Autoregressive Conditional Heteroscedasticitywith estimates of Variance of United Kingdom Inflation", Econometrica, 50: 987-1007.

Engle, R.F., V.K. Ng, and M. Rotschild 1990, Asset Pricing with Factor ARCH Covariance Structure: Empirical Estimates for Treasury Bills", *Journal of Econometrics*, 45: 213-37.

Engle, R.F. and K.F. Kroner, 1995, "Multivariate Simultaneous Generalised ARCH", *Econometric Theory*, 11:122-50.