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SPILLOVER EFFECTS AMONG SHARE PRICES IN THE ATHENS' STOCK EXCHANGE

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Abstract

The aim of this paper is to investigate the spillover effects among shares in the Athens Stock Exchange. The data sample covers the period between 2001 and 2006 and is of daily frequency. The econometric part of the analysis is based on the VAR (q) - BEKK GARCH (1,1) framework in order to capture the dynamics of the spillover effects between share prices after eliminating the returns interdependence. According to the empirical results of our analysis, there exist significant spillover effects between share prices. Hence, the examined share prices seem to share an interactive structure on their volatilities, which might be potentially useful for effective risk management and/or profitable asset allocation. JEL Classifications: G11 – Portfolio Choice; Investment Decisions.

Keywords: Spillover effects, Share returns, Diffusion of volatility and portfolio risk management.

1. Introduction

Volatility, as measured by the time varying variance of financial products' returns, is one of the most interesting issues for both econometricians and financial analysts, especially during the last decade, which is characterized by a complex structure of interdependencies between financial markets and financial products.

The majority of the empirical studies concern the dynamic spillover effects between international stock exchanges rather than within financial products of the same financial market and consequently the analysis on a domestic level might shed much light on the specific characteristics of the examined financial exchange.

The investigation of the relationships of returns and volatilities between financial products might be either unidirectional or bidirectional, increasing thus, the structure of interdependences of financial products.

2. Literature review

Many researchers who examine the relationship between financial markets worldwide have applied the Cointegration Analysis. *Makridakis and Wheelwright (1974)*, and *Kaplanis (1988)*, have found evidence of time varying characteristics of the cross-correlations between international stock exchange indices. *Constantinou, Kazandjian, Kouretas and Tahmazian (2008)* applied the cointegration analysis in order to investigate the profitability which stems from portfolio diversification of the shares of sector-based indices in the Cyprus Stock Exchange. According to their empirical findings, there exist a profitably investment path, when considering shares of cointegrated indices. *Arshanapalli and Doukas (1993)* examined the impact of the October 1987 financial crises in the cointegration analysis of several financial markets. Before the crises the relationship between US and UK, France and German was not significant, while for the post crises period the linkages between these markets are significant.

Kroner and Ng (1998) based on multivariate GARCH models which embed the leverage effect coefficient, examined the spillover effects among shares of different size. *Kutan and Li (2002)* investigated the spillover effects, in a domestic framework, using data from five market sectors in Shanghai. Based on daily data from 1999 to 2001 they applied asymmetric GARCH models and according to their empirical results the sectors of trade and industry spillover to the remaining sectors.

The investigation of the spillover effects among financial products has attracted the interest of many researchers who apply either univariate or multivariate GARCH models. *Hamao et al. (1990)* examined the spillover effects among the US, UK and Tokyo stock markets using the multivariate GARCH framework. They considered the 1987 financial crises and found that in the post crises period there were spillovers from US to UK and Tokyo and from UK to Tokyo, in contrast to the post crises period. *Bala and Premaratne (2004)* applied the multivariate GARCH framework studied the covariances between the Singapore market and the markets of America, England, Hong Kong, and Japan. For this purpose they used univariate and multivariate GARCH models in combination with VAR models. The empirical examination showed that a high cross-correlation of markets exists at the level of volatility, particularly between Singapore and the remaining major markets. *Longin and Solnik (1995)*, applied the *Bollerslev's (1990)* CCC model in order to investigate the spillover effects among the stock exchange markets of America, France, Switzerland, Japan, and England, during the period of 1960 to 1990. According to their empirical results there is evidence that the US financial market volatility has a leading role in the spillover effects of the financial system, especially during periods of high volatility. *Karolyi (1995)* applied the BEKK GARCH model using data from Canadian (TSE 300) and US (S&P 500) financial markets in order to investigate the spillover effects between them. According to his empirical results there exist significant spillover effects between the aforementioned markets. *Kearney and Potì (2006)* applied the DCC GARCH model using data from six stock exchange indices and closing prices of forty-two shares from the Dow Jones and Eurostoxx50 indices. According to their empirical results there exist significant spillover effects which are driving the financial system in a dynamic structure of both volatilities and correlations. *Kanas (1998)* investigated the spillover effects among three major European markets during the period from 1984 to 1993 with reference time point the 1987 financial crises. Based on the EGARCH model in order to capture the asymmetric response of volatility due to the returns' information, they found that the UK financial market has a leading role in the formulation of the interdependencies structures, the post crises period is characterized by higher correlations and finally the leverage effect is statistical significant.

It is obvious that according to the literature the investigation of the spillover effects among and/or within financial markets is based mainly on GARCH models. The objective of this paper is to investigate the spillover effects among selected shares of the Athens Stock Exchange in order to improve the efficient portfolio risk management.

3. Data

In order to investigate the dynamics of the relationship between financial products we use data from the Athens Stock Exchange (henceforth ASE). More specifically we use a representative sample of twenty shares that are negotiated in the ASE and compose the FTSE/ASE-20 index. Furthermore, we use the GI index of the ASE as a proxy of the current level of the financial system. The FTSE/ASE-20 index is the highest capitalisation index in ASE and contains the major twenty (blue chips) quoted companies, with respect to capital, marketability and dissemination of free float. The criteria used for indexing shares on the FTSE/ASE-20 are the capitalization, the marketability and the heterogeneity at sector levels. In order to avoid the homogeneity which is apparent within sectors (it is expected that shares of the same sector will interact and have a common tendency over time) we use eight shares which are representative of each sector. The sample under examination covers the period from 12/12/2001 to 06/11/2006, which is following the high volatile period of 1999 and the stock exchange crisis of 2000-2001.

The data frequency is daily and correspond to the closing prices of the General Index and the eight representative shares. They were drawn from the Bloomberg database and amount to 1,220 observations in total[1]. Consequently, we remain with a representative sample of eight shares that are presented in the table below:

TABLE 1

The final sample of shares

Company Name	Share Code	Sector – Sub-sector	% of weight	Monetary Value	% of partici-pation	Date of Entry
NATIONAL BANK OF GREECE S.A.	ETE	Banks – Banks	100	17,222,672,40176	22.4	22/2/1905
HELLENIC TELECOM ORG.	HTO	Telecommunications – Fixed Line Communications	75	10,195,128,091.20	9.9	19/4/1996
GREEK ORGANIZATION OF FOOTBALL PROGNOSTICS S.A.	OPAP	Travel and Leisure – Gambling	75	9,174,440,000.00	8.88	25/4/2001
COCA-COLA E.E.E. S.A.	EEEK	Food and Beverage – Refreshments	40	6,137,646,051.00	3.27	15/7/1991
TITAN CEMENT COMPANY S.A.	TITK, TITP	Construction and Materials - Building Materials and Parts	75	3,055,094,327.20	3.14	22/2/1912
PUBLIC POWER CORPORATION S.A.	PPC	Utilities- Conventional Electricity	50	4,640,000,000.00	3.08	12/12/2001
HELLENIC PETROLEUM S.A.	ELPE	Oil & Gas – Integrated Oil & Gas	40	3,178,471,348.00	1.63	30/6/1998
VIOHALKO HELLENIC COPPER AND ALUMINIUM INDUSTRY S.A.	BIOX	Industrial Goods and Services - Diversifie Industries	50	1,847,130,082.66	1.2	11/12/1947

4. Research methodology & econometric analysis

According to the literature review the investigation of the interdependencies between financial products is based either on Cointegration or GARCH models, in order to account for the long term relationship and the spillover effects among financial products, respectively.

For the purposes of our analysis we incorporate both the Cointegration and the GARCH framework (Bivariate VAR-BEKK-GARCH) in order to examine the returns' correlations as well as the time varying volatility matrices of the financial products under examination. The BEKK model is based on the volatility specification of *Bollerslev (1986)* and *Baba, et al (1990)*.

The mathematical formulation of the autoregressive model VAR(q) and the BEKK-GARCH are given below:

$$R_{it} = \alpha_{0i} + \sum_{j=1}^{n} \alpha_{ij} R_{j,t-1} + \varepsilon_{it}$$

$$[\varepsilon_{it}] | \Omega_{t-1} \approx N(0, H_t) \tag{1}$$

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

$$H_t = C_0' C_0 + \begin{bmatrix} \alpha_{11} & \alpha_{12} \\ \alpha_{21} & \alpha_{22} \end{bmatrix}' \begin{bmatrix} \varepsilon_{1,t-1}^2 & \varepsilon_{1,t-1}, \varepsilon_{2,t-1} \\ \varepsilon_{1,t-1}, \varepsilon_{2,t-1} & \varepsilon_{2,t-1}^2 \end{bmatrix} \begin{bmatrix} \alpha_{11} & \alpha_{12} \\ \alpha_{21} & \alpha_{22} \end{bmatrix} + \begin{bmatrix} \beta_{11} & \beta_{12} \\ \beta_{21} & \beta_{22} \end{bmatrix}' H_{t-1} \begin{bmatrix} \beta_{11} & \beta_{12} \\ \beta_{21} & \beta_{22} \end{bmatrix}$$

According to the BEKK specification the volatility is determined by the squared innovations of the VAR models and the lagged volatility.

Econometric analysis was conducted and estimates were made with the use of two econometric programs: EVIEWS 3.1 and WINRATS 6.0. Finally, it is important to note that the chronological lines of closing share prices have not been «corrected» regarding factors that can considerably influence the price of a share, much like the various corporate practices of dividends, stock split, bonus share, etc., factors that can lead to biased results.

Before we adopt the VAR(q)-[BEKK] GARCH(1,1) method, we must first determine the order of the VAR model. The vector autoregressive models (VAR) are models widely used for the analysis of dynamic effects of accidental disturbances in a system of variables. Based on these models, we are able to answer questions with regard to the direction of causality of variables, effect of change in a variable on the remainder over time, etc. For the majority of variables, as in our case, a VAR model constitutes a system of equations for which each one of the shares is determined as dependent upon the previous prices of all remaining shares in the system. Thus one VAR model per two shares will have the form:

$$\begin{bmatrix} R_{1t} \\ R_{2t} \end{bmatrix} = C + \begin{bmatrix} G_{11} & G_{12} \\ G_{21} & G_{22} \end{bmatrix} \begin{bmatrix} R_{1t\ 1} \\ R_{2t-1} \end{bmatrix} + \begin{bmatrix} \varepsilon_{1t} \\ \varepsilon_{2t} \end{bmatrix} \quad (3)$$

Where $\begin{bmatrix} \varepsilon_{1t} \\ \varepsilon_{2t} \end{bmatrix} \Big| \Omega_{t-1}$

This model offers an initially simple analysis of interactions of two shares, at the level of returns. The data of matrix G constitutes estimates that show the interactions between the shares at the level of returns and expresses that the current returns of a share can be used in order to forecast future returns for some other share or the share itself. Specifically, in order to verify the hypothesis that the return of share 1 does not have a causal effect on share 2, we examine the null hypothesis:

Ho: $G_{21}=0$ against the alternative

H1: G_{21} 0

In order to verify the hypothesis that share 2 does not have a causal effect on share 1, we examine the null hypothesis:

Ho: $G_{12}=[o]$ against the alternative

Ho: G_{12} 0

These hypotheses can be verified based on the classic F statistics and the model can be estimated with the OLS method for each equation separately, assuming that there exists an interaction effect between their errors. Then, we examine the stationarity of the system by application of the ADF test. In order to determine the number of time lags, we apply either the AIC or the SIC or the likelihood ratio statistics, as shown on Table 2[2]:

TABLE 2

Choice of Time Lag VAR Model			
	VAR(1)	VAR(2)	VAR(3)
Log Likelihood	-17916.01	-17865.63	-17809.98
Akaike Information Criteria	29.53697	29.58362	29.62167
Schwarz Criteria	29.83874	30.15401	30.46104

Our next step is the estimate of the bivariate model BEKK GARCH (1,1) in which the bivariate VAR is incorporated, so that we may examine the interactions of shares at the level of volatility and furthermore, at the level of returns. We are thereby lead to a specialization VAR(1)-[BEKK] GARCH(1,1) model. This model allows for the calculation of temporally altered variances and covariances, and can locate which share variances have statistically significant effects on other share variances, interactions which cannot be incorporated from the simple methodologies as is the case of cointegration theory as well as the investigation of relations of causality via the granger causality test.

The estimation of the VAR(1)-[BEKK] GARCH(1,1) is a stepwise procedure, according to which initially we formulate the mean equations:

$$R_{1,t} = A_0 + G_{11}R_{1,t-1} + G_{12}R_{2,t-1} + e_{1,t}$$
$$R_{2,t} = B_0 + G_{22}R_{2,t-1} + G_{21}R_{1,t-1} + e_{2,t}$$
$$\begin{bmatrix} e_{1,t} \\ e_{2,t} \end{bmatrix} \Big| \Omega_{t-1} \approx N(0, H_t) \qquad (4)$$

We then suppose that the matrix of variances and covariances depends on the errors of the previous period and on the variance of the previous time period for each share. The mathematical table of variances is given from:

$$H_t = C_0'C_0 + A'\varepsilon_{t-1}\varepsilon_{t-1}'A + B'H_{t-1}B \qquad (5)$$

Where Ht is the (n x n) relational table of variances-covariances in per year t, with cross data $h_{i,t}$ and non-cross $h_{ij,t}$. Co is a (n x 1) vector parameter, and A and B is (n x n) tables of estimated parameters. Therefore the following is in effect:

$$\begin{bmatrix} H_{11t} & H_{12t} \\ H_{21t} & H_{22t} \end{bmatrix} = C_0'C_0 + \begin{bmatrix} \alpha_{11} & \alpha_{12} \\ \alpha_{21} & \alpha_{22} \end{bmatrix}' \begin{bmatrix} \varepsilon_{1,t-1}^2 & \varepsilon_{1,t-1}, \varepsilon_{2,t-1} \\ \varepsilon_{1,t-1}, \varepsilon_{2,t-1} & \varepsilon_{2,t-1}^2 \end{bmatrix} \begin{bmatrix} \alpha_{11} & \alpha_{12} \\ \alpha_{21} & \alpha_{22} \end{bmatrix} + \begin{bmatrix} \beta_{11} & \beta_{12} \\ \beta_{21} & \beta_{22} \end{bmatrix}' H_{t-1} \begin{bmatrix} \beta_{11} & \beta_{12} \\ \beta_{21} & \beta_{22} \end{bmatrix}$$

The above mathematical expression is developed in the following equations of variances and covariances:

$$\begin{aligned} \mathbf{h}_{11,t} &= \mathbf{c}_{11}^2 + \alpha_{11}(\alpha_{11}\varepsilon_{1,t-1}^2 + \alpha_{21}\varepsilon_{1,t-1}\varepsilon_{2,t-1}) + \alpha_{21}(\alpha_{11}\varepsilon_{1,t-1}\varepsilon_{2,t-1} + \alpha_{21}\varepsilon_{2,t-1}^2) \\ &+ \beta_{11}(\beta_{11}\mathbf{h}_{11,t-1} + \beta_{21}\mathbf{h}_{21,t-1}) + \beta_{21}(\beta_{11}\mathbf{h}_{12,t-1} + \beta_{21}\mathbf{h}_{22,t-1}) \end{aligned}$$

$$\begin{aligned} \mathbf{h}_{12,t} &= \mathbf{c}_{11}\mathbf{c}_{21} + \alpha_{12}(\alpha_{11}\varepsilon_{1,t-1}^2 + \alpha_{21}\varepsilon_{1,t-1}\varepsilon_{2,t-1}) + \alpha_{22}(\alpha_{11}\varepsilon_{1,t-1}\varepsilon_{2,t-1} + \alpha_{21}\varepsilon_{2,t-1}^2) \\ &+ \beta_{12}(\beta_{11}\mathbf{h}_{11,t-1} + \beta_{21}\mathbf{h}_{21,t-1} + \beta_{22}(\beta_{11}\mathbf{h}_{12,t-1} + \beta_{21}\mathbf{h}_{22,t-1}) \end{aligned} \tag{6}$$

$$\begin{aligned} \mathbf{h}_{22,t} &= \mathbf{c}_{21}^2 + \mathbf{c}_{22}^2 + \alpha_{12}(\alpha_{12}\varepsilon_{1,t-1}^2 + \alpha_{22}\varepsilon_{1,t-1}\varepsilon_{2,t-1}) + \alpha_{22}(\alpha_{12}\varepsilon_{1,t-1}\varepsilon_{2,t-1} + \alpha_{22}\varepsilon_{2,t-1}^2) \\ &+ \beta_{12}(\beta_{11}\mathbf{h}_{11,t-1} + \beta_{21}\mathbf{h}_{21,t-1}) + \beta_{22}(\beta_{12}\mathbf{h}_{12,t-1} + \beta_{22}\mathbf{h}_{22,t-1}) \end{aligned} \tag{7}$$

$$h_{12,t} = h_{21,t} \tag{8}$$

With the aid of the above equations, we can establish the diffusions at the level of volatility with the estimate of a bivariate model, with a variable for each pair of shares. We then take into consideration twenty-eight estimates of the model as they result in twenty-eight pairs of shares based on the n(n-1)/2 type. In accordance with the equations, the modeling of dynamic process in the table of variances-covariances takes the form of one linear function of its own past prices as well as past prices of square errors $\varepsilon^2_{1,t-1}$ and $\varepsilon^2_{2,t-1}$, allowing for the joint effect not just with regard to past variances of a share but also with regard to dynamic interactions presented in the variances between shares.

With regard to the estimates of the aforementioned equations, the terms of the symmetrical matrix $c_{11}c_{21}c_{22}$ are the constant parameters of the model, the terms $\alpha_{21}\alpha_{12}$ of the symmetrical matrix A measures the interactions and specifically the effect of new information from a share in variance of another share, while the data $\alpha_{11}\alpha_{22}$ measures the effectual degree of new information from a share on the variance of the same share. Finally, the data $\beta_{12}\beta_{21}$ of matrix B constitutes one measure of »volatility persistence» duration between two shares, while the data $\beta_{11}\beta_{22}$ measures the effect of variance persistence of the previous period's share with the same share.

Furthermore, the spillover effects from one share to another, are found by the parameters a_{12} and α_{21}. It is for this reason that we are mainly interested in the influence of square errors $\varepsilon^2_{1,t\text{-}1}$ and $\varepsilon^2_{2,t\text{-}1}$ above in variances $h_{11,t}$ and $h_{22,t}$. These errors can be translated as a shock from new information that enters the market and influences the volatility of shares. More specifically, considering that the variance of share 1 $h_{11,t}$ is and the variance of another share 2 is $h_{22,t}$, we can establish that the influence of share 2 on share 1 is given by the estimate of its factor $\varepsilon^2_{2,t\text{-}1}$, which is a_{21}. Similarly, the influence of share 1 on share 2 is proportionally given by the estimate of its factor $\varepsilon^2_{1,t\text{-}1}$, which is a_{12}. The following Table demonstrates the channels via which the diffusion of volatility is developed.

TABLE 3

Channels of Diffusion of Volatility

1	$\varepsilon^2_{2t-2} \xrightarrow{a^2_{21}\neq 0} h_{11t-1}$
2	$\varepsilon^2_{2t-2} \xrightarrow{a^2_{22}\neq 0} h_{22t-1} \xrightarrow{b^2_{21}\neq 0} h_{11t}$
3	$\varepsilon^2_{2t-2} \xrightarrow{a_{21},a_{22}\neq 0} h_{12t-1} \xrightarrow{b_{11},b_{21}\neq 0} h_{11t}$
4	$\varepsilon^2_{2t-2} \xrightarrow{a_{21},a_{22}\neq 0} h_{21t-1} \xrightarrow{b_{11},b_{21}\neq 0} h_{11t}$
5	$\varepsilon^2_{1t-2} \xrightarrow{a^2_{12}\neq 0} h_{22t-1}$
6	$\varepsilon^2_{1t-2} \xrightarrow{a^2_{11}\neq 0} h_{11t-1} \xrightarrow{b^2_{12}\neq 0} h_{22t}$
7	$\varepsilon^2_{1t-2} \xrightarrow{a_{12},a_{11}\neq 0} h_{12t-1} \xrightarrow{b_{22},b_{12}\neq 0} h_{22t}$
8	$\varepsilon^2_{1t-2} \xrightarrow{a_{12},a_{11}\neq 0} h_{21t-1} \xrightarrow{b_{22},b_{12}\neq 0} h_{22t}$

Source: Holmes and Pentecost (2006) p. 25.

The applied econometric analysis examines the covariances between the variances and thus it is possible to check the null hypothesis of the existence of spillover effects of volatility in either direction. Consequently, the basic hypotheses that will be examined are:

<u>For the mean equations from VAR(1) model:</u>

H_0: $G_{12}=0$ (no effect exists at the level of returns from share 2 to share 1)

H_1: $G_{12} \neq 0$ (an effect exists at the level of returns from share 2 to share 1)

H_0: $G_{21}=0$ (no effect exists at the level of returns from share 1 to share 2)

H_1: $G_{21} \neq 0$ (an effect exists at the level of returns from share 1 to share 2)

For the equations of variances and covariances:

H_0: $\alpha_{12}=\alpha_{21}=\beta_{12}=\beta_{21}=0$ (no diffusion of volatility exists between shares)

H_1: at least a factor of $\neq 0$ (diffusion of volatility exists between shares)

The above hypotheses simply indicate the existence of no diffusion of volatility.

However, in order to recognize the nature of volatility and the directions of causality between shares, we need to also examine the following hypotheses:

H_0: $\alpha_{12}=\beta_{12}=0$ (no diffusion of volatility exists from share 1 to share 2)

H_1: $\alpha_{12}\neq 0$ or H_1: $\beta_{12}\neq 0$ (diffusion of volatility exists from share 1 to share 2)

H_0: $\alpha_{21}=\beta_{21}=0$ (no diffusion of volatility exists from share 2 to share 1)

H_1: $\alpha_{21}\neq 0$ or H_1: $\beta_{21}\neq 0$ (diffusion of volatility exists from share 2 to share 1)

The model estimate is made with the maximum likelihood method, while the estimates are received via the BFGS non-linear algorithms of optimization. Επιτήρηση

$$l_t(\theta) = \log(2\pi) - \log|\mathbf{H}_t| - \frac{1}{2}\varepsilon_t'\mathbf{H}_t^{-1}\varepsilon_t$$

5. Empirical results

In this section we present the estimates of the VAR(1)-BEKK GARCH(1,1) model. The estimate of the model is made possible through the use of the econometric software WinRats 6.0.[3]. The following tables critically present the estimate results for every pair of shares and the parameters that are considered statistically significant at a 5% level of significance. Through these estimates it is shown whether diffusions of variability exist amongst the sample shares under examination. The estimates are given per pair of shares and each estimate provides us with the possibility to examine not only the one-way form but the form of bi-directional relation as well.

TABLE 4

Interactions HTO with the Remaining Shares

	HTO-ETE	HTO-OPAP	HTO-EEEK	HTO-TITK	HTO-PPC	HTO-ELPE	HTO-BIOX
MEAN EQUATIONS							
G11	0,045	0,057	0,045	0,042	0,047	0,047	0,052
G12	0,021	-0,006	0,09	0,066	0,044	0,006	-0,017
B1	0,510	0,04	0,043	0,052	0,051	0,059	0,041
G22	**0,14***	0,04	**-0,055***	0,055	**0,06***	-0,025	0,039
G21	-0,00	-0,02	0,012	0,011	-0,019	0,028	0,011
B2	0,077	**0,10***	0,057	**0,086***	0,05	0,059	0,024
VARIANCE EQUATIONS AND COVARIANCE EQUATIONS							
c11	0,519	**0,222***	**0,390***	**0,213****	**0,25***	**0,208***	**-0,008**
c12	**0,307***	0,306	**-0,713***	0,034	**0,632***	0,129	-0,254
c22	0,000	0,00	**0,468***	**0,373***	-0,00	**0,458***	**0,477***
a11	**0,849***	**1,011***	**0,897***	**0,975***	**0,983***	**0,974***	**1,023***
a12	**-0,192***	-0,157	**0,107***	0,005	0,00	0,001	**0,784***
a21	**0,12***	**0,379***	**0,140***	-0,003	**-0,095***	0,002	-0,086
a22	**1,000***	**0,98***	**0,752***	**0,908***	**0,084***	**0,919***	**-0,953***
β11	**0,293***	**0,159***	**0,252***	**0,177***	**0,193***	**0,184***	**0,155***
β12	**0,243***	0,019	-0,011	-0,001	0,057	0,024	0,048
β21	**-0,177***	**0,057***	-0,087	0,029	**0,093***	0,002	**-0,08***
β22	0,090	**0,221***	**0,252***	**0,326***	**0,266***	**0,265***	**0,31***
DIAGNOSTIC ERRORS TESTS							
	HTO | ETE	**HTO | OPAP**	**HTO | EEEK**	**HTO | TITK**	**HTO| PPC**	**HTO | ELPE**	**HTO| BIOX**
Log-likelihood	-4596	-4593	-4502	-4397	-4383	-4597	-4916
Q(10)	10.61 | 2.98	11.25 | 10.74	11,36 | 15,60	10.90 | 8,01	10.32 | 14,25	11,31 | 5,78	9,08 | 3,85
$Q^2(10)$	4.68 | 14.76	9.94 | 8.41	4,09 | 1,78	10,09 | 10,92	5,38| 7,99	6,87 | 6,28	13,57 | 4,54
ARCH TEST	(0.91) | (0.13)	(0.53) | (0.61)	(0.93) | (0.99)	(0.65) | (0.30)	(0.87) | (0.61)	(0.76) | (0.80)	(0.34) | (0.92)

PAIR OF SHARES	EXISTENCE OF DIFFUSION OF VOLATILITY	DIRECTION OF DIFFUSION VOLATILITY
HTO-ETE	YES	HTO ←→ETE
HTO-OPAP	YES	HTO←OPAP
HTO-EEEK	YES	HTO←→EEEK
HTO-TITK	NO	--
HTO-PPC	YES	HTO←PPC
HTO-ELPE	NO	--
HTO-BIOX	YES	HTO ←→BIOX

We observe that the estimate of model with share 1, the share of HTO and share 2, the remaining sample shares (a share for each estimate), gives the following results:

- For the mean equations we observe that the effect of share returns on the same share's returns is statistically important for the ETE, EEEK, and PPC shares, a factor that indicates the possible prediction of these share's returns. With regard to the interactions at the level of returns between share HTO and the remaining shares, there is no relationship at a 5% level of statistical importance.

• For the variance and covariance equations, one can at first glance observe that there is a strong interconnection between the HTO share and the ETE, BIOX and EEEK shares. A closer study of estimates leads us to the conclusion that a bi-directional diffusion of volatility exists amongst these shares; that is, the HTO share influences variance of these shares and is also influenced by the other shares. More specifically, a shock to the HTO share negatively influences (-0.192) volatility of the ETE share and the share risk, while at the same time a shock to the ETE share positively influences (+0.12) the volatility and the share risk of the HTO share. Over and above, there is another channel effect via past variances of shares in the current variance. Correspondingly, with regard to the bi-directional interactions of HTO-EEEK and OTE-BIOX shares, we observe that for first pair of shares, there is a positive interaction at the level of volatility that is owed to new information emerging from each share, while for second pair we observe that a shock to the HTO share considerably influences (+0.784) the BIOX share, while the BIOX share has a very slight negative influence (-0.08) on the volatility of the HTO share through the channel of past volatility.

• Regarding the remaining shares, we distinguish two one-directional relationships of effect from the OPAP and the PPC on HTO. In particular, a shock to the OPAP and PPC shares a positive influence (+0.379) and has a very slight negative influence (-0.095) correspondingly, on the volatility of the HTO share.

• Finally, according to the statistical importance of parameters $a_{11}/[b]_{11}$ and $a_{22}/[b]_{22}$, we can say that new information and past volatility concerning sample shares are useful in forecasting the volatility of the next period of shares in which these parameters are statistically important.

• In conclusion, based on the previous results we can say that the volatility of the HTO share depends on the volatility of the share itself as well as ETE, OPAP, EEEK, PPC and BIOX shares.

TABLE 5

Interactions ETE with the Remaining Shares

	ETE-OPAP	ETE-EEEK	ETE-TITK	ETE-PPC	ETE-ELPE	ETE-BIOX
MEAN EQUATIONS						
G11	**0,127***	**0,144***	**0,127***	**0,13***	**0,121***	**0,133***
G12	0,019	-0,059	0.00	-0,003	0,019	-0,031
B1	0,079	0,07	0,06	0,079	**0,089***	0,083
G22	0,059	-0,04	**0,057***	**0,068***	-0,210	0,022
G21	-0,024	0,032	0,004	-0,029	0,009	0,055
B2	**0,106***	0,04	0,08	0,054	0,057	0,027
VARIANCE EQUATIONS AND COVARIANCE EQUATIONS						
c11	**0,454***	0,073	0,25	0,23	**0,369***	**0,296***
c12	-0,053	**0,88***	-0.00	**0,515***	-0,195	-0,496
c22	**0,331***	**0,92***	**0,46***	0,00	**0,666***	-0,445*
a11	**0,928***	**1,03***	**0.98***	**0,964***	**0,940***	**0.88***
a12	0,039	**0,295***	0,07	**0,453***	0,099	-0,051
a21	0,001	**-0.346***	-0,10	**-0,78***	0,012	**0,126***
a22	**0,936***	**-0,12**	**0,83***	**0,53***	**0,812***	**0,906***
β11	**0,274***	**0,136***	0,177	**0,22***	**0,233***	-0,159
β12	-0,054	**-0,319***	-0,10	-0,08	**-0,145***	0,149
β21	0,004	**0,14***	0,16	**0.155***	0,048	0,034
β22	**0,249***	**0,41***	**-0,38***	**0,179 ***	**0,329***	**0,288***
DIAGNOSTIC ERRORS TESTS						
	ETE | OPAP	**ETE | EEEK**	**ETE |TITK**	**ETE | PPC**	**ETE | ELPE**	**ETE | BIOX**
Log-likelihood	-4656	-4539	-4428	-4443	-4636	-4916
Q(10)	3,03 | 10,83	3,14 | 16,18	3,38 | 11,27	3,02 | 16,03	2,82 | 5,83	3,65 | 3,61
$Q^2(10)$	14,08 | 8,58	11,37 | 1,52	14,41 | 10,93	17,23 | 15,01	15,94| 10,76	13,63 | 6,15
ARCH TEST	(0.17) | (0.59)	(0.32) | (0.99)	(0.15) | (0.31)	(0.07) | (0.13)	(0.09) | (0.44)	(0.189) | (0.81)

PAIR OF SHARES	EXISTENCE OF DIFFUSION OF VOLATILITY	DIRECTION OF DIFFUSION OF VOLATILITY
ETE-OPAP	NO	--
ETE-EEEK	YES	ETE ←→EEEK
ETE-TITK	NO	--
ETE-PPC	YES	ETE ←→PPC
ETE-ELPE	NO	ETE→ELPE
ETE – HTO	YES	ETE ←→ HTO
ETE-BIOX	YES	ETE←BIOX

According to the estimate model for the determination of interconnections of action ETE with the remainder action we observe that:

- For the mean equations, the effect of share returns upon the return of the same share is statistically important for the ETE, TITK and PPC shares. With regard to interactions at level of returns between the ETE share and the remaining shares, there is no account of a connection to a 5% level of statistical importance.

• Concerning the variances and covariances equations for the ETE share, three bi-directional relationships exist at the level of volatility amongst the EEEK, PPC and HTO shares[4]. More critically, a shock to share ETE influences the future variance of the above shares that are positively connected, while in contrast, a shock to the EEEK, PPC and HTO shares negatively influence future variance of share ETE. The degree of interaction for ETE with the above shares is significant provided that the channels of diffusion of volatility are based not just on past share shock but also on past volatility influence on current volatility.

• There is also a one-way relationship between shares ETE and ELPE and accordingly the past volatility of share ETE negatively influences (-0.145) share ELPE while a shock to the share BIOX positively influences (+0.126) the future variance of share ETE.

• We thus conclude that the volatility of share ETE is greatly influenced by shock/new information that is concerned with the share itself (after a_{11} 0) but is also influenced by the shares EEEK, PPC, HTO and BIOX, with more intense influence from share PPC.

TABLE 6

Interactions EEEK with the Remaining Shares

	EEEK-OPAP	EEEK-TITK	EEEK-PPC	EEEK-ELPE	EEEK-BIOX
MEAN EQUATIONS					
G11	-0,04	-0,06	-0,01	-0,049	-0,018
G12	0,02	0,37	0,04	0,00	-0,031
B1	0,038	0,016	0,035	0,051	0,043
G22	**0,05***	0,059	**0,061***	-0,012	0,029
G21	-0,02	0,010	**-0,04***	0,015	0,063
B2	**0,09***	**0,079***	0,043	0,05	0,012
VARIANCE EQUATIONS AND COVARIANCE EQUATIONS					
c11	**0.372***	**1,33***	**-0,08***	1,01	0,35
c12	**-0,209***	0,06	**-0,52***	-0,17	-0,295
c22	0,003	-0,15	**0,515***	0,25	**0,33***
a11	**0,909***	-0,306	**0,741***	0,66	**0,934***
a12	**0,59***	0,20	**0,587***	0,15	0,032
a21	**0,164***	0,360	**0,572***	0,07	0,04
a22	**-0,897***	**0,866***	**-0,57***	**0,907***	**0,93***
β11	**0,163***	**-0,331***	**0,146****	0,319	**-0,17***
β12	0,031	-0,051	-0,027	-0,103	0,067
β21	0,019	**0,196***	0,032	-0,011	0,02
β22	**-0,229***	**0,304***	**0,362***	0,248	**0,25***
DIAGNOSTIC ERRORS TESTS					
	EEEK | OPAP	**EEEK | TITK**	**EEEK | PPC**	**EEEK | ELPE**	**EEEK | BIOX**
Log-likelihood	-4530	-4299	-4316	-4540	-4824
Q(10)	16,29 | 10,52	14,52 | 10,08	14,41 | 13,97	13,84 | 5,4	15,11| 3,97
$Q^2(10)$	4,14 | 8,84	1,96 | 11,48	4,17| 13,77	2,20 | 8,95	4,20| 6,28
ARCH TEST	(0.94) | (0.55)	(0.99) | (0.25)	(0.94) | (0.18)	(0.99) | (0.63)	(0.94) | (0.79)

PAIR OF SHARES	EXISTENCE OF DIFFUSION OF VOLATILITY	DIRECTION OF DIFFUSION OF VOLATILITY
EEEK-OPAP	YES	EEEK ←→OPAP
EEEK-TITK	YES	EEEK ←TITK
EEEK-PPC	YES	EEEK ←→PPC
EEEK- ETE	YES	EEEK ←→ ETE
EEEK – HTO	NO	EEEK ←→HTO
EEEK-ELPE	NO	--
EEEK-BIOX	NO	--

- Interactions at the level of returns account for a 5% level of statistical importance from share EEEK to share PPC. That is to say that future mean return for share PPC is negatively influenced (-0.04) by current returns of share EEEK.

- Regarding share EEEK, there are bi-directional relationships of diffusion of volatility with shares ETE, OPAP, PPC and HTO. Specifically, shock to share EEEK positively influences variance of all the above shares and negatively influences variances of share ETE, while shock to shares OPAP, PPC, HTO and ETE positively influence the variance of share EEEK, with the greatest influence of share EEEK is on the PPC share.

• The current variance of share EEEK is positively influenced (+0.196) by past variance of share TITK.

• In conclusion, volatility of share EEEK depends on the shares ETE, OPAP, PPC, TITK and HTO.

In accordance with the estimate of variances and covariances equations:

TABLE 7

Interactions OPAP with the Remaining Shares

	OPAP-TITK	OPAP-PPC	OPAP-ELPE	OPAP-BIOX
MEAN EQUATIONS				
G11	0,043	**0,061**	0,040	0,046
G12	-0,006	-0,061	0,008	-0,010
B1	**0,110***	**0,093***	**0,101***	**0,0957***
G22	**0,059***	0,015	0,011	**0,049***
G21	0,007	0,051	0,017	0,03
B2	0,079	0,046	0,026	0,026
VARIANCE EQUATIONS AND COVARIANCE EQUATIONS				
c11	**0,298***	**0,36***	**0,238****	**0,309***
c12	0,089	0,095	-0,289	0,140
c22	**0,37***	**0,19***	**0,392****	0,232
a11	**0,957***	**0,94***	**0,95***	**0,956***
a12	0,00	-0,02	0,007	-0,019
a21	0,007	-0,009	**0,054***	0,002
a22	**0,906***	**0,971***	**0,92***	**0,976***
β11	**0,228***	**0,255***	**0,225***	**0,226***
β12	0,005	-0,003	-0,024	0,029
β21	-0,030	0,031	-0,049	-0,004
β22	**0,333***	**0,18***	**0,264***	0,188
DIAGNOSTIC ERRORS TESTS				
	OPAP | TITK	**OPAP | PPC**	**OPAP | ELPE**	**OPAP | BIOX**
Log-likelihood	-4396	-4382	-4609	-4956
Q(10)	11,07 | 9,96	10,28 | 14,18	10,48 | 5,73	10,86 | 3,79
$Q^2(10)$	8,75 | 10,75	5,83 | 12,37	7,90| 7,20	8,30 | 9,78
ARCH TEST	(0.58) | (0.32)	(0.83) | (0.29)	(0.66 | (0.72)	(0.62) | (0.51)

(to be continued)

PAIR OF SHARES	EXISTENCE OF DIFFUSION OF VOLATILITY	DIRECTION OF DIFFUSION OF VOLATILITY
OPAP-TITK	NO	--
OPAP-PPC	NO	--
OPAP-HTO	YES	OPAP→HTO
OPAP- ETE	NO	--
OPAP-ELPE	YES	OPAP ←ELPE
OPAP -EEEK	YES	OPAP←→EEEK
OPAP-BIOX	NO	--

• For share OPAP, there is a two-way relationship of diffusion of volatility with share EEEK. For this relationship, which resulted from the above estimate previously mentioned, we simply mention here the core results concerning the interactions of share OPAP with the remaining shares.

• Furthermore, a shock to share ELPE has a slightly positive influence (+0.054) on the variance of OPAP, while a shock to share OPAP positively influences (+0.379) the volatility of share HTO.

• Interactions between shares at the level of returns do not account for a 5% level of statistical importance.

TABLE 8

Interactions TITK with the Remaining Shares

	TITK-PPC	TITK-ELPE	TITK-BIOX
MEAN EQUATIONS			
G11	0,038	0,05	0,048
G12	0,052	-0,005	0,00
B1	0,068	0,063	**0,086***
G22	**-0,064***	-0,00	0,030
G21	**-0,064***	-0,02	0,042
B2	0,057	0,031	0,040
VARIANCE EQUATIONS AND COVARIANCE EQUATIONS			
c11	**0,344***	-0,405	**0,35***
c12	**0,249***	**-0,031***	-0,093
c22	0,000	**0,31***	**-0,161**
a11	**0,921***	**0,88***	**0,903***
a12	0,004	-0,064	**-0,059***
a21	**0,067***	0,042	0,017
a22	**0,963***	**0,963***	**0,989***
β11	**0,346***	**0,339***	**0,34***
β12	0,143	**0,227***	0,11
β21	-0,02	-0,029	-0,03
β22	**-0,165***	**-0,23***	**0,158***
DIAGNOSTIC ERRORS TESTS			
	TITK | PPC	**TITK | ELPE**	**TITK | BIOX**
Log-likelihood	-4187	-4399	-4700
Q(10)	11,51 | 17.06	10,41| 5.56	10,72 | 11.19
$Q^2(10)$	8,93 | 15.63	10.86 | 12,12	4.32 | 12.82
ARCH TEST	(0.50) | (0.13)	(0.31) | (0.34)	(0.29 | (0.29)

PAIR OF SHARES	EXISTENCE OF DIFFUSION OF VOLATILITY	DIRECTION OF DIFFUSION OF VOLATILITY
TITK-PPC	YES	TITK ←PPC
TITK –OPAP	NO	--
TITK- EEEK	YES	TITK→ EEEK
TITK –HTO	NO	--
TITK- ETE	NO	--
TITK-ELPE	YES	TITK →ELPE
TITK-BIOX	YES	TITK →BIOX

In accordance with the estimates, we establish that:

- There is a relationship of interaction at the level of returns according to what returns share TITK negatively influences (-0.064) the returns of the PPC share.

- At the level of volatility with regard to the TITK share, we establish there is no bi-directional relationship of diffusion of volatility. However, one-way relationships are established with shares PPC, EEEK, ELPE and BIOX. More critically, a shock to share TITK negatively influences (-0.059) the volatility of share BIOX, while at the same time a shock to share PPC positively influences (+0.067) the volatility of share TITK. The remaining two relationships occur through the channel of past volatility, i.e. the past volatility of share TITK positively influences (+0.196 and 0.227) the variance of share EEEK and ELPE espectively.

- Furthermore, based on the above results, share TITK is influenced by the share TITK (that is a_{11} 0) itself, as well as by the PPC share, particularly at both the level of returns and at the level of volatility.

TABLE 9

Interaction PPC with the Remaining Shares

	PPC-ELPE	PPC-BIOX
MEAN EQUATIONS		
G11	0,06*	0,070*
G12	-0,03	-0,039*
B1	0,049	0,050
G22	-0,025	0,049**
G21	0,068*	-0,08
B2	0,044	0,040
VARIANCE EQUATIONS AND COVARIANCE EQUATIONS		
c11	0,00	0,410
c12	0,161	0,365*
c22	0,485*	0,208
a11	1,00*	0,925*
a12	0,309*	-0,069
a21	-0,218*	-0,004
a22	0,821*	0,952*
β11	0,252*	0,227
β12	0,184*	0,059
β21	-0,08	0,035
β22	0,225*	0,249*
DIAGNOSTIC ERRORS TESTS		
	PPC | ELPE	PPC | BIOX
Log-likelihood	-4404	-4399
Q(10)	16.38 | 5.02	13.82 | 3.92
Q^2(10)	9.62 | 23.78	10.72 | 6.12
ARCH TEST	(0.45) | (0.06)	(0.39) | (0.81)

PAIR OF SHARES	EXISTENCE OF DIFFUSION OF VOLATILITY	DIRECTION OF DIFFUSION OF VOLATILITY
PPC-ELPE	YES	PPC ←→ELPE
PPC-BIOX	NO	--
PPC –TITK	YES	PPC →TITK
PPC- OPAP	NO	--
PPC- EEEK	YES	PPC ←→ EEEK
PPC- ETE	YES	PPC ←→ ETE
PPC –HTO	YES	PPC→ HTO

TABLE 10

Interactions KLPE with the Remaining Shares

	ELPE-BIOX
MEAN EQUATIONS	
G11	-0,003
G12	0,04
B1	0,043
G22	-0,01
G21	0.00
B2	0,034
VARIANCE EQUATIONS AND COVARIANCE EQUATIONS	
c11	0,304*
c12	0,22*
c22	0.77*
a11	-0,92*
a12	-0,544*
a21	-0,132
a22	0.754*
β11	-0,288*
β12	-0,121*
β21	-0,009
β22	0,331*
DIAGNOSTIC ERRORS TESTS	
	ELPE | BIOX
Log-likelihood	-4916
Q(10)	4.00 | 7.03
Q^2(10	7.35 | 15.92
ARCH TEST	(0.70) | (0.16)

PAIR OF SHARES	EXISTENCE OF DIFFUSION OF VOLATILITY	DIRECTION OF DIFFUSION OF VOLATILITY
ELPE-BIOX	YES	ELPE → BIOX
ELPE –TITK	YES	ELPE ← TITK
ELPE – OPAP	YES	ELPE→ OPAP
ELPE-EEEK	NO	--
ELPE- PPC	YES	ELPE ←→ PPC
ELPE- ETE	NO	ELPE← ETE
ELPE - OHTO	NO	--

- Regarding the PPC share, there is a bi-directional relationship of diffusion volatility with the shares ELPE, EEEK and ETE, that is to say that the PPC share influences the variance of these shares, as well as the PPC share itself. Specifically, a shock to share PPC positively influences (0.309) the volatility of share ELPE, while at the same time a shock to share ELPE negatively influences (-0.218) volatility and the share risk of PPC. Concurrently, the past variance of share PPC positively influences (+0.184) variance of the ELPE share. The two remaining relationships that concern interaction of the PPC share with shares EEEK and ETE that have been described in previous estimates.

- One-directional relationships of causality at the level of volatility are limited between shares PPC-TITK and shares PPC-HTO. These relationships had been observed in previous estimates, thus we had also discovered that a shock to share PPC positively influences (+0.067) variance in share TITK and negatively influences (-0.095) the variance of share HTO. In addition, past variance of share PPC positively influences (0.093) variance of share HTO.

- With regard to the interactions of the PPC share with other shares at the level of returns, we had observed that the EEEK and TITK shares negatively influence the returns of the PPC share, while based on the current estimate we conclude that BIOX also negatively influences (-0.039) the returns of the PPC share, which continues to positively influence (+0.068) returns for share ELPE.

- In conclusion, we can we say that share PPC presents sufficient dynamic interconnections with the remaining shares, whereas it distinguishes its interaction with share ELPE, which exists not just at the level of returns but the level of volatility as well.

- With regard to the ELPE share, there is a bi-directional relationship of diffusion of volatility, in which it became significant in the previous estimate of the interaction of share PPC with the remaining shares.

- One-directional relationships exist, and in turn regard shares BIOX, TITK, OPAP and ETE. The majority of these shares have been described in previous estimates and thus we limit the new estimate of share ELPE-BIOX. In accordance with this limitation we observe that a shock and alteration of past variance to share ELPE negatively influences (-0.544 and -0.121 correspondingly) future volatility of share BIOX.

- At the level of returns between ELPE-BIOX, there is no statistically important relationship for a 5% level of importance. However there is interaction at the level of returns between PPC-ELPE, as we observed in the previous estimate. Specifically, we established that the PPC share positively influences (+0.068) returns for share ELPE.

With regard to share BIOX, we end up with the following table:

TABLE 11

Interaction BIOX with the Remaining Shares

PAIR OF SHARES	EXISTENCE OF DIFFUSION OF VOLATILITY	DIRECTION OF DIFFUSION OF VOLATILITY
BIOX-HTO	YES	BIOX ←→HTO
BIOX-ETE	YES	BIOX →ETE
BIOX-TITK	YES	BIOX ←TITK
BIOX-OPAP	NO	--
BIOX-EEEK	NO	--
BIOX-PPC	NO	
BIOX-ELPE	YES	BIOX ← ELPE

The above relationships concerning share BIOX have been analyzed in previous estimates.

Finally, it is important to note that after the application of the model and each of its estimates concerning a pair of shares for each time, the basic statistical data of errors for the model were also calculated. The results of diagnostic control in the errors show that the model constitutes a sound specialization and form of modeling interactions of shares, as there is a significant reduction of autocorrelation in the errors which now approach the form of normal distribution, while concurrently the arch effects cease to exist.

It is important to report that at the level of share returns, the phenomenon of return effect with time lag, in the return of the same share (G_{11}, G_{22} 0), is presented in twenty of the fifty-six relatively appreciated parameters and is limited only by certain sample shares as observed in the previous analysis. Conversely, the presence of interactions at the level of returns between sample shares (G_{12}, G_{21} 0) is almost non-existent and concerns the interactions of shares PPC-ELPE, PPC-BIOX, PPC-TITK, EEEK-PPC. This result implies that the interactions of the sample shares under examination at the level of returns are minimal and furthermore without particular intensity, implying that the return of each share is benefited by its own dynamic behaviour. An autonomous share at the level of interactions is share PPC, the returns of which as a result affect the returns of shares ELPE, BIOX, TITK and EEEK.

With regard to the estimate of unconditional variances and covariances equations, the results are differentiated as many of the estimates of parameters that quantify the effects of past share shock in the same (a_{11}, a_{22} 0) or in other shares, (a_{12}, a_{21} 0) or the effect of past variance on the volatility of a share in the same share (b_{11}, b_{22} 0) or in other shares (b_{12}, b_{21} 0), are statistically important. Certainly the diffusion of volatility that stems from a share and influences the variance of the same share so intense that in certain cases it is the largest unit, as in the cases of shares HTO, ETE and PPC. This fact implies the presence of possible ARCH effects and the statistical importance of ARCH parameters shows that the diffusion of information / shock takes place fast enough from a direct channel influence of volatility. In contrast, concerning GARCH parameters, the non-statistical importance of many GARCH parameters shows that the phenomenon of volatility persistence is not particularly intense. This means that shock to the volatility of a previous period does not considerably affect future variance; therefore the phenomenon of duration of volatility is not obvious in all share variances. Characteristically, twenty-four and twelve equivalent ARCH and GARCH parameters are statistically important from a total of fifty-six parameters for all shares.

It is also important to note that the spillover effects which originate from the same share are much greater than the spillover effects of volatility concerning the interaction of different shares. Consequently, we may state that future variance of many shares is explained in large part by the diffusion of volatility of the share itself and not so much from its interactions with other shares. The same applies, as seen above, at the level of returns.

The overall results indicate the existence of statistically important relationships and interactions between most of the sample shares. In accordance with these results, the question that someone might ask as to what reasons lies behind these share interactions is justified. For certain pairs of shares, the reasons can be owed to the narrow economic interconnection of enterprises. Characteristically, pairs of shares that we would expect with an ad-hoc analysis to have interactions are shares PPC, TITK, ELPE, BIOX, shares which concern sectors of energy, manufacturing, and industrial products. Certainly econometric analysis indicates pairs of shares with significant interaction for these shares, not just at the level of returns but also at the level of volatility, and more characteristically, the bi-directional relationship between PPC and ELPE, shares that are both related to energy. For the remaining shares, there are statistically important relationships in the form of one-way directions. The remaining four shares (ETE, HTO, EEEK, OPAP) also present interactions, not only with each other but with the remaining shares as well. We should note that for shares ETE, HTO, OPAP, the Greek state possesses a portion of participation in every one of these enterprises, and as the PPC is a public enterprise, it is therefore likely that interconnections between these shares can be owed to the existence of a common shareholder. The fact that all shares represent the largest in capital companies certainly cannot be overlooked and naturally, it is the volatility of a share that affects the volatility of another share within the mechanisms of behaviour and the expectations that shape investors, who are active with regard to blue chip stocks. Generally however, the interconnections of enterprises can be due to various reasons. The economic and enterprising interconnections of companies that belong in sectors that influence one another can constitute many times over a reasonable explanation; however, when we divert from this frame of reasonable economic interconnection company shares, then the reasons and the mechanisms that create the diffusion of volatility should be sought within the microstructure of stock exchange market, a fact that requires extensive analysis, collection and treatment of enough data so that we might refer appropriately determination of mechanisms of diffusion. At the theoretical level of approach, basic mechanisms of share interactions of were reported in literature review. However this present study diverts from the framework of research and econometric analysis and has as its main goal the selection and description of the type of dynamic relationships of interaction between shares. This diversion stresses the importance not just of the behaviour of investors but also the better understanding of the structure and operation of stock markets.

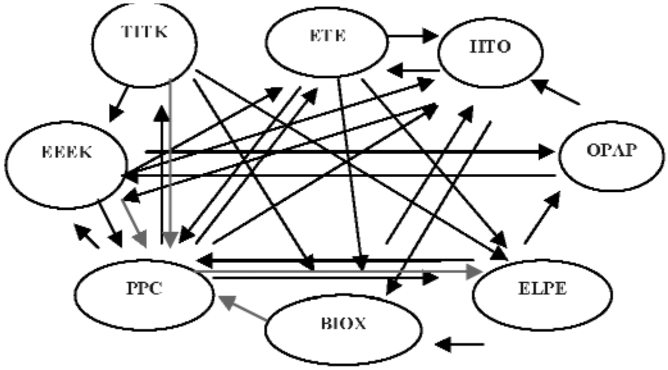
TABLE 12

Summary Presentation of Results

	PAIR OF SHARES	EXISTENCE OF DIFFUSION OF VOLATILITY	DIRECTION OF DIFFUSION OF VOLATILITY
1.	HTO-ETE	YES	HTO ←→ETE
2.	HTO-OPAP	YES	HTO ← OPAP
3.	HTO-EEEK	YES	HTO ←→EEEK
4.	HTO-TITK	NO	--
5.	HTO-PPC	YES	HTO ←PPC
6.	HTO-ELPE	NO	--
7.	HTO-BIOX	YES	HTO ←→BIOX
8.	ETE-OPAP	NO	--
9.	ETE-EEEK	YES	ETE ←→EEEK
10.	ETE-TITK	NO	--
11.	ETE-PPC	YES	ETE ←→PPC
12.	ETE-ELPE	YES	ETE →ELPE
13.	ETE-BIOX	YES	ETE←BIOX
14.	EEEK-OPAP	YES	EEEK ←→OPAP
15.	EEEK-TITK	YES	EEEK ←TITK
16.	EEEK-PPC	YES	EEEK ←→PPC
17.	EEEK-ELPE	NO	--
18.	EEEK-BIOX	NO	--
19.	OPAP-TITK	NO	--
20.	OPAP-PPC	NO	--
21.	OPAP-ELPE	YES	OPAP ←ELPE
22.	OPAP-BIOX	NO	--
23.	TITK-PPC	YES	TITK ←PPC
24.	TITK-ELPE	YES	TITK →ELPE
25.	TITK-BIOX	YES	TITK →BIOX
26.	PPC-ELPE	YES	PPC ←→ELPE
27.	PPC-BIOX	NO	--
28.	ELPE-BIOX	YES	ELPE →BIOX

FIGURE 1

Interactions among the shares



The arrows in Figure 1 demonstrate either one-directional or bi-directional paths of volatility between all shares. The arrows that are in red represent interactions at the level of share returns.

Taking into consideration the results of the above controls with regard to diffusion of volatility and the interactions between shares, we can number the shares that not only influence each share but also the shares which are influenced, so that we may recognize the independent shares under the sample examination for the particular time period.

TABLE 13

Number of Interactions

SHARES	NUMBER OF SHARES WHICH INFLUENCE	NUMBER OF SHARES FROM WHICH ARE INFLUENCED
HTO	3	5
ETE	4	4
OPAP	2	2
EEEK	4	5
PPC	5	3
ELPE	3	3
TITK	3	1
BIOX	2	3

There is a remarkable result with regard to shares ETE, EEEK, and PPC, which can be characterized as independent shares that sustain a significant influence on remaining shares. Conversely, share OPAP first and foremost, followed by the remaining shares, does not appear to considerably influence the remaining shares. With regard to the sensitivity of shares, we observe that shares TITK and OPAP are not quite influenced by the remaining shares in contrast to the remaining shares.

Based on the above, the most «energetic» shares, if we can characterize them as such, are shares HTO, ETE, EEEK and PPC, all of which present a great number of interconnections with the remaining shares.

6. Spillover Effects & Portfolio Risk Management

The implications of spillover effects on risk management are important for individual investor as well as for portfolio managers. Within the framework of this optimization, a basic element constitutes the possibility of portfolio differentiation, which can be achieved via the choice of suitable shares. The comprehension of links between shares can thus significantly benefit investors regarding the choice of a suitable portfolio as well as its risk management. Other basic reasons for the study of the degree and the nature of the interactions of share prices is that it is linked with the level of efficient operation of a given market, the valuation of financial elements that negotiate this and the growth of hedge techniques. The examined spillover effects are important, due to possible benefits from diversification. As shown on Exhibit 15 there exist positive and/or negative interactions of the share prices.

TABLE 14

Determination of the Kind of Interconnections

PAIR OF SHARES	EXISTENCE OF DIFFUSION OF VOLATILITY	DIRECTION OF DIFFUSION OF VOLATILITY
HTO-ETE	YES	(+ -) HTO ←→ETE
HTO-OPAP	YES	(+) HTO ← OPAP
HTO-EEEK	YES	(+ +) HTO ←→EEEK
HTO-PPC	YES	(+ -) HTO ←PPC
HTO-BIOX	YES	(- +) HTO ←→BIOX
ETE-EEEK	YES	(- +) ETE ←→EEEK
ETE-PPC	YES	(- +) ETE ←→PPC
ETE-ELPE	YES	(-) ETE →ELPE
ETE-BIOX	YES	(+) ETE←BIOX
EEEK-OPAP	YES	(+ +) EEEK ←→OPAP
EEEK-TITK	YES	(+) EEEK ←TITK
EEEK-PPC	YES	(+ +) EEEK ←→PPC
OPAP-ELPE	YES	(+) OPAP ←ELPE
TITK-PPC	YES	(+) TITK ←PPC
TITK-ELPE	YES	(+) TITK →ELPE
TITK-BIOX	YES	(-) TITK →BIOX
PPC-ELPE	YES	(- +) PPC ←→ELPE
ELPE-BIOX	YES	(-) ELPE →BIOX

TABLE 15

Danger management strategies from an investor

PAIR OF SHARES	SHOCK/NEW SHARES INFORMATION	DANGER MANAGEMENT STRATEGIES FROM AN INVESTOR
HTO-ETE	$\varepsilon^2_{HTO,t-1}>0$ $\varepsilon^2_{ETE,t\ 1}>0$	PURCHASE ETE SELL HTO
HTO-OPAP	$\varepsilon^2_{OPAP,t\ 1}>0$	SELL HTO
HTO-EEEK	$\varepsilon^2_{HTO,t\ 1}>0$ $\varepsilon^2_{EEEK,t\ 1}>0$	SELL EEEK SELL HTO
HTO-PPC	$\varepsilon^2_{PPC,t\ 1}>0$	PURCHASE HTO
HTO-BIOX	$\varepsilon^2_{HTO,t-1}>0$ $\varepsilon^2_{BIOX,t-1}>0$	SELL BIOX PURCHASE HTO
ETE-EEEK	$\varepsilon^2_{ETE,t-1}>0$ $\varepsilon^2_{EEEK,t\ 1}>0$	SELL EEEK PURCHASE ETE
ETE-PPC	$\varepsilon^2_{ETE,t-1}>0$ $\varepsilon^2_{PPC1,t\ 1}>0$	SELL PPC PURCHASE ETE
ETE-ELPE	$\varepsilon^2_{ETE,t\ 1}>0$	PURCHASE ELPE
ETE-BIOX	$\varepsilon^2_{BIOX1,t\ 1}>0$	SELL ETE
EEEK-OPAP	$\varepsilon^2_{EEEK,t\ 1}>0$ $\varepsilon^2_{OPAP,t\ 1}>0$	SELL OPAP SELL EEEK
EEEK-TITK	$\varepsilon^2_{TITK1,t\ 1}>0$	SELL EEEK
EEEK-PPC	$\varepsilon^2_{EEEK,t\ 1}>0$ $\varepsilon^2_{PPC,t\ 1}>0$	SELL PPC SELL EEEK
OPAP-ELPE	$\varepsilon^2_{ELPE,t-1}>0$	SELL OPAP
TITK-PPC	$\varepsilon^2_{PPC,t-1}>0$	SELL TITK
TITK-ELPE	$\varepsilon^2_{TITK,t\ 1}>0$	SELL ELPE
TITK-BIOX	$\varepsilon^2_{TITK,t-1}>0$	PURCHASE BIOX
PPC-ELPE	$\varepsilon^2_{PPC,t-1}>0$ $\varepsilon^2_{ELPE,t\ 1}>0$	SELL ELPE PURCHASE PPC
ELPE-BIOX	$\varepsilon^2_{ELPE,t-1}>0$	PURCHASE BIOX

Based on the estimated spillover effects between pairs of shares, we show on Table 15 the source of volatility and the possible strategy that an investor could follow in order to achieve profits.

Furthermore, we conclude that for the pair of shares HTO-ETE a positive shock/information to share HTO negatively influences the unconditional variance of share ETE. Furthermore, it is in the interest of an investor to take a position in the market in share ETE, seeing that a decrease in volatility for share ETE is foreseen for the following day and consequently the risk that this share embeds. On the other hand, a shock of the ETE share influences positively the volatility of share HTO, and as a consequence an investor would benefit by a short position on HTO share, in order to avoid the increased risk that the share brings the following day. In the same framework, an investor with long position on the examined shares, could follow the above strategies of transaction in order to achieve the best possible management of portfolio risk.

The results of the unconditional cross-correlations of the empirical results are particularly important for an investor, especially if we take into consideration the renowned investor's portfolio theory of *Markowitz (1952)*, in which the factor of cross-correlation constitutes the basic component regarding the choice of different financial elements for the configuration of a well differentiated portfolio. Thus, in the case of portfolio composition based on sample shares, an investor should be very careful in the choice of a share with significant positive interactions and high level cross-correlation with each other. The best choice would be to include in the portfolio pairs from the above shares that have a low factor of cross-correlation so that it can compensate for the risk of changeable shares and effectively differentiate an investor's portfolio. Also important in the estimate of portfolio risk is the existence of temporally altered cross-correlations, a result that was evident in the estimate of the model. It is extremely important for an investor to realize that this temporally altered nature of cross-correlation because when an investor takes for granted the existence of constant cross-correlations between the shares in unconditional form, they are then led to an unrealistic estimate of portfolio risk.

On the other hand, the finding of shares with a high factor of cross-correlation and bi-directional interaction between them can constitute an opportunity for the strategic realization that may provide returns for investors. Characteristically, there is a theory (pairs trading strategy) according to which the pair of shares based on historical data have proved to have important interaction between them and cross-correlation throughout time, can constitute a tool for an investor to achieve returns *(Gatev, et al, 2006)*. Given that the spillover effects are time varying an investor could benefit by taking a short position on a share that increases its returns and a long position on a share with decreasing returns.

7. Conclusions

The objective of this paper is to investigate the dynamics of the spillover effects among selected shares of the Athens Stock Exchange. According to the empirical results of our analysis the interactions of the shares' returns is not statistical significant in most cases. Based on the VAR-BEKK-GARCH there exist significant spillover effects either in a unidirectional (8 cases) level or a bidirectional (10 cases) level.

The result of existing significant relationships between shares at the level of volatility reflects the multitude of factors involved on the process of information flow and the consequent spillover effects between shares. The present study however, deviates from the frameworks of research on account of these reasons and has as its central aim to elect and describe the type of dynamic relationships of interaction between shares and stresses their importance not just for the behaviour of investors but also for the improved comprehension of the structure and operation of financial markets.

Undoubtedly, the usefulness of research results is significant. From the viewpoint of individual investors and portfolio managers of the ASE, the existence and type of relationships between shares must be taken into consideration provided that these relationships have an impact on differentiation strategies of portfolio and hedge risk.

Provided that the temporally altered covariance can produce more precise estimates and forecasts, the incorporation of interactions between the shares can provide information and the possibility for forecasts in relation to the volatility of a share following the course of another share with which it is connected, providing parallel data for the level of effectiveness that exists between these shares. Furthermore, a shock in a market or in a specific share could possible spillover in another share and thus, the investigation of the dynamics of the covariance structure is very important for effective risk management and portfolio analysis. In other words, the investigation of spillover effects might be useful for the participants in a stock exchange market who can profit from the knowledge of these interactions and achieve profitable strategies of transactions between dependent shares.

8. Proposals for further research

Financial markets thus can be regarded as complicated systems and investors should have dynamic portfolios in order to achieve benefits by spillover effects. It would be very interest to enrich our analysis with the asymmetric response of volatility to information (leverage effect). It would be interesting to extend the sample to a larger number of small and large capital companies and to investigate each of their interactions. A different time period can also be selected in which periods of particularly intense volatility would exist, with the objective being how the dynamic interactions of shares in periods of intense volatility differentiate.

Finally, it would be very interesting to investigate the dynamics of share spillover effects with respect to the introduction of the International Financial Reporting Standards (IFRS). Based on the empirical results of *Bellas et al. (2007)*, there are significant effects of IAS on share prices and hence it is possible to affect their volatility as well. *Bellas et al. (2007)* recorded that the required accounting conversion, brought about important changes in the financial statements of Greek listed companies and in the value relevance of accounting information. Therefore it would be particularly useful to extend the examination of the sample to after 2006, in order to observe the changes that occurred within the interconnections of shares in accordance with the application of IFRS (i.e. after 2005).

Notes

1. BLOOMBERG constitutes an electronic platform and a source of data that provides economic data and economic information in real time within the investment community (institutional investors).

2. The estimates of models VAR are mentioned in detail at the end of the study.

3. The estimation of the model was based on the codes that are available on the Chris Brooks, «Introductory Econometrics for Finance», 2002. Furthermore, the codes were modified according to the needs of the model in the present study. Data for the modification of the program were found on the site www.estima.com. The code of the program is found in the appendix, while specifically the estimates of the model exist on the cd-rom that is mentioned at the end of the study.

4. The interaction of share ETE with share HTO resulted from the previous estimate of the bivariate model, therefore it is not necessary to repeat the same estimate of the model for these two shares. The same is also in effect for other pairs of shares, as it appears in the following estimates.

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