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THE INVESTIGATION OF VOLATILITY SPILLOVER EFFECT BETWEEN STOCK MARKETS OF TURKEY, ITALY, GREECE AND RUSSIA

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ABSTRACT

In this study, the volatility spillover effects in stock markets of various countries are examined. Volatility spillover effect occurs in two forms as heat wave and meteor shower in literature. From this point to these two effects were investigated in stock markets of Turkey, Italy, Russia and Greece. In the research, cointegration, ARCH-LM, VAR, and finally VAR-MGARCH analyzes were used. According to the results of the analysis, it was concluded that the volatility spillover effect is effective in all stock markets. Also, it was determined that more meteor shower hypothesis is more effective when the time was extended, although heat wave hypothesis is effective in the short term.

Keywords:

Volatility Spillover Effect,

Financial Markets,

Stock Market,

VAR-MGARCH-Diagonal VECH Analysis

JEL Codes:

G13, G15

TÜRKİYE, İTALYA, YUNANİSTAN VE RUSYA MENKUL KIYMET PİYASALARINDA VOLATİLİTE YAYILIMI ETKİSİNİN İNCELENMESİ

ÖZ

Bu çalışmada, çeşitli ülkelerin borsalarındaki volatilitenin yayılma etkileri incelenmiştir. Volatilite yayılma etkisi literatürde sıcak hava dalgası ve meteor yağmuru olmak üzere iki şekilde ortaya çıkmaktadır. Bu noktadan hareketle Türkiye, İtalya, Rusya ve Yunanistan'ın borsalarında bu iki etki incelenmiştir. Araştırmada eş bütünleşme, ARCH-LM, VAR ve son olarak VAR-MGARCH analizleri kullanılmıştır. Analiz sonuçlarına göre, Volatilite yayılma etkisinin tüm borsalarda etkili olduğu sonucuna varılmıştır. Ayrıca, kısa vadede ısı dalgası hipotezi etkili olurken süre uzadığında meteor yağmuru hipotezinin daha etkili olduğu belirlenmiştir.

Anahtar Kelimeler:

Volatility Yayılım Etkisi

Finansal Piyasalar

Menkul Kıymetler Borsası

VAR-MGARCH-Diagonal VECH Analizi

JEL Kodları:

G13, G15

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1. INTRODUCTION

Financial markets are basically established to bring funders and suppliers together (Perry, Keown, Scott Jr. & Martin, 1993). With the spread of information technologies and the internet in recent years, these markets have started to provide services at an international level. This situation has further improved with factors such as the expansion of the international business activity volume, and the facilitation of international banking transactions and fund transfers. These developments enabled the capital to be easily transferred to cross-border areas without being subject to any restrictions. With the effect of this process called financial globalization, not only financial markets in developed countries but also financial markets in developing countries began to gain importance.

Also, these developments removed international investments from the monopoly of a certain group and made them accessible to everyone. Countries are making efforts to attract international funds, which are constantly on the move, to their own countries. One of the most important tools used for this is the securities markets. In this context, each country tries to make its own stock market more attractive. While investors prefer among alternative markets, they pay attention to the factors affecting these markets. In this subject exist many factors. One of them is that the volatility in the stock markets affects the future situation of the market. This is the effect of volatility in the past on the pricing of the same market in the future.

Due to the very fast capital movements, volatility in one market may have an effect on the market in another country. This situation makes the markets in different countries interrelated. These two conditions are named as volatility spillover effect in the literature. The problematic of this study is defined as determining the existence and direction of volatility spillover effect among the securities markets.

This is very important for investors and decision makers. The determination of the structure and direction of the current intra-market and inter-market relationship will be a guide for those trading in these markets. In the study, in order to examine this relationship in Turkey and other securities markets, primarily described the volatility spillover effect and literature within the conceptual framework of the research have been examined. Then, under the title of methodology, the purpose, hypotheses, data set and methods to be used in the research are explained respectively. Finally, the findings and conclusion of the research are given.

2. CONCEPTUAL FRAMEWORK

2.1. Volatility Spillover Effect

When the literature on the subject examined, the Volatility Spillover Effect occurs in two ways. These (Engle, Ito & Lin, 1990);

- The Heat Wave Hypothesis
- The Meteor Shower Hypothesis

Heat wave hypothesis is stated that the information generated in the market will affect the next day. For example, a hot day in New York will likely follow a hot day. However, this situation will not have an impact on Tokyo. According to this theory, the volatility that occurs due to information in the market will affect the same market and will continue in that market. It will not spread to different country markets. In the heat wave hypothesis, price movements occur only because of the problems of that country. Therefore, they do not affect the markets in other countries (Engle, at all, 1990).

Meteor shower hypothesis is expressed as the volatility occurring in one stock exchange affects the stock markets of other countries. For example, a meteor shower in New York will almost surely be followed by one in Tokyo. The meteor shower effect can often be caused by money supply, cooperative or competitive monetary policies. If the policy switch by the Fed increases the uncertainties of the monetary stance of the Bank of Japan, or vice versa, then this would show up as the meteor shower (Engle, at all, 1990).

This effect can be one-way from one market to another, or it can be two-way as mutual interaction (Demirgil & Gök, 2014). These two situations can be seriously important in investors' decisions. It is also important for determining the level of integration of financial markets (Korkmaz & Çevik, 2009). Countries' geographical locations, trade volumes, political and economic cooperations, etc. features can be effective in the interaction between their financial markets. Besides, the development levels of countries financial markets may cause a different level of volatility spillover effects between the markets.

2.2. Literature

Some of the studies related to the volatility spillover effect in the literature are given below.

Booth, Chowdhury, Martikainen and Tse, (1997) analyzed the stock futures markets of the USA, UK and Japan between 1988-1994 with last prices. In the study, both heat wave and meteor shower effects were found between the US and UK markets. In the Japanese market, only the heat wave effect was observed. Aggarwal and Park (1993) examined the relationship between the US S&P 500 and the Japanese Nikkei 225 exchanges at opening prices. Accordingly, it was concluded that the meteor shower hypothesis was supported among the used markets in the study (Aggarwal & Park, 1994). In another study involving the same exchanges, Pan and Hsueh (1998) examined future market prices using the GARCH method. In the study conducted with the price index, a one-way meteor shower effect was detected from the USA to Japan, while in the study conducted with the return index, the effect of a two-way meteor shower was determined. Pena (1992) concluded that there is a relationship between the two exchanges in his study on the determination of the relationship between the USA (New York) and Spain (Madrid) stock exchanges. Accordingly, the one-way meteor shower effect was determined from the US stock exchange to the Spanish stock exchange. Besides, this effect was found to be double high in negative news. Miyakoshi (2003) investigated the return and volatility spillover of the Japanese and US markets on seven Asian markets, namely Korea, Taiwan, Thailand, Singapore, Malaysia, Indonesia and Hong Kong. For this purpose, the last prices data of the stock indexes of the countries between January 1, 1998, and April 30, 2000, were analyzed using GARCH models. As a result of the study, three main findings were reached. In the first review with the price index, the effect of the meteor shower was detected from both the Japanese and US stock exchanges to the Asian stock exchanges, but the effect of the Japanese stock market was stronger. In the examination made with the return index, the effect of the meteor shower of the USA towards the Asian markets was significant, but no impact of Japan was detected.

Hassan, Nassir and Mohamad (2006) examined the relationships in some developed and developing Asian exchanges, including Japan, Hong Kong, Thailand, Singapore, Philippines, Indonesia, Malaysia and Australia for the period of January 1991- December 2000. From 1991 to 1996, in which high growth was achieved, a strong heat wave effect was detected in developing countries and even developed Asian countries. During the 1997 Asian crisis and afterwards, the effect of the meteor shower was determined among the stock markets of the developing countries.

Gök and Kalaycı (2015), examined the effects of returns and volatility spillover between Turkey (BIST 30) and the US (S & P 500) index futures markets using daily data for the 2010-2012 period. In the study, the Johansen cointegration test and multivariate generalized autoregressive conditional heteroskedasticity model were applied. However, at both the return and price indexes the one-way meteor shower effect was determined from the United States to Turkey. In addition to these results, it is concluded the heat wave hypothesis is more effective in the US market, while the meteor shower hypothesis is more effective in the Turkey market. Demirgil and Gök (2014), examined the volatility spillover effects between stock exchanges of the United Kingdom, Germany and France with Turkey's stock exchange for 2002-2013 period with the last prices and VAR-EGARCH model. According to the findings; the meteor shower effect from European stock exchange to Turkey has been identified. Besides, it has been determined that the most effective among these countries are Germany. Dimitriou, Mpitsios and Simos (2011) examined the volatility spillover between the stock markets of Germany, Italy, Spain, Greece and Portugal in the context of the 2007 financial crisis. For this purpose, to determine the magnitude and direction of volatility spillover, the daily data of the period 1994-2009 were analyzed using the MGARCH (multivariate generalized autoregressive conditional heteroskedasticity) model. According to the results obtained, the effect of both heat wave and meteor shower in the pre-crisis period is higher in Germany than in other countries. Germany was followed by Spain, Italy, Greece and Portugal. In the post-2007 period, the effects of heat wave and meteor shower increased even more than before 2007. Spain was the country most affected during this period. This was followed by Germany, Italy, Portugal and Greece.

3. METHODOLOGY

3.1. Purpose of the Study and Hypotheses

Based on the above information, the volatility spillover effect, which has two different forms in the literature as heat wave and meteor shower, has been examined between stock exchanges of Greece, Italy, Russia with Turkey's stock exchanges. These countries were preferred because they are close to each other in terms of geographical and economic relations.

In the light of all this information, the purpose of the research is determined as examining by volatility spillover effects (the meteor shower and heat waves) hypothesis of stock exchanges of Turkey, Greece, Italy and Russian. In this context, the hypotheses of the research are as follows;

H_1: *Volatility spillover effect exists among the stock exchanges subject to the research.*

H_{1a}: *Meteor shower effect exists among the stock exchanges subject to the research.*

H_{1b}: *Heat wave effect exists among the stock exchanges subject to the research.*

3.2. Data Set and Method

The most popular indexes in the countries have been discussed to examine the effects of hypotheses. So, to review, BIST 100 in Turkey, FTSE MIB in Italy, the MICEX in Russia and Athens General in Greece indexes are used. During crisis periods, unusual fluctuations and movements occur in the indexes. To exclude the effects of the 2008 crisis, the data set was created between 01.01.2010 and 31.12.2018. As suggested by Kutlar (2017, p.87), natural logarithms have been taken to bring more stability to the series and have been converted into logarithmic return series with the formula below.

$$(LY_{i,t}) = Ln(Y_{i,t}/Y_{i,(t-1)})$$

Where $LY_{i,t}$ represents the logarithmic return of the series i (Countries) at time t and $Y_{i(t-1)}$ represents the return of the i series at time t-1

It is not in the category of studies requiring ethics committee permission in the research. Therefore, an ethics committee document is not required for the study.

The data were obtained from investing.com and the end-of-day closing values of the indices were used. In the data set, which was created taking into consideration the days when all four markets are open, there are 2068 observations in total. Firstly, stationarity status of all series should be examined in order to perform the analyzes safely. In this context, Fourier KPSS (FKPSS), which takes into account the structural breaks, and ADF unit root tests were performed. Then, relevant tests were carried out to determine the appropriate lag length.

The variance obtained from the whole of a time series has an unconditional (random) structure and is not related to past returns. If the series' variances for a specific time period are different, the Heteroscedasticity problem emerges. This also shows that returns are affected by past values. The method developed by Engle (1982) for the detection of this relationship is named as the autoregressive conditional heteroscedasticity (ARCH) in the literature. This method helps to make future predictions with the past values of the series (Gujarati, 2016, p.358). however, Bollerslev (1986) stated the deficiencies in the ARCH model as follows (Gujarati, 2016: p.364);

- Requiring coefficient estimates of a certain amount of autoregressive terms reduces the degree of freedom,
- Generally, all of the coefficients are difficult to interpret,
- The least-squares method is not very suitable,

For all these reasons, the GARCH model has been developed for ARCH models higher than ARCH (3). The GARCH model changes the variance equation by keeping the average constant.

Also, cointegration analysis is performed to examine the long-term relationship between the two variables (Engle & Granger, 1987, p. 251). When the number of variables is more than two, the Johansen-Juselius cointegration test is used instead of the Engle-Granger cointegration test (Johansen & Juselius, 1990, p. 169). However, in case of structural breakage in the series, methods that take into account breaks should be used. One of these methods is the Fourier ADL (2017) cointegration test. In the study, Fourier ADL (2017) cointegration analysis was used while examining the long-term co-integration relationship due to the use of 4 country data and exists of structural breakage in the series.

In the ongoing stage, the ARCH / GARCH relationship should be examined to detect the presence of an autoregressive structure in the series. Therefore, at this stage, ARCH-LM test was performed to determine the ARCH / GARCH effect. After doing analysis of long-term relationship status between series and autoregressive process within the series, multivariate GARCH (MGARCH) models are used for autoregressive process analysis between multiple series (Mensi, Beljid, Baubaker, & Managi, 2013, p.17).

While the method is preferred to examine this situation, first of all, it is aimed to determine the variables (their own lags, other indices and lags) that affect the relevant indices. The VAR method was used to determine this. As a result of the established VAR model, the equations of the index to be estimated involving other indexes and their lags were obtained. MGARCH model is estimated with the help of the obtained equations.

The MGARCH model was used by Kraft and Engle (1982). In this model, the {yt} series is assumed to be an Nx1 dimensional stochastic process. θ as a finite number of parameters and a conditional mean vector of μt (θ) (Songül, 2010, p.3);

$$y_t = \mu_t(\theta) + \varepsilon_t$$

$$\mathcal{E}_t = H_t^{1/2}(\theta) Z_t$$

is expressed as. where the Ht1/2 matrix is the NxN dimensional positive matrix, while the Nx1 dimensional random zt vector has the moments

$$E(zt) = 0$$

$$Var(Zt) = IN$$

to represent the n dimensional unit matrix.

$$Var\left\{ y_t \mid I_{t-1} \right\} = Var_{t-1}\left(y_t\right) = Var_{t-1}\left(\varepsilon_t\right) = H_t^{\frac{1}{2}}\, Var_{t-1}(Z_t) \left(H_t^{\frac{1}{2}}\right)' = H_t$$

Ht matrix shows the conditional variance matrix of yt with NxN dimension. Ht1/2 matrix is obtained by subjecting the Ht matrix to Cholesky factorization. In this context, multivariate GARCH models are divided into five groups according to the different definitions received by the Ht matrix (Songül, 2010, p.3);

- VECH-GARCH Model
- BEKK-GARCH Model
- Matrix Exponential GARCH Model
- Factor GARCH Models
- Conditional Correlation GARCH Models

In calculating the VECH GARCH model, there are some problems such as (Enders, 2014, p.167);

- The number of parameters to be calculated is quite high,
- not always achieving optimum results,
- conditional variances are not always positive,

Diagonal VECH GARCH method has been developed to eliminate these problems. In this method, only conditional variances can have a negative value problem (Enders, 2014, p.167).

In this context, VAR-Diag-VECH-GARCH (1,1) analysis was performed to determine the volatility spillover effect (heat wave and meteor shower effects) between indices. Finally, the Ljung-Box Q statistic autocorrelation test analysis was done.

3.3. Findings of The Research

The logarithmic index data of Turkey, Italy, Russia and Greece is shown in Figure 1 below. It can be said that the slope of the Athens General index is different from the indexes of the other three countries. All country indices experienced a decline in 2012. After 2012, an increase has been observed in other countries except for Greece.

However, in this process, the rise in Turkey and Russia stock market indices has been more than the other two countries stock indexes.

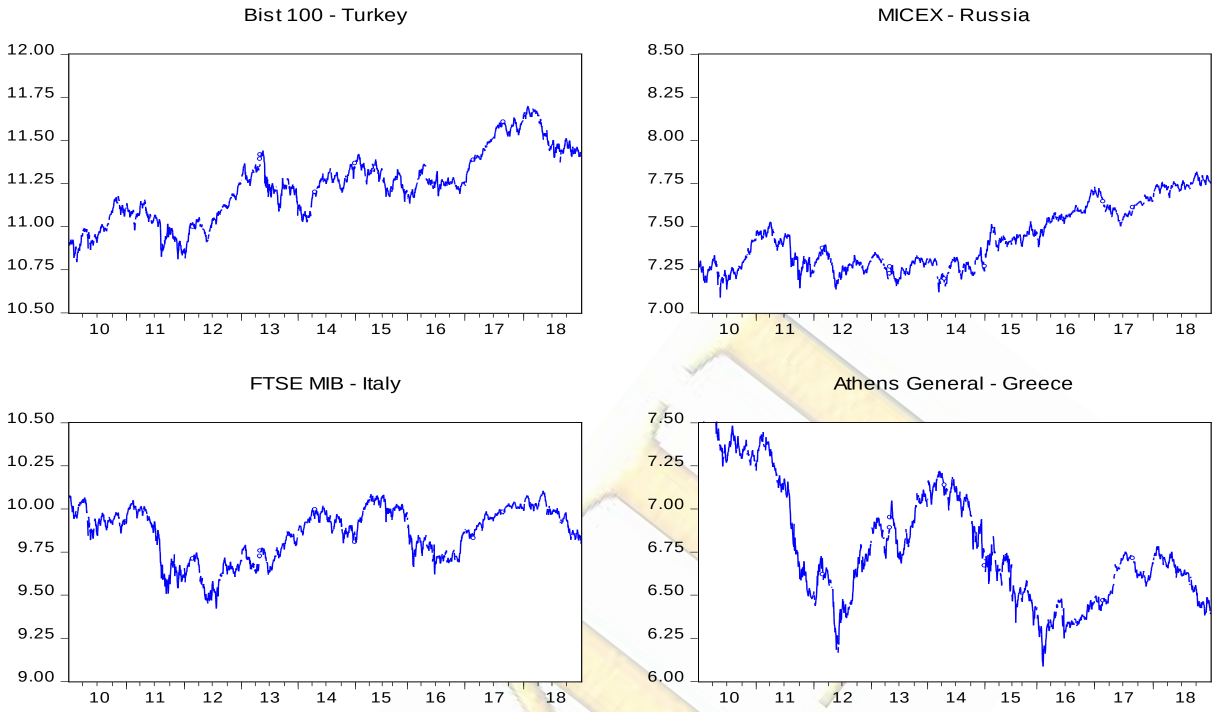

Figure 1. The Data of Stock Market Indices

On the other hand, when the figures above are examined, it is seen that there are irregular ups and downs. Besides, when the above indices are converted to return series, they take the following form.

When the below figures are analysed, it can be said that the volatility in Athens general return index is higher than the other indices. It can also be said that the volatility in the indices is compatible with each other. According to this, it can be said that big changes follow big ones and small changes follow small ones. This situation shows the existence of ARCH effect in the series.

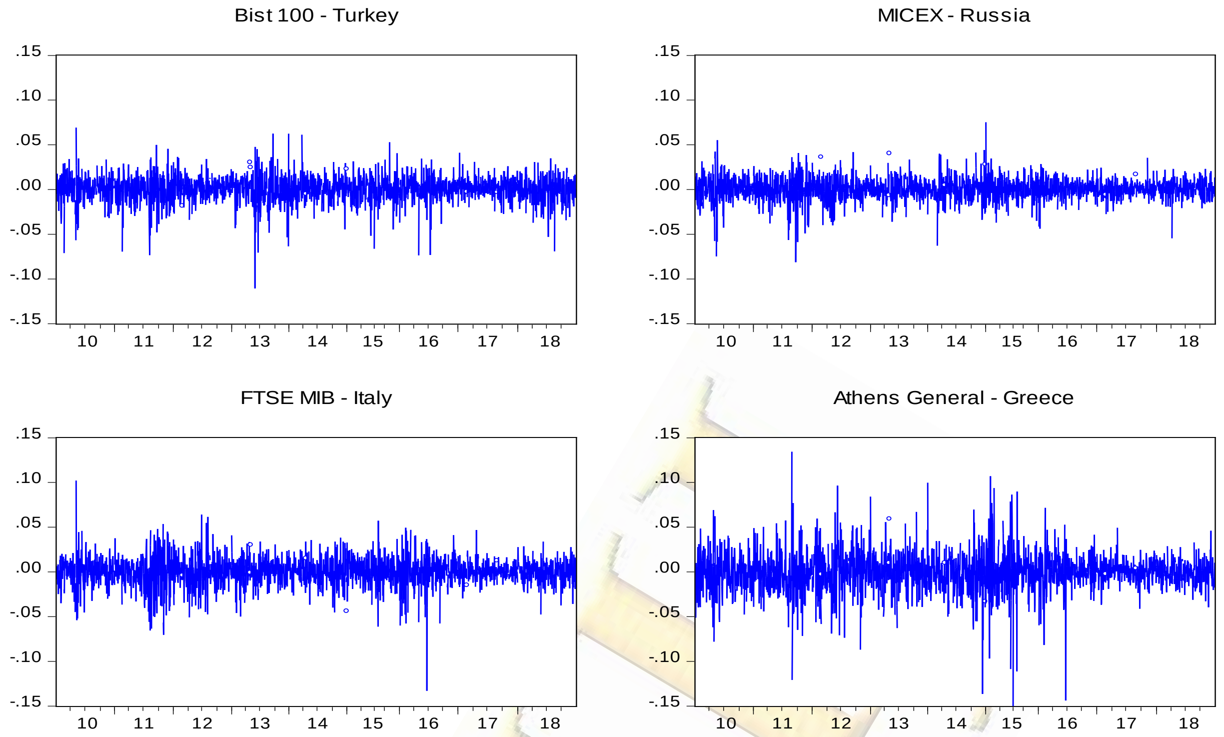

Figure 2. Stock Market Return Indices

In order to perform cointegration analysis in time series, all series must be stationary at the same level. Otherwise, a spurious regression problem will arise. In the time series, many analysis methods are used to determine at what level the series are stationary. In this study, firstly, Augmented Dickey-Fuller (ADF) unit root test was used. The results of the analysis are given in the table below.

Table 1. ADF Test Results

	I(0)		I(1)	
	Constant	**Trend and Constant**	**Constant**	**Trend and Constant**
Log BIST 100	-1,965	-3,203	-25,80**	-25,79**
Log MICEX	-1,181	-2,804	-44,25**	-44,24**
Log FTSE MIB	-2,684	-2,923	-47,42**	-47,41**
Log Athens General	-2,546	-2,518	-42,79**	-42,79**

* p < 0,05 and ** p < 0,01

As can be seen from the table, while all series contain unit root at the level, they become stationary in their first difference.

On the other hand, structural breaks in the time series can cause a non-stationary series to appear stationary or a stationary series to appear as non-stationary. To overcome this problem, unit root analyzes that are not affected by structural breaks are required. In this context, Becker, Enders and Lee (2006) developed the Fourier

KPSS (FKPSS) stationarity test. Accordingly, the strength of FKPSS analysis is not affected by factors such as the shape, location and number of structural breaks. FKPSS analysis results are given in the table below.

Table 2. Fourier KPSS (FKPSS) stationary test

	I(0)				I(1)			
	Frekans	Min SSR	FKPSS	F stat	Frekans	Min SSR	FKPSS	F stat
LBIST 100	4	11,197	0,229	982,71	4	0,459	0,016	3,192
LMICEX	1	9,170	0,118	1564,02	5	0,342	0,017	1,030
LFTSE MIB	2	23,201	0,358	855,61	4	0,547	0,060	1,508
LAthens General	2	58,647	0,443	1510,87	2	1,028	0,049	3,242

Hypothesis for KPSS test; H_0: Series does not contain a unit root. H_1: Series Contains Unit Root.
Significance hypotheses of trigonometric variables; H_0: H0: trigonometric terms are equal to zero (insignificant). H_1: trigonometric terms are different from zero (significant). The table value of F test at the level of 5% is 4,669. The table critical values of Becker at all. (2006:389) for the number of samples and Frequency Values are below;

K	1	2	3	4	5
T >1000 and %5	0,0538	0,1275	0,1398	0,1436	0,1541

When the FKPSS values obtained and the table values are compared, it is seen that the values of all series are higher than the table values. Accordingly, H_0 is rejected and it is determined that the series contains unit root at the level. For the 1st difference of the series, H_0 is accepted because all FKPSS values are smaller than the table critical values, and therefore it is determined that all the series are stationary at 1st difference. After H_0 is accepted, the significance of trigonometric terms should be examined with the F test. Since the F values obtained as a result of the test are smaller than the table value, the H_0 hypothesis is accepted. In this case, it can be said that standard ADF test results, which are given in Table 1, are valid. According to the unit root analysis results, all series become stationary at the 1st difference values. In this context, the cointegration analysis can be done. It is necessary to determine the appropriate lag length before proceeding to the cointegration analysis. Test results on this subject are given in Table 3.

According to the results in the Table 3, the different tests reached different results. for example; the LR test reached the 6th lag length, the FPE and AIC tests reached the 3rd lags length, and the SC and HQ tests reached the 1st lag length. The most effective of these tests are AIC and SC tests. the test which has lower value should be chosen when choosing between these two. In this context, the suitable lag length has been determined as 3. Also, the structure of the data is important when determining the appropriate lag length.

Table 3. Appropriate Lag Length Analysis

Lags	LogL	LR	FPE	AIC	SC	HQ
0	3252.621	NA	5.04e-07	-3.149414	-3.138494	-3.145411
1	23006.25	39411.50	2.47e-15	-22.28429	-22.22969*	-22.26428*
2	23038.26	63.74285	2.43e-15	-22.29981	-22.20153	-22.26378
3	23054.48	32.23922	2.43e-15*	-22.30003*	-22.15807	-22.24799
4	23062.57	16.04938	2.45e-15	-22.29236	-22.10672	-22.22431
5	23084.37	43.14579	2.43e-15	-22.29798	-22.06866	-22.21391
6	23101.29	33.44261*	2.43e-15	-22.29888	-22.02588	-22.19880
7	23107.82	12.87642	2.45e-15	-22.28970	-21.97302	-22.17360
8	23114.89	13.90559	2.48e-15	-22.28104	-21.92068	-22.14893

* Selected lag

In this context, it can be said that the data at most 3 days ago can be effective in the stock exchanges. Besides, a second reason for not choosing the 1st lag length is that it causes a high autocorrelation problem in the analysis. After determining the appropriate lag length, the Fourier ADL Cointegration Test developed by Banerjee, Arčabić and Lee (2017) that allows multiple structural breaks is used. The results obtained are given in Table 4.

Table 4. Fourier ADL (2017) Cointegration Test Results

	LTurkey			LRussia			Litaly			LGreece		
FADL(k)	-1,815			-4,272			-3,003			-2,447		
k	4			1			1			3		
AIC	-5,569			-5,869			-5,401			-4,778		
LAGS												
LTurkey	1			1			1			2		
LRussia	1			2			3			2		
LItaly	1			1			1			1		
LGreece	3			1			1			2		
Results	No Cointegration			No Cointegration			No Cointegration			No Cointegration		
	Banerjee et al (2017), Table Statistics											
	%1	**%5**	**%10**	**%1**	**%5**	**%10**	**%1**	**%5**	**%10**	**%1**	**%5**	**%10**
	-5,18	-4,55	-4,23	-5,28	-4,70	-4,39	-5,39	-4,83	-4,53	-5,28	-4,70	-4,39

H_0: No Cointegration.

According to the results obtained, since the absolute value of the calculated FADL (k), statistical values is lower than the table statistics values, the long-term co-integration relationship between the series could not be determined. On the other hand, ARCH-LM test was performed to determine the presence of ARCH effect in the series. The test results are given in Table 5.

Table 5. ARCH-LM Test Results

	Log BIST 100	Log MICEX	Log FTSE MIB	Log Athens General
F-Statistics	25,447	37,487	59,391	39,003
Observation*R^2	25,161	36,854	57,787	38,317
Prob.F(1,2066)	0,000	0,000	0,000	0,000
Prob. Chi-Square(1)	0,000	0,000	0,000	0,000

H_0: There is no ARCH effect in the series.

As can be seen from the results in the table, H_0 is rejected in all series. In this context, there is an ARCH effect in all series.

ARCH effect between different series is analyzed by multivariate ARCH or GARCH analysis method. While creating the equations to be used in the analysis, the long-term relationship between the series must be examined first. If there is a long-term relationship between the series, the equations to be established for the MGARCH method must be created using the Vector Error Correction Method (VECM) method.

In the absence of a long-term relationship, equations are created by the vector autoregressive (VAR) method. It was previously determined that there was no long-term co-integration relationship between the series. For this reason, the results of VAR analysis are given in the table below.

Table 6 VAR Model Test Results

	DLTURKEY		DLRUSSIA		DLITALY		DLGREECE	
	(-1)	(-2)	(-1)	(-2)	(-1)	(-2)	(-1)	(-2)
DLTURKEY	-0.04672	0.01985	0.00334	-0.01783	0.01188	0.00019	0.05816	-0.03020
	(0.0247)	(0.0247)	(0.0213)	(0.0213)	(0.0269)	(0.0269)	(0.0366)	(0.0367)
	[-1.8889]	[0.8021]	[0.1567]	[-0.8366]	[0.4414]	[0.0070]	[1.5851]	[-0.8226]
DLRUSSIA	0.00933	-0.02554	0.03132	-0.05179	0.00371	-0.03847	-0.053975	0.09905
	(0.0300)	(0.0300)	(0.0259)	(0.0259)	(0.0327)	(0.0327)	(0.0446)	(0.0446)
	[0.3102]	[-0.8494]	[1.2094]	[-2.0003]	[0.1134]	[-1.1756]	[-1.2100]	[2.2206]
DLITALY	0.01499	0.01133	-0.01437	0.03694	-0.08096	-0.01260	0.14228	0.04567
	(0.0252)	(0.0253)	(0.0217)	(0.0218)	(0.0274)	(0.0275)	(0.0374)	(0.0375)
	[0.5937]	[0.4480]	[-0.6610]	[1.6958]	[-2.9469]	[-0.4577]	[3.8000]	[1.2170]
DLGREECE	0.01746	-0.00146	0.01230	-0.02122	0.05699	-0.00805	0.01536	-0.05586
	(0.0165)	(0.0163)	(0.0141)	(0.0140)	(0.01791)	(0.0177)	(0.02441)	(0.0242)
	[1.0612]	[-0.0892]	[0.8679]	[-1.5106]	[3.1825]	[-0.4535]	[0.6292]	[-2.3091]
C	0.000268		0.000246		-9.98E-05		-0.000639	
	(0.00033)		(0.00028)		(0.00036)		(0.00049)	
	[0.8137]		[0.8664]		[-0.2786]		[-1.3099]	
R-squared	0.003057		0.005551		0.008398		0.018724	
Adj. R-squared	-0.000816		0.001687		0.004546		0.014912	
Sum sq. resids	0.459260		0.340585		0.544009		1.010488	
S.E. equation	0.014935		0.012861		0.016255		0.022153	
F-statistic	0.789294		1.436731		2.179871		4.911081	
Log likelihood	5764.136		6073.253		5589.028		4948.752	
Akaike AIC	-5.565896		-5.864848		-5.396546		-4.777323	
Schwarz SC	-5.541375		-5.840327		-5.372025		-4.752802	
Mean dependent	0.000244		0.000240		-0.000124		-0.000619	
S.D. dependent	0.014929		0.012872		0.016292		0.022320	

Determinant resid covariance (dof adj.)	2.38E-15
Determinant resid covariance	2.33E-15
Log-likelihood	23098.80
Akaike information criterion	-22.30445
Schwarz criterion	-22.20636
Number of coefficients	36

Since the VAR model is made by taking the differences of the variables, the lag length is determined as 2 (1 number less than value than the value determined for the cointegration analysis). As a result of the VAR analysis, the equations to be used for the MGARCH analysis are created as follows;

DLTurkey = C(1)* DLTurkey (-1) + C(2)* DLTurkey (-2) + C(3)*DLRussia(-1) + C(4)* DLRussia (-2) + C(5)*DLItaly(-1) + C(6)* DLItaly (-2) + C(7)*DLGreece(-1) + C(8)* DLGreece (-2) + C(9)

DLRussia = C(10)* DLTurkey (-1) + C(11)* DLTurkey (-2) + C(12)* DLRussia (-1) + C(13)* DLRussia (-2) + C(14)* DLItaly (-1) + C(15)* DLItaly (-2) + C(16)* DLGreece (-1) + C(17)* DLGreece (-2) + C(18)

DLItaly = C(19)* DLTurkey (-1) + C(20)* DLTurkey (-2) + C(21)* DLRussia (-1) + C(22)* DLRussia (-2) + C(23)* DLItaly (-1) + C(24)* DLItaly (-2) + C(25)* DLGreece (-1) + C(26)* DLGreece (-2) + C(27)

DLGreece = C(28)* DLTurkey (-1) + C(29)* DLTurkey (-2) + C(30)* DLRussia (-1) + C(31)* DLRussia (-2) + C(32)* DLItaly (-1) + C(33)* DLItaly (-2) + C(34)* DLGreece (-1) + C(35)* DLGreece (-2) + C(36)

Besides, the results of the tests done to examine the unit root problem analysis of the VAR analysis are given below.

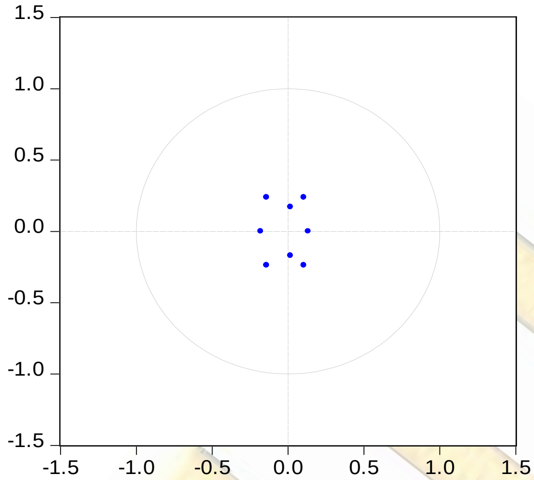

Figure 3. Unit Root Analysis in The VAR Model

As can be seen from Figure 3, all points are located in the circle. Therefore, it can be said that there is no unit root problem in the model. Also, the Ljung-Box Q statistical test was used to examine the problem of autocorrelation in the model. The test result is given in the table below.

According to the results of the analysis, both normal and standardized Q statistics are not significant (Prob. > 0.05). Accordingly, it can be said that there is no autocorrelation problem in the model and that the model is consistent.

Table 7. Portmanteau Test

Lags	Q-Stat	Prob.	Adj Q-Stat	Prob.	df
1	7.299272	0.9671	7.302804	0.9670	16
2	12.07025	0.9995	12.07840	0.9995	32
3	26.98081	0.9939	27.01063	0.9938	48
4	70.55495	0.2679	70.66921	0.2648	64
5	97.90097	0.0848	98.08150	0.0829	80
6	114.4513	0.0964	114.6800	0.0939	96
7	129.2557	0.1266	129.5347	0.1231	112
8	146.6888	0.1237	147.0355	0.1197	128
9	167.4293	0.0884	167.8667	0.0847	144
10	176.1889	0.1806	176.6688	0.1741	160
11	188.1200	0.2524	188.6637	0.2436	176
12	227.5955	0.0402	228.3696	0.0372	192

On the other hand, the presence of structural breaks in the time series causes serious problems in the analysis. For this case, the CUSUM test was applied and the results are given below.

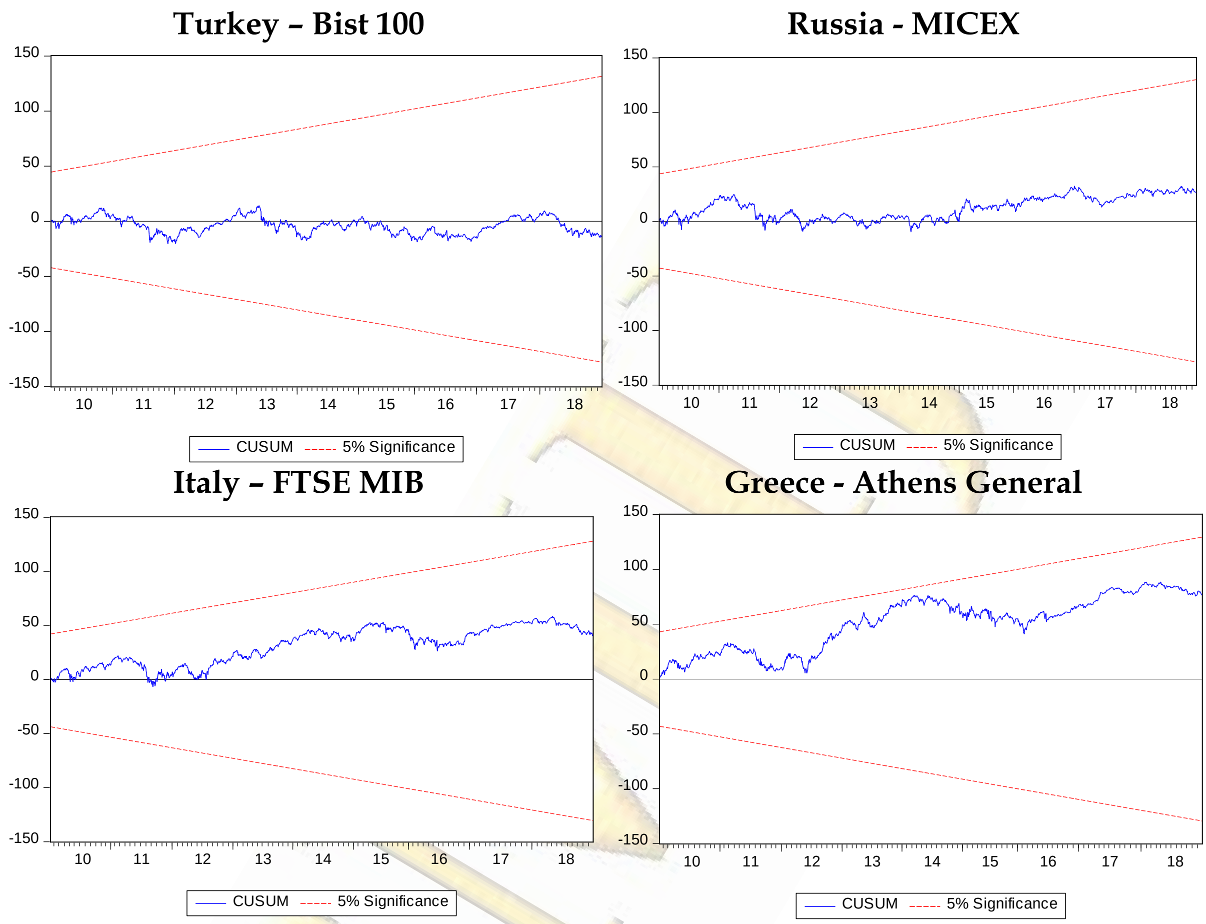

Figure 4. CUSUM Test Results

As can be seen from the above results, all series are within the limits within the determined time. Therefore, it can be said that "models are significant". As a result of the pre-tests, it was determined that multivariate ARCH / GARCH analysis results will be consistent. Therefore, VAR-MGARCH (1,1) -Diagonal VECH modelling was performed to examine the volatility spillover effects among the 4 stock market indices. With the analysis made, volatility spillover between exchanges between 2010-2018 was tried to be examined. The results obtained are given in Table 8.

Table 8. VAR-MGARCH (1,1) Diagonal VECH Analysis Results

	Transformed Variance Coefficients			
	Coefficient	**Std. Error**	**z-Statistic**	**Prob.**
M(1,1)	7.99E-06	1.61E-06	4.971242	0.0000
M(1,2)	8.50E-07	2.51E-07	3.384805	0.0007
M(1,3)	7.68E-07	2.83E-07	2.716533	0.0066
M(1,4)	1.63E-06	6.45E-07	2.535029	0.0112
M(2,2)	3.77E-06	6.49E-07	5.807802	0.0000
M(2,3)	1.10E-06	2.67E-07	4.122252	0.0000
M(2,4)	1.54E-06	6.03E-07	2.553862	0.0107
M(3,3)	5.39E-06	9.83E-07	5.482570	0.0000
M(3,4)	4.36E-06	9.89E-07	4.405714	0.0000
M(4,4)	1.42E-05	2.52E-06	5.625225	0.0000
A1(1,1)	0.044319	0.005034	8.803799	0.0000
A1(1,2)	0.024884	0.004283	5.810441	0.0000
A1(1,3)	0.028566	0.004000	7.141449	0.0000
A1(1,4)	0.028138	0.007065	3.982896	0.0001
A1(2,2)	0.043890	0.005851	7.500833	0.0000
A1(2,3)	0.024559	0.003890	6.312809	0.0000
A1(2,4)	0.029295	0.007420	3.948184	0.0001
A1(3,3)	0.055210	0.005270	10.47629	0.0000
A1(3,4)	0.040851	0.005465	7.475154	0.0000
A1(4,4)	0.098725	0.010273	9.610141	0.0000
B1(1,1)	0.918253	0.010671	86.05102	0.0000
B1(1,2)	0.957315	0.006558	145.9834	0.0000
B1(1,3)	0.956961	0.005518	173.4296	0.0000
B1(1,4)	0.940244	0.013184	71.31726	0.0000
B1(2,2)	0.930571	0.008827	105.4182	0.0000
B1(2,3)	0.958376	0.005075	188.8294	0.0000
B1(2,4)	0.939115	0.014556	64.51834	0.0000
B1(3,3)	0.922112	0.007687	119.9537	0.0000
B1(3,4)	0.921301	0.011242	81.95315	0.0000
B1(4,4)	0.874221	0.012494	69.97371	0.0000

Note: M: Constants, A: ARCH effects B: GARCH effects
where (1): Turkey; (2): Russia; (3): Italy; (4): Greece
The conditional variances were examined and all values were found to be positive.

According to the multivariate GARCH analysis results, the ARCH and GARCH effects on markets themselves and other markets are calculated. Accordingly, the crosswise and their own lags ARCH and GARCH effects of all indices were found significant. From these results, the presence of heat wave (Own ARCH, GARCH effect) and meteor shower effects (cross-market ARCH, GARCH effect) were determined in the markets. According to all these results, A(1,1), A(2,2), A(3,3) and A(4,4) represents the ARCH effect, while B(1,1), B(2,2), B(3,3) and B(4,4) represents the GARCH effect in equity markets' own lags. Therefore, the heat wave hypothesis is examined with these coefficients. Other A and B represent the results of crossover volatility effects. In other words, the meteor shower effect can be examined with other A and B coefficients. In light of all this information, the table showing the volatility spillover status prepared with the data in Table 9 is given below.

Table 9. Volatility Spillover Effects

		ARCH effects	GARHC effects
Heat Wave	Own past of Bist 100	0.044319**	0.918253**
	Own past of MICEX	0.043890**	0.930570**
	Own past of FTSE MIB	0.055209**	0.922111**
	Own past of Athens General	0.098724**	0.874221**
Meteor Shower	Between BIST 100 and MICEX	0.024884**	0.957315**
	Between BIST 100 and FTSE MIB	0.028566**	0.956961**
	Between BIST 100 and Athens General	0.028138**	0.940243**
	Between MICEX and FTSE MIB	0.024558**	0.958376**
	Between MICEX and Athens General	0.029295**	0.939115**
	Between FTSE MIB and Athens General	0.040850**	0.921301**

* $p < 0.05$ and ** $p < 0.01$

ARCH coefficients allow measuring the effect of volatility in series at a certain level. A lot of parameters are required to capture high levels of ARCH coefficients. In this context, GARCH parameter can easily catch the high level of ARCH effect (Asteriou and Hall, 2011: 301). Accordingly, the ARCH effects are given in the table express the short-term volatility spillover effects, whereas the GARCH effects indicate the long-term volatility spillover effects. First, the volatility spillover effect of the markets' own lags (Heat Wave) is examined and the result has been reached that Greece (0.098724) is the country that is most affected in the short term. This is followed by Italy (0.055209), Turkey (0.044319) and Russia (0.043890). However, when this investigation was done with GARCH model, which measures longer-lasting effect, ranking changed as Russia (0.930570), Italy (0.922111), Turkey (0.918253) and Greece (0.874221). These results show that the heat wave hypothesis, which is one of the volatility spillover effects, is valid.

Secondly, the crossover effect of volatility in the markets on other markets (meteor shower hypothesis) was examined. Accordingly, the cross-volatility distribution among the markets is first examined by ARCH method. Among them, the highest cross-interaction takes place between Italy and Greece (0.040850). This is followed by the relationship between Russia and Greece (0.029295). Italy (0.028566) is the country with the highest interaction with Turkey. This is followed by the markets of Greece (0.028138) and Russia (0.024884). When this situation is analysed with the GARCH model in which the longer-term volatility spillover effect is examined, it is seen that the highest relationship between the markets is between Russia and Italy markets (0.958376). That is followed by relationships between markets of Turkey and Russia (0.957315), Turkey and Italy (0.956961) and Turkey with Greece (0.940243). Then comes the relationship between Greece and Russia (0.939115). Lastly, the relationship between Italy and Greece (0.921301) comes. According to all this information, it is seen that among the mentioned markets the meteor shower effect is one of the volatility spillover effects.

Besides, it is seen that the heat wave effect is more effective in a short time while the meteor shower becomes more effective in a long time. In light of all this information, the effects of ARCH and GARCH between the equity markets are summarized with the following formulas.

Volatility Spillover Effects with ARCH

- BIST 100 = Own lags, Italy, Greece, Russia
- MICEX = Own lags, Greece, Turkey, Italy
- FTSE MIB = Own lags, Greece, Turkey, Russia
- Athens General = Own lags, Italy, Russia, Turkey

Volatility Spillover Effects with GARCH

- BIST 100 = Russia, Italy, Greece, Own lags
- MICEX = Italy, Turkey, Greece, its own lags
- FTSE MIB = Italy, Turkey, its own lags, Greece
- Athens General = Turkey, Russia, Italy, its own lags

The index examined on the left side of the equation and the countries affecting the Index on the right side are given respectively.

4. CONCLUSION

In this study, the interactions between Turkey, Italy, Russia and Greece equity markets, which are close together in terms of geographic and economic relations, was examined in the context of the Volatility Spillover hypothesis. Accordingly, the last prices of the main stock exchange indexes of 4 countries were taken as a basis. Taking into consideration the negative effects of the 2008 global crisis on the stock markets and economies the dates of 01.01.2010-31.12.2018 were chosen as the working period.

VAR-MGARCH (1,1) Diagonal VECH method was applied to reveal the volatility spillover effect between indices. According to the findings, volatility spillover effects are observed among the equity markets of the countries. In terms of volatility spillover, the biggest interaction appears to be between MICEX and FTSE MIB indices. BIST 100 index is affected by respectively MICEX, FTSE MIB and Athens General indices. The fact that all four country indices have volatility spillover effect on each other supports to exist of the "meteor shower" hypothesis. Also, this result, Aggarwal and Park (1993), Pena (1992), Miyakoshi (2003), Dimitriou et al. (2011) has similar findings with studies demonstrating that volatility spillover effect among the markets in the countries they study.

Besides, research findings show that both meteor shower and heat wave hypotheses are effective in all markets. Accordingly, it can be said that all markets should be followed while making investments. It is determined that the market most affected by external volatility changes is the Greek stock exchange. This situation can be said to stem from the weak Greek economy in the recent period.

It is seen that the market that most affects all exchanges is the Russian market. Therefore, the Russian market can be used as a leading indicator for investment. Also, in terms of Volatility spillover, heat wave effect is more effective in Russia, while in other countries the meteor shower is more effective. This study can be used as a guide for investors in their investments. However, this subject can be studied for different markets other than the stock market.

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