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Volatility Spillover between the Foreign Exchange and the Stock Markets: Turkey, USA and Germany Cases

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Abstract: *The adoption of freely floating exchange rate regime and the increase in international capital movements have increased the interaction between foreign exchange and stock markets and the national financial markets exposed to external shocks with globalization of financial markets. In this context, the study examined the volatility spillover between Turkish foreign exchange and stock markets, American and German stock markets. MGARCH BEKK model was used in the volatility spillover analysis. The empirical findings of this study point out significant volatility spillovers between the markets. Volatility relations between markets bear significance for investors in terms of risk management and portfolio diversification decisions, and for politicians in terms of providing financial stability and the efficiency of policies.*

Keywords: *Foreign exchange market, MGARCH BEKK model, stock market, volatility spillover.*

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I. Introduction

The adoption of freely floating exchange rate regime and the increase in international capital movements have brought along the volatility problem on exchange rates. As exchange rates became more sensitive towards the shocks in stock markets and global portfolio investments, currency risks of companies has increased and stock markets started being affected by the exchange rate movements and the increasing volatility. With the globalization of financial markets, national financial markets have become vulnerable to external shocks, and foreign capital movements have begun to have significant effects on both the level and the volatility of prices in stock and foreign exchange markets.

In Turkey, the financial system was liberalized in 1989 with the removal of the controls over foreign capital movements. Liberalization of capital movements which is offering transaction opportunities for foreign investors in stock markets and the market domination of big foreign investors have created dependency relationships between financial markets. Now, it can be seen that a shock in international markets easily spreads to the national market in a short time. The adoption of freely floating exchange rate regime after 2001 and the increase in capital movements since 2003 have increased the exchange rate volatility in Turkey. Therefore, Turkish foreign exchange and stock markets have progressively met with the notion of volatility spillover. Within this framework, the aim of this study is to examine the volatility spillover between Turkish foreign exchange and stock markets and foreign stock markets. This paper is organized as follows. Section 2 reviews the literature, section 3 discusses the data and methodology, section 4 outlines the results of the analysis and section 5 provides the conclusion.

II. Literature

The analysis of the volatility spillover process in the literature is generally done in two ways. The first is the co-integration analysis used to examine the transmission of shocks between asset prices and returns. This approach focuses on long term co-movement in different international financial markets. The second area of research on volatility spillover studies the process of volatility over time. In this area, researchers use the ARCH (autoregressive conditional heteroskedasticity) model developed by Engle (1982) to analyze time varying variance (Hassan and Malik, 2007) [1]. ARCH and also GARCH (generalized ARCH) models are used to study volatility spillovers between different markets and different assets in different countries (Yang and Doong, 2004) [2].

The relationship between stock prices and the exchange rate was first discussed by Frank and Young in their paper in 1972, but they did not find a significant interaction between the two variables. The first studies examined the relationship between the two variables with regression and correlation [3].

Subsequent studies have examined the simultaneous relationships of two variables. While Ajayi, Friedman and Mahdian (1998) [4] found causal relations between securities markets and foreign exchange markets in developed countries, they did not find any stable relationship between the two markets in developing countries. Granger, Huang and Yang (2000) [5] analyzed stock price and exchange rate relationship with unit root and co-integration techniques in nine Asian countries. They found no relationship between two variables in Japan and Indonesia, but found one way relationship from exchange rate to stock price in Korea and the relationship is vice versa for other countries. Nieh and Lee (2001) [6] noted that there is no long term dynamic relationship between stock prices and the exchange rates in the G-7 countries, but that the short term relationship takes place one day later, that shock in one country shows the effect in other countries in the next day.

GARCH models have been widely used in volatility spillover analyses in recent years. Kanas (2000) [7] indicated that the symmetric volatility spillover from equity returns to exchange rates in United States, England, Japan, Canada and France except in Germany. Grambovas (2003) [8] examined the interaction between exchange rates and stock prices in Greece, the Czech Republic and Hungary, and found that the change in stock prices had an impact on the exchange rates. In an another study, in which the GARCH model based on the portfolio approach, emphasized the existence of volatility spillover across all countries, but also mentioned that different mechanisms might occur especially in crisis periods for four East Asian countries (Caporale, Pittis and Spangnolo, 2002) [9].

Yang and Doong (2004) [2] analyzed volatility spillovers using the EGARCH model for weekly closing stock prices and exchange rates for the G-7 countries. The findings of the study show that changes in stock prices affect exchange rate movements while changes in exchange rates have less effect on stock price movements. While volatility spillovers has occurred from stock markets to foreign exchange markets for France, Italy, Japan and the United States, no volatility spillover has been detected in these countries from foreign exchange markets to stock market.

Beer and Hebein (2008) [10] analyzed the volatility spillover between developed countries (America, Kanda, England, Japan) and developing countries (Hong Kong, Singapore, South Korea, Philippines) by using the EGARCH model. The findings point to the positive spread of market prices from the foreign exchange markets to stock markets in Canada, Japan and South Korea. Although they have not found strong evidence of volatility persistence in the stock and foreign exchange markets for developed countries, they have achieved opposite results for developing countries. Morales (2008) [11] stated that the volatility link between stock returns and the exchange rates is unidirectional moving from stock prices towards the exchange rates in one European and six Latin American countries. In another study of six emerging countries of Asia, significant volatility spillover from stock markets to foreign exchange markets has confirmed for Indonesia, Malaysia, Korea, Thailand and Taiwan (Lee, Doong and Chou, 2011) [12]. Empirical studies emphasize the existence of conflicting results regarding the dynamic relationship between exchange rates and stock prices.

III. Data And Methodology

This paper examines the volatility between Turkish foreign exchange and stock markets and foreign stock markets and addresses whether shocks from any market affect the volatility of the assets of other markets. In other words whether there is volatility spillover between markets is questioned and if so, the persistence of volatility spillover is investigated.

DAX30 index for the German Stock Exchange, S&P500 index for the American Stock Exchange and NAT100 index for the Borsa İstanbul were selected as representative data for stock markets. US Dollar/Turkish Lira (USD/TRY) and Euro/Turkish Lira (EUR/TRY) markets data were used for Turkish foreign exchange market. Daily closing values of stock indexes and nominal exchange rates were used. All data was gathered from data stream. The sample period is March 1, 2001 to August 3, 2009, including 2198 observations. Johansen co-integration test and the MGARCH (multivariate GARCH) BEKK model were used to analyze volatility spillover and persistence of volatility.

MGARCH BEKK model estimates own and cross market volatility spillovers and also the persistence of volatilities.

Engle and Kroner (1995) [13], define BEKK (1,1,K) model as follows.

$$H_t = C_0^{*'} C_0^* + \sum_{k=1}^{K} A_{1k}^{*'} \varepsilon_{t-1} \varepsilon_{t-1}^{'} A_{1k}^* + \sum_{k=1}^{K} G_{1k}^{*'} H_{t-1} G_{1k}^* \tag{1}$$

C_0^* , A_{1k}^* and G_{1k}^*, are nxn parameter matrices, C_0^* is a triangular matrix, K , determines the generality of the process. On the equation above, the second term is defined as ARCH term, and the third term is defined as GARCH term.

The BEKK model for the GARCH (1,1) process is expressed as the following for $K = 1$.

$$H_t = C_0^{*'} C_0^* + A_{11}^{*'} \varepsilon_{t-1} \varepsilon_{t-1}^{'} A_{11}^* + G_{11}^{*'} H_{t-1} G_{11}^* \tag{2}$$

In the bivariate case, BEKK model becomes as the following.

$$H_t = C_0^{*'} C_0^* + \begin{bmatrix} a_{11}^* & a_{12}^* \\ a_{21}^* & a_{22}^* \end{bmatrix}' \begin{bmatrix} \varepsilon_{1,t-1}^2 & \varepsilon_{1,t-1}\varepsilon_{2,t-1} \\ \varepsilon_{2,t-1}\varepsilon_{1,t-1} & \varepsilon_{2,t-1}^2 \end{bmatrix} \begin{bmatrix} a_{11}^* & a_{12}^* \\ a_{21}^* & a_{22}^* \end{bmatrix} + \begin{bmatrix} g_{11}^* & g_{12}^* \\ g_{21}^* & g_{22}^* \end{bmatrix}' H_{t-1} \begin{bmatrix} g_{11}^* & g_{12}^* \\ g_{21}^* & g_{22}^* \end{bmatrix} \quad (3)$$

If subscripts and GARCH terms are ignored, the model will become as the following.

$$h_{11} = c_{11} + a_{11}^{*2}\varepsilon_{1,t-1}^2 + 2a_{11}^* a_{21}^* \varepsilon_{1,t-1}\varepsilon_{2,t-1} + a_{21}^{*2}\varepsilon_{2,t-1}^2 + g_{11}^{*2} h_{11,t-1} + 2g_{ss}^* g_{21}^* h_{12,t-1} + g_{12}^{*2} h_{22,t-1} \quad (4)$$

$$h_{12} = c_{12} + a_{11}^* a_{12}^* \varepsilon_{1,t-1}^2 + \left(a_{21}^* a_{12}^* + a_{11}^* a_{22}^*\right)\varepsilon_{1,t-1}\varepsilon_{2,t-1} + a_{21}^* a_{22}^* \varepsilon_{2,t-1}^2 + g_{11}^* g_{12}^* h_{11,t-1}$$
$$+ (g_{12}^* g_{21}^* + g_{11}^* g_{22}^*) h_{12,t-1} + g_{21}^* g_{22}^* h_{22,t-1} \quad (5)$$

$$h_{22} = c_{22} + a_{12}^{*2}\varepsilon_{,t-11}^2 + 2a_{12}^* a_{22}^* \varepsilon_{1,t-1}\varepsilon_{2,t-1} + a_{22}^{*2}\varepsilon_2^2 + g_{12}^{*2} h_{11,t-1} + 2g_{12}^* g_{22}^* h_{12,t-1} + g_{22}^{*2} h_{22,t-1} \quad (6)$$

In the BEKK (1,1,1) model, the number of parameters to be estimated is (Bauwens, Laurent and Rombouts, 2006) [14].

In the model, both the conditional variances ($h_{ii,t}$) and the conditional covariances ($h_{ij,t}$) of the asset returns are influencing each other. c_{ii} represents constant term for asset i, and c_{ij} represents constant term of volatility spillover between asset i and asset j. a_{ii} describes the effect of a shock in the past on conditional variance, a_{ij} describes the effect of a shock in the past on conditional covariance (volatility spillover). The term b_{ii} refers the persistence of past shocks effects on conditional variance and b_{ij} refers the persistence of past shocks effects on conditional covariance.

IV. Results

Asset returns at time t are calculated using the daily closing values of stock indexes and nominal exchange rates as the following.

$$\Delta p_{i,t} = \ln\left(\frac{p_{i,t}}{p_{i,t-1}}\right) x100 \quad (7)$$

Augmented Dickey Fuller (ADF), Phillips Perron (PP) and Kwiatkowski, Phillips, Schmidt and Shin (KPSS) unit root tests were applied on the level series and first differences of logarithmic series to determine their stationarity. The results of all three unit root tests show that first differences of logarithmic series are stationary.

Table 1. Unit root test results of first differences of logarithmic series

	DLNDAX30	DLNS&P500	DLNNAT100	DLNUSD/TRY	DLNEUR/TRY
ADF	-48,74351*	-37,55035*	-45,53954*	-47,21220*	-49,12218*
PP	-48,81311*	-52,21562*	-45,55852*	-47,22371*	-49,06801*
KPSS	0,157905*	0,120190**	0,061174*	0,132905**	0,093842*

* Significance at the 1% level.
** Significance at the 5% level.

Table 2 represents descriptive statistics, Jarque Bera and ARCH-LM test results. While all series show standard deviations close to each other, the highest standard deviation belongs to DLNNAT100 stock index. The DLNNAT100 stock index has both the lowest and highest returns among the series. These series carry excess kurtosis features with a large scale from 3. All of the series show very little deviations from zero skewness. According to Jarque Bera test statistic, the null hypothesis that the series exhibit normal distribution is rejected and ARCH-LM test statistic shows that all series exhibit ARCH effects.

Table 2. Descriptive Statistics

	DLNDAX30	DLNS&P500	DLNNAT100	DLNUSD/TRY	DLNEUR/TRY
Mean	-0.0055	-0.0097	0.0709	0.0210	0.0410
Standard Deviation	1.6992	1.3925	2.2921	1.1254	1.1677
Minimum	-8.8747	-9.4695	-13.3408	-8.2800	-9.3100
Maximum	10.7975	10.9572	12.6858	7.3412	7.8784
Skewness	0.0504	-0.1214	0.0531	0.5864	0.3877
Kurtosis	7.6914	11.8100	6.4705	11.6865	11.5510
Jarque Bera	2015.730 (0.000)	7110.564 (0.000)	1103.622 (0.000)	7033.363 (0.000)	6748.580 (0.000)
TR^2	64.631 (0.000)	86.418 (0.000)	50.263 (0.000)	163.57 (0.000)	161.51 (0.000)

Numbers in parenthesis are p values.

Unit root tests indicate that first differences of logarithmic series are first order integrated. Johansen co-integration test was used to determine whether logarithmic series have a relationship in the long term. Johansen co-integration test results show that according to trace statistics there is 1, and according to maximum eigenvalue statistics there are 2 co-integration relationships at 5% significance level.

Table 3. Johansen Co-integration test results

Trace Test			
Hypotheses	Eigenvalue	Trace statistic	0.05 critical value
$H_0: r = 0, H_0: r \geq 1$	0,020515	108,4316*	88,80380
$H_0: r \leq 1, H_0: r \geq 2$	0,014974	63,07824	63,87610
$H_0: r \leq 2, H_0: r \geq 3$	0,007615	30,06771	42,91525
$H_0: r \leq 3, H_0: r \geq 4$	0,004237	13,34315	25,87211
$H_0: r \leq 4, H_0: r \geq 5$	0,001850	4,051901	12,51798
Maximum Eigenvalue Test			
Hypotheses	Eigenvalue	Max-Eigen statistic	0.05 critical value
$H_0: r = 0, H_1: r = 1$	0,020515	45,35332*	38,33101
$H_0: r \leq 1, H_1: r = 2$	0,014974	33,01052*	32,11832
$H_0: r \leq 2, H_1: r = 3$	0,007615	16,72456	25,82321
$H_0: r \leq 3, H_1: r = 4$	0,004237	9,291253	19,38704
$H_0: r \leq 4, H_1: r = 5$	0,001850	4,051901	12,51798

* The null hypothesis is rejected at the 5% significance level.

The results of the MGARCH BEKK model used in volatility spillover analysis are given in Table 4. The estimated a_{ii} parameters from the MGARCH BEKK model are significant at 1% level and higher than cross market volatility parameters. The volatility of markets is affected more by its own past shocks rather than shocks arising from other markets. USD/TRY market with the maximum a_{ii} parameter is the market which is affected by its own past volatility the most.

All b_{ii} parameters are significant at 1% level and higher than b_{ij} parameters; hence, persistence of own market volatilities is stronger than persistence of cross market volatilities. Borsa İstanbul has the highest own volatility persistence coefficient.

The results of the model show that there is volatility spillover from stock market of Germany to stock markets of USA and Turkey and foreign exchange market of Turkey. In other words, conditional variance of S&P500, NAT100, USD/TRY and EUR/TRY return series are affected from the shocks of stock market of Germany. The volatility arising from stock market of USA affects stock markets of Germany and Turkey and foreign exchange market of Turkey. The effects of a volatility caused by Borsa İstanbul can be observed on DAX30, S&P500 and EUR/TRY return series, whereas the only market unaffected by Borsa İstanbul related volatility is USD/TRY market. The volatility arising from USD/TRY market affects all markets except Borsa İstanbul. The volatility of EUR/TRY currency return affects NAT100 index return and USD/TRY currency return volatilities; other markets considered in this work are not being affected.

The volatility of German Stock Exchange has permanent effects in all markets, in other words, the volatilities of all markets caused by the volatility of German Stock Exchange will be permanent for at least one day. Only Borsa İstanbul and USD/TRY market are permanently affected by the volatility of the American Stock Exchange. The permanent effect of volatility arising from Borsa İstanbul can be seen on DAX30 index and the EUR/TRY currency pair. The volatility in EUR/TRY market creates permanent effects on both USD/TRY market and Borsa İstanbul.

Table 5. MGARCH BEKK (1,1) model results

c_{11}	0.1227*	(0.0172)	a_{32}	0.0543*	(0.0200)
c_{12}	0.0293**	(0.0145)	a_{35}	-0.1237*	(0.0438)
c_{22}	-0.0732*	(0.0098)	a_{41}	0.0150***	(0.0083)
c_{13}	0.1313*	(0.0467)	a_{42}	-0,0293*	(0.0099)
c_{23}	0.0710***	(0.0429)	a_{45}	0.0840*	(0.0198)
c_{33}	0.2021*	(0.0266)	a_{53}	0.0211*	(0.0067)
c_{14}	-0.0539*	(0.0195)	a_{54}	0.1786*	(0.0229)
c_{44}	-0.1107*	(0.0102)	b_{11}	0.9671*	(0.0036)
c_{45}	-0.1008*	(0.0111)	b_{22}	0.9738*	(0.0028)
a_{11}	0.2154*	(0.0141)	b_{33}	0.9816*	(0.0031)
a_{22}	0.2171*	(0.0099)	b_{44}	0.9330*	(0.0070)
a_{33}	0.1660*	(0.0119)	b_{55}	0.9688*	(0.0062)
a_{44}	0.3129*	(0.0224)	b_{12}	-0.0085**	(0.0038)
a_{55}	0.2409*	(0.0212)	b_{13}	0.0070*	(0.0027)
a_{12}	0.0738*	(0.0144)	b_{14}	0.0404*	(0.0094)
a_{13}	-0.0288**	(0.0096)	b_{15}	-0.0164**	(0.0083)
a_{14}	-0.1344*	(0.0307)	b_{23}	0.0062*	(0.0019)
a_{15}	0.0501***	(0.0275)	b_{24}	0.0124***	(0.0070)
a_{21}	-0.0192***	(0.0103)	b_{31}	-0.0188*	(0.0046)
a_{23}	-0.0211*	(0.0073)	b_{35}	0.0306*	(0.0113)
a_{24}	-0.0623**	(0.0254)	b_{43}	-0.0051*	(0.0019)
a_{25}	0.0389***	(0.0230)	b_{53}	-0.0099*	(0.0020)
a_{31}	0.0346***	(0.0188)	b_{54}	-0.0570*	(0.0070)

Numbers in parenthesis are the standard deviations.
* Significance at the 1% level.
** Significance at the 5% level.
*** Significance at the 10% level.
$i = 1,2,3,4,5$ and $j = 1,2,3,4,5$ represent the DAX30, S&P500, the NAT100 index returns, the USD/TRY and EUR/TRY nominal exchange rates returns respectively.

V. Conclusion

Financial liberalization and international integration increased the exchange rate volatility in Turkey, also strengthened the relationship between the foreign exchange and stock markets and exposed national financial markets to external shocks. In this study, volatility spillover between foreign exchange market of Turkey, stock markets of Turkey, Germany and USA is examined and the findings of this study point out significant volatility spillovers between the markets. Volatility originating from German and American Stock

Markets has important volatility effects on foreign exchange and stock markets of Turkey. All markets are influenced by the volatility of Borsa İstanbul except USD/TRY market and there is volatility spillover between USD/TRY market and the other markets except Borsa İstanbul. The volatility of EUR/TRY market has effects on only national financial markets.

The volatility of markets is affected more by its own past shocks rather than shocks arising from other markets. Persistence of own market volatilities is stronger than persistence of cross market volatilities, in other words, past volatility shocks in a market have greater effects on their future volatilities than the past volatility shocks in other markets.

Volatility relations between markets bear significance for investors in terms of risk management and portfolio diversification decisions, and for politicians in terms of providing financial stability and the efficiency of policies.

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