Asymmetries and Spillover Effects in the Greek Real Estate Equity Market

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Abstract

This study investigates the real estate stock market in Greece during the period December 2009 - November 2014, using various GARCH and asymmetric models (GJR-GARCH, EGARCH) to daily returns. Furthermore, we examine the return and volatility linkages between the Greek real estate index and the general index, as well as, between each REIT and its parent bank. The results suggest that the Athens stock exchange general index has a significant impact on real estate stock returns but there is not any significant impact in respect of the day of the week effect. The asymmetry of the volatility response to news seems to be present. Additionally, we found evidence of unidirectional slightly positive volatility linkage running from the general index to the real estate index and slightly positive unidirectional stock transmission running from Eurobank to Grivalia. Finally, we did not identify any volatility spillover between the two Greek REITs and their parent banks.

Keywords: *REITs; GARCH; Asymmetry; Volatility Spillover; BEKK*

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1. Introduction

Real Estate Investment Trusts (REITs) exist since 1960 in the United States. In Greece they are commonly referred as Real Estate Investment Companies (REICs) or with the Greek acronym “ΑΕΕΑΠ”. The first Greek REIT was listed in 2005 and there are currently three listed REITs which are traded on the Athens Stock Exchange: Trastor (established as REIT in 2003, listed in 2005), Eurobank Properties which is now renamed to Grivalia (established in 2005, listed in 2006) and MIG Real Estate (established in 2007, listed in 2009). There are also two not yet listed REITs: NBG PANGAEA and ICI (Intercontinental International REIC). It is worth mentioning that four out of the above five companies are bank subsidiaries, with the sole exception of the ICI. On aggregate, their portfolios comprise a total of approximately 450 commercial properties, mostly bank premises in prime locations across Greece. Nevertheless, some diversification can be observed in certain portfolios, including other types of commercial property, such as warehouses, gas stations, supermarkets, etc.

REITs in Greece are governed by the provisions of article 19 of Law 4141/2013 as this amends articles 21-31 of Law 2778/1999 “Real Estate Mutual Funds – Real Estate Investment Companies and other provisions”, as amended by Laws 2892/2001, 2992/2002 and 3581/2007, as well as the provisions of Law 2190/1920. REITs benefit from a number of tax-exemptions and as any listed company they are obligated to comply with the stock market legislation framework. Instead of the company income tax, they pay an annual Investment Tax based on the value of their property assets and cash balances, calculated as 10% of the interest rate of European Central Bank increased by 1%. They are also excluded from property transfer tax on acquisitions (currently 8-10%), supplementary tax on rental income, withholding tax on dividends and they pay reduced rates of annual property taxes.

At this point a brief analysis of the Greek crisis is very useful because it is part of our examined period. The Greek government-debt crisis is part of the ongoing Eurozone crisis and the global economic recession in October 2008. In late 2009, the government debt levels reported a strong increase and this led to a crisis of confidence. On May 2, 2010 the International Monetary Fund (IMF) agreed on a €110 billion bailout loan for Greece, conditional on compliance with a bunch of monetary measures. In mid-May 2012 the crisis and the failure to form a new coalition government after elections, led to a strong speculation that Greece would have to leave the Eurozone. This became known as “Grexit” and started affecting the international market behavior. Finally, a second election in mid-June, ended with a formation of a new government supporting a continued adherence to the main principles outlined by the signed bailout plan. Baltas (2013) presented a review of the Eurozone crisis in 2008 and investigated the causes of the Greek crisis, concluding that negative lessons from public sector adjustment in Greece show that positive measures must be taken.

The Greek market has heavily been affected by the long economic recession and 2013 is the 6^{th} consequent year of negative growth. In contrast to the United States, the real estate market is not the primary cause of the Greek debt crisis but has been certainly affected. Low occupier activity and stable investments are present. Since the European debt crisis in 2009, foreign investors have mostly ignored Greek real estate as they jumped back in Spain, Italy and Ireland. Since 2013 this seems to have changed and buyers’ interest swifts to Greece. Recent big deals include the Fairfax’s purchase of a majority stake in Eurobank Properties REIT, announced in June 19, 2013. From October 13, 2014 Eurobank Properties REIT changed its name to Grivalia Properties REIT.

Our study is the first to apply various GARCH models in the Greek real estate equity market. We investigate the best-fitted model using various GARCH models (GARCH, GJR-GARCH, EGARCH). We apply these models for the Greek real estate index (DAP) and for each of the two REITs and two SAs from which it consists. GJR-GARCH and EGARCH models allow market volatility to respond asymmetrically to positive and negative shocks. We also study their relationship with the general stock index and any day of the week effect. GARCH models are often much more parsimonious than ARCH models. GARCH models are better to capture the nature of volatility and incorporate much of the information than a much larger ARCH model with large numbers of lags. Especially in asymmetric GARCH models due to the leverage effect with asset prices, a positive shock could have less effect on the conditional variance compared to a negative shock. This was introduced by Glosten, Janathann and Runkle (1993) and showed that asymmetric adjustment was an important consideration with asset prices. An alternative model is the exponential autoregressive conditional heteroskedastic (EGARCH) model with additional leverage terms to capture asymmetries in volatility. This study focused especially in these asymmetries.

Another contribution to the existing literature is the extension of volatility analysis by using a multivariate GARCH (M-GARCH) framework. M-GARCH models are ideal for modeling volatility transmission. The purpose of this study is to consider volatility spillover by using three BEKK GARCH bivariate pair-wise models. The modeled pairs are: the general index and the Greek real estate index, Trastor REIT and its parent bank (Piraeus bank), as well as, Grivalia REIT and its parent bank (Eurobank). The BEKK specification enables us to study the possible transmission of volatility from one market to another, as well as any increased persistence in market volatility Engle et al. (1990).

The remainder of this paper is structured as follows. Section 2 briefly details the data set and the methodological approach of the study. Section 3 provides an overview of the real estate market in Greece, presents the empirical results and discusses the implications. The final section states the conclusions.

2. Literature review

The REIT sector in Greece is relatively new and there are no extensive quantitative researches yet. Mitrakos et al. (2013) provide a theoretical overview of the REIT sector in Greece by presenting their characteristics (asset values, share prices and dividends yields). They found that Greek REITs show resilience in crisis because they perform better than the overall stock market and are able to distribute income to shareholders. Apergis (2012) investigated the relationship between the banking institutions and REITs in Greece using a GARCH methodology. The results show that the returns of REITs affect the stock returns of banking institutions involved in the real estate market and this impact is stronger after the recent international financial crisis. Additionally, there is a research in the Greek real estate market before the entrance of the Greek REITs in the Athens Stock Exchange by Kapopoulos and Siokis (2005). They found that the stock market and the housing market in Greece are integrated based on an investigation of the Greek Stock Exchange Index and the real estate prices in Athens and other urban areas in Greece.

We use a GARCH model introduced by Bollerslev (1986) and we examine any presence of asymmetry, using the GJR-GARCH (Glosten et al., 1993) and the exponential GARCH model by Nelson (1991). This attempt will help to further examine the real estate stock market in Greece in terms of returns and volatility. The theory of real estate and stock market co-integration assumes that capital gains and risk reduction are possible through holding assets in both markets. In the worldwide literature this issue has not produced unified results regarding the direction of integration between real estate and stock markets (Apergis and Lambrinidis, 2007). Petrova (2010) used an OLS methodology in the young financial market in Bulgaria and its real estate market. The results show that changes in real estate and changes in stocks influence each other.

This paper extends the analysis of volatility by using a multivariate GARCH (M-GARCH) framework. M-GARCH models are ideal for modeling volatility transmission and understanding the comovements of financial returns. For example Mondal L (2013) used a bivariate GARCH model to test volatility spillover among RBI'S intervention and exchange rate. The most obvious application of M-GARCH models is the study of the relations between the volatilities of several markets. It is now widely accepted that financial volatilities move together over time across assets and markets. On the other hand univariate models are unable to show volatility and correlation transmission, so multivariate modelling leads to more relevant empirical models and facilitate better decision. M-GARCH models were initially developed in the late 1980s and the first half of the 1990s, and after a period of tranquility in the second half of the 1990s, this area seems to be experiencing again a quick expansion phase. Regarding the recent research in Bauwens et al. (2006) mentioned that the crucial point in MGARCH modelling is to provide a realistic but parsimonious specification of the variance matrix ensuring its positivity. To date research that examines volatility spillovers and return co-movements in the Greek real estate equity market has been very limited. This is the gap that the current research is trying to address.

3. Data and methodology

The conducted empirical tests utilize the Greek real estate index (DAP) and the Athens Stock Exchange General index (GD) as the proxy for the real estate market and the market portfolio respectively. The Greek real estate index (DAP) consists of four real estate companies. Two of them (Grivalia and Trastor) are legislated as REITs and the other two (Lamda development and Kekrops) are real estate S.A.

companies. The dataset comprises of daily data for the period December 2009 through November 2014 from the Athens Stock Exchange. The Greek real estate index first launched in December 2009; therefore, due to data availability, we are bounded to restrict our analysis starting from this day onwards. We have also excluded the MIG REIT because of its late listing (in the end of July, 2009) that will further reduce our sample range and in addition it is not a component of the Greek real estate index. Our sample consists of 1294 observations for each examined index (5 days a week period).

The main modeling method in this study is the Generalized Autoregressive Conditional Heteroskedasticity (GARCH) model by Bollerlev (1986) and is specified as follows:

$$\text{mean equation: } x_t = \beta_0 + \beta_1 x_{t-1} + \beta_2 GD_t + u_t \quad (1)$$

$$\text{variance equation: GARCH(1,1):} h_t = a_0 + a_1 h_{t-1} + a_2 u_{t-1}^2 + a_3 GD_t \quad (2)$$

x_t denotes the dependent variable return series and x_{t-1} refers to its lagged 1-day return. In our study we use the following dependent variables: DAP, GRIVALIA, TRASTOR, LAMDA and KEKROPS and GD variable represents the Greek general index as an explanatory variable. Let u_t denotes the error terms (return residuals, with respect to a mean process). Equation h_t refers to the conditional variance equation of each asset. In our analysis we tested all the possible GARCH(p,q) models with p=1,2 and q=1,2. GARCH(1,2) and GARCH(2,2) are two additional best-fitted GARCH models and their variances are presented below as:

$$\text{GARCH(1,2): } h_t = a_0 + a_1 u_{t-1}^2 + a_2 h_{t-1} + a_3 h_{t-2} + a_4 GD_t \quad (3)$$

$$\text{GARCH(2,1): } h_t = a_0 + a_1 u_{t-1}^2 + a_2 u_{t-2}^2 + a_3 h_{t-1} + +a_4 GD_t \quad (4)$$

Dummy variables of the weekdays are also included in the specification when mentioned. Monday is represented by the variable Mon and Tuesday by the variable Tue. Variables Wen and Fri denote Wednesday and Friday respectively. Thursday's dummy variable is excluded in order to avoid the dummy variable trap and still include the intercept. When we include the dummy variables (the days of the week) the mean model can be specified as follows:

$$x_t = \beta_0 + \beta_1 x_{t-1} + \beta_2 GD_t + \beta_3 Mon + \beta_4 Tue + \beta_5 Wen + \beta_6 Fri + u_t \quad (5)$$

and the selected best-fitted variance models are:

$$\text{GARCH(1,1)}: h_t = a_0 + a_1 h_{t-1} + a_2 u_{t-1}^2 + a_3 GD_t + a_4 Mon + a_5 Tue + \\ + a_6 Wen + a_7 Fri \quad (6)$$

$$\text{GARCH(2,2)}: h_t = a_0 + a_1 u_{t-1}^2 + a_2 u_{t-2}^2 + a_3 h_{t-1} + a_4 h_{t-2} + a_5 GD_t + \\ + a_6 Mon + a_7 Tue + + a_8 Wen + a_9 Fri \quad (7)$$

A major restriction of the GARCH specification is the fact that it is symmetric. By this we mean that what matters is only the absolute value of the innovation and not its sign (because the residual term is squared). Therefore, in these models a positive shock will have exactly the same effect on the volatility of the series as a negative shock of the same magnitude. However, for equities it has been observed that negative shocks (or 'bad news') in the market have a larger impact on volatility than positive shocks (or 'good news') of the same magnitude. The Glosten-Jagannathan-Runkle GARCH (GJR-GARCH) model was introduced by the work of Glosten, Jagannathan and Runkle (1993) and is commonly used to handle leverage effects. This model adds into the variance equation a multiplicative dummy variable to check whether there is statically significant difference when shocks are negative. The specification of the conditional variance equation for GJR-GARCH (1,1) is given by:

$$h_t = a_0 + a_1 u_{t-1}^2 + a_2 u_{t-1}^2 d_{t-1} + a_3 h_{t-1} + a_4 GD_t \quad (8)$$

and when we include the dummy variables:

$$h_t = a_0 + a_1 u_{t-1}^2 + a_2 u_{t-1}^2 d_{t-1} + a_3 h_{t-1} + a_4 GD_t + a_5 Mon + a_6 Tue + \\ + a_7 Wen + a_8 Fri \quad (9)$$

where d_t takes the value of 1 for $u_t < 0$, and 0 otherwise. So 'good news' and 'bad news' have a different impact. Good news has an impact a_1, while bad news has an impact of $\alpha_1+\alpha_2$. If $\alpha_2 > 0$ we conclude that there is asymmetry, while if $a_2=0$ the news impact is symmetric. The selected best-fitted variance equation models are:

$$\text{GJR-GARCH(2,1)}: h_t = a_0 + a_1 u_{t-1}^2 + a_2 u_{t-1}^2 d_{t-1} + a_3 u_{t-2}^2 + a_4 h_{t-1} + \\ + a_5 GD_t \quad (10)$$

$$\text{GJR-GARCH(2,2)}: h_t = a_0 + a_1 u_{t-1}^2 + a_2 u_{t-1}^2 d_{t-1} + a_3 u_{t-2}^2 + a_4 h_{t-1} + \\ + a_5 h_{t-2} + a_6 GD_t \quad (11)$$

GJR-GARCH(2,1): $h_t = a_0 + a_1 u_{t-1}^2 + a_2 u_{t-1}^2 d_{t-1} + a_3 u_{t-2}^2 + a_4 h_{t-1} +$
$$+a_5 GD_t + a_6 Mon + a_7 Tue + +a_8 Wen + a_9 Fri \qquad (12)$$

In addition, another model that captures the asymmetric volatility reaction to the good and bad news is the exponential GARCH or EGARCH model which was first developed by Nelson (1991), and the variance equation for the EGARCH(1,1) model is given by:

$$\log(h_t) = a_0 + a_1 \left|u_{t-1}/\sqrt{h_{t-1}}\right| + a_2 (u_{t-1}/\sqrt{h_{t-1}}) + a_3 \log(h_{t-1}) + a_4 GD_t \qquad (13)$$

and when we add the dummy variables in the variance equation:

$$\log(h_t) = a_0 + a_1 \left|u_{t-1}/\sqrt{h_{t-1}}\right| + a_2 + a_2 (u_{t-1}/\sqrt{h_{t-1}}) + a_3 \log(h_{t-1}) +$$
$$+a_4 GD_t + a_5 Mon + a_6 Tue + +a_7 Wen + a_8 Fri \qquad (14)$$

where a_0 is a constant. This model differs from the GARCH model in several ways. First of all it uses logged conditional variance to relax the positiveness constraint of model coefficients and enable the model to respond asymmetrically to positive and negative lagged values. On the left-hand side is the log of the variance series and this makes the leverage effect exponential instead of quadratic, therefore the estimates of the conditional variance are guaranteed to be non-negative. The EGARCH model allows for the testing of asymmetries as well as the QJR-GARCH. To test for asymmetries the parameter of importance is the α_2. If α_2=0, then the model is symmetric. When $\alpha_2 < 0$, positive shocks (good news) generate less volatility than negative shocks (bad news). Additional best-fitted EGARCH variance representations include the following models:

EGARCH(2,2): $\log(h_t) = a_0 + a_1 \left|u_{t-1}^2/\sqrt{h_{t-2}}\right| + a_2 \left|u_{t-2}^2/\sqrt{h_{t-2}}\right| +$
$$+a_3 \left(\frac{u_{t-1}}{\sqrt{h_{t-1}}}\right) + a_4 \log h_{t-1} + a_5 \log h_{t-2} + a_6 GD_t \qquad (15)$$

EGARCH(2,1): $\log(h_t) = a_0 + a_1 \left|u_{t-1}^2/\sqrt{h_{t-1}}\right| + a_2 \left|u_{t-2}^2/\sqrt{h_{t-2}}\right| +$
$$+a_3 \left(\frac{u_{t-1}}{\sqrt{h_{t-1}}}\right) + a_4 \log h_{t-1} + a_5 GD_t + a_6 Mon + a_7 Tue +$$
$$+a_8 Wen + a_9 Fri \qquad (16)$$

In the second part of our analysis we have to determine the suitability of the BEKK model. This requires the existence of heteroskedastic effects in the return series. Using the Engle (1982) LM test for ARCH(p) effects, we find strong evidence of ARCH effects for all cases. The following mean equations were estimated for each index.

$$r_t = c + \theta r_{t-1} + \varepsilon_t \qquad (17)$$

where r_t is an $2x1$ vector of daily returns at time t for each index, and $\varepsilon_t|\varepsilon_{t-1} \sim N(0, H_t)$ is an $2x1$ vector of random errors for each index at time t. This model helps us in the examination of any volatility transmission. The main advantage of the BEKK model is that it has few parameters and ensures positive definiteness of the conditional covariance matrix to ensure non-negative estimated variances. The bivariate version of the BEKK GARCH specification (Engle and Kroner, 1995) is defined as:

$$H_t = CC' + A\varepsilon_{t-1}\varepsilon'_{t-1}A' + BH_{t-1}B' \qquad (18)$$

$$y_t = \mu_t + \varepsilon_t$$

$$\varepsilon_t \sim N(0, H)$$

where y_t is a $2x1$ vector of random variables incorporating the returns and ε_t is a normally distributed error term. H_t, denotes the conditional variance-covariance matrix at t and matrices B and A as well as the diagonal elements of C have to be positive. The elements of the covariance matrix H_t, depends only on past values of itself and past values of $\varepsilon_t'\varepsilon_t$, which is innovation. Each matrix C, A and B dimension is $2x2$ and C is restricted to be upper triangular. The elements of matrix A measure the effects of shocks or "news" on the conditional variances (ARCH effects). The $2x2$ square matrix B shows how past conditional variances affect the current levels of conditional variances, in other words, the degree of volatility persistence in conditional volatility among the markets (GARCH effects). The diagonal parameters in matrices A and B measure the effects of own past shocks and volatility on its conditional variance. The volatility spillover measures the cross-market effects of shocks and volatility using the off-diagonal parameters in matrices A and B. This model is suitable for cross dynamics of conditional covariances because A and B do not need to be diagonal.

We assume that $a_{11} > 0$ and $b_{11} > 0$ due to the uniqueness of the BEKK representation. Then, if $K=1$ there exists no other C, B, A in the model that will give an equivalent representation. The purpose of the restrictions is to eliminate all other observationally equivalent structures. The amount of parameters to be estimated in is

N(5N+1)/2, thus in a bivariate model (*N=2*, with *p=q=1*) *11* parameters should be estimated. We can differentiate between three alternative specifications presented analytically below:

Bivariate Unrestricted Specification

GARCH(1,1) - BEKK, N=2:

$$H_t = CC' + \begin{bmatrix} a_{11} & a_{12} \\ a_{21} & a_{22} \end{bmatrix} \begin{bmatrix} \varepsilon_{1t-1}^2 & \varepsilon_{1t-1}\varepsilon_{2t-1} \\ \varepsilon_{2t-1}\varepsilon_{1t-1} & \varepsilon_{2t-1}^2 \end{bmatrix} \begin{bmatrix} a_{11} & a_{12} \\ a_{21} & a_{22} \end{bmatrix}'$$

$$+ \begin{bmatrix} b_{11} & b_{12} \\ b_{21} & b_{22} \end{bmatrix} \begin{bmatrix} h_{11t-1} & h_{12t-1} \\ h_{21t-1} & h_{22t-1} \end{bmatrix} \begin{bmatrix} b_{11} & b_{12} \\ b_{21} & b_{22} \end{bmatrix}'$$

The matrix multiplication is presented as:

$$h_{11,t} = c_{11}^2 + a_{11}^2\varepsilon_{1,t-1}^2 + 2a_{11}a_{21}\varepsilon_{1,t-1}\varepsilon_{2,t-1} + a_{21}^2\varepsilon_{2,t-1}^2 + b_{11}^2 h_{11,t-1} + 2b_{11}b_{21}h_{21,t-1} + b_{21}^2 h_{22,t-1} \quad (19)$$

$$h_{22,t} = c_{21}^2 c_{22}^2 + a_{12}^2\varepsilon_{1,t-1}^2 + 2a_{12}a_{22}\varepsilon_{1,t-1}\varepsilon_{2,t-1} + a_{22}^2\varepsilon_{2,t-1}^2 + b_{12}^2 h_{11,t-1} + 2b_{12}b_{22}h_{21,t-1} + b_{22}^2 h_{22,t-1} \quad (20)$$

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

4. Empirical Results

Fig. 1 depicts the price movements from December 2009 to November 2014 of the general Greek stock market index and the real estate index in order to have a first understanding of their range over time. The examined period covers the Greek government-debt crisis which started after the revelation of the Greek debt levels in 2010. We observed that the real estate index exceeded the general Greek stock market throughout the whole period under examination. They follow a familiar pattern, with small differences and they both reach their lowest price in the end of May 2012. This is consistent with the mid-May 2012 crisis and the failure to form a new coalition government after elections. DAP index constituents' price movements report high degree of differentiation. Of particular interest is the fact that Grivalia's prices after 2013 have surpassed the 2009 prices.

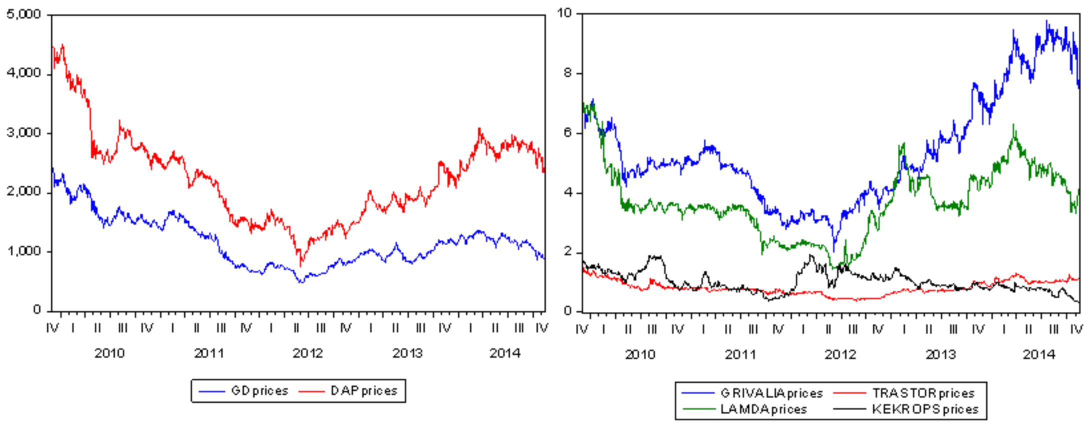

Fig. 1. Daily Closing Prices

Table 1 reports the descriptive statistics of our daily return series. All our dependent variables outperform the general index (GD). The large Jarque-Bera statistic leads to the rejection of the null hypothesis of a normal distribution. The Jarque - Bera statistics can be used to test a null hypothesis where each variable is considered to have a normal distribution. The null hypothesis that each variable has a normal distribution is rejected based on its zero p-value. This test is based on the fact that the skewness and kurtosis of normal distribution equal to zero. DAP has negative skewness that denotes that the distribution is left skewed and GD is right skewed. It is very common in time series that the data are not normally distributed. The correlation matrix in Table 1 provides us with a preliminary indication of the statistical relationships involving dependence. However statistical dependence is not sufficient to demonstrate the presence of causal relationship.

Table 1. Descriptive statistics of daily returns series

	GD	DAP	GRIVALIA	TRASTOR	LAMDA	KEKROPS
Panel A: Moments						
Mean	-0.0008	-0.0004	0.0002	-0.0001	-0.0004	-0.0012
Std. Dev.	0.0213	0.0268	0.0274	0.0320	0.0305	0.0466
Skewness	0.1999	-0.7502	-1.4235	0.2024	0.3988	0.2487
Kurtosis	5.2732	27.1585	28.313	6.4053	8.5846	7.6563
Jarque-Bera	287.24	31589.1	32022.17	634.06	1715.84	1182.33
Observations	1294	1294	1294	1294	1294	1294
Panel B: Correlation matrix						
GD		0.4026	0.02158	0.2280	0.2926	0.2734
DAP			-0.1856	0.2019	0.2841	0.2162
GRIVALIA				-0.0164	0.0216	-0.0081
TRASTOR					0.0487	0.0369
LAMDA						0.0769

Notes. The first two moments are expressed in percentage form. The skewness and kurtosis statistics have a value 0 for a normal distribution. The correlation matrix gives a preliminary indication of the linkage between the indexes.

Our main empirical analysis used different GARCH models (symmetric GARCH; asymmetric GJR-GARCH and EGARCH). First of all we have examined the influence of the market and then added the additional day-of-the-week impact for each of the three GARCH models. To select the best fitted model we want a statistically significant p-value (<α) and a large DW-statistic. The Akaike Information Criterion (AIC) and the Schwarz Criterion (BIC) are used to select non-nested models. A model is called nested of the set of its independent variables is a subset of the independent variables of the other model. A non-nested model should be selected to have smaller values of AIC or BIC. In our study we prefer the Schwarz Criterion that is usually used in big samples (n>50).

Table 2 GARCH model selection

Model	Schwarz	Leverage coef z-statistic		Schwarz	Leverage coef z-statistic
	DAP			DAP **with dummies**	
GARCH(1,1)	-4.7662		GARCH(1,1)	-4.7437	
GARCH(1,2)	-4.7910*		GARCH(1,2)	-4.7637	
GARCH(2,1)	-4.7748		GARCH(2,1)	-4.7534	
GARCH(2,2)	-4.7866		GARCH(2,2)	-4.7486	
GJRGARCH(1,1)	-4.6564	2.6941**	GJRGARCH(1,1)	-4.7410	2.8879**
GJRGARCH(1,2)	-4.7855	-0.2276	GJRGARCH(1,2)	-4.7582	0.2818
GJRGARCH(2,1)	-4.5569	1.1934	GJRGARCH(2,1)	-4.7484	1.2949
GJRGARCH(2,2)	-4.7816	1.5796	GJRGARCH(2,2)	-4.7527	0.5728
EGARCH(1,1)	-4.7011		EGARCH(1,1)	-4.7047	
EGARCH(1,2)	-4.7889		EGARCH(1,2)	-4.7556	
EGARCH(2,1)	-4.6963		EGARCH(2,1)	-4.8170*	
EGARCH(2,2)	-4.7834		EGARCH(2,2)	-4.7506	
	GRIVALIA			GRIVALIA **with dummies**	
GARCH(1,1)	-4.4012		GARCH(1,1)	-4.3755	
GARCH(1,2)	-4.3715		GARCH(1,2)	-4.3723	
GARCH(2,1)	-4.4150		GARCH(2,1)	-4.3840	
GARCH(2,2)	-4.3841		GARCH(2,2)	-4.3691	
GJRGARCH(1,1)	-4.4073	2.7301**	GJRGARCH(1,1)	-4.3779	2.5016**
GJRGARCH(1,2)	-4.3579	2.5113**	GJRGARCH(1,2)	-4.3726	2.5395**
GJRGARCH(2,1)	-4.4069	3.5545**	GJRGARCH(2,1)	-4.3831	2.4747**
GJRGARCH(2,2)	-4.4111	3.1401**	GJRGARCH(2,2)	-4.3721	2.8566**
EGARCH(1,1)	-4.4221		EGARCH(1,1)	-4.3974	
EGARCH(1,2)	-4.4204		EGARCH(1,2)	-4.3944	
EGARCH(2,1)	-4.4261		EGARCH(2,1)	-4.3992*	
EGARCH(2,2)	-4.4263*		EGARCH(2,2)	-4.3988	
	TRASTOR			TRASTOR **with dummies**	
GARCH(1,1)	-4.2034		GARCH(1,1)	-4.1809	
GARCH(1,2)	-4.1986		GARCH(1,2)	-4.1765	
GARCH(2,1)	-4.2027		GARCH(2,1)	-4.1819	
GARCH(2,2)	-4.2053		GARCH(2,2)	-4.1846*	
GJRGARCH(1,1)	-4.2021	-4.1040**	GJRGARCH(1,1)	-4.1763	-2.0897**
GJRGARCH(1,2)	-4.1972	-2.5493**	GJRGARCH(1,2)	-4.1719	-1.7781
GJRGARCH(2,1)	-4.2033	-4.3438**	GJRGARCH(2,1)	-4.1782	-2.1934**
GJRGARCH(2,2)	-4.2060*	-2.8996**	GJRGARCH(2,2)	-4.1808	-1.8392
EGARCH(1,1)	-4.1979		EGARCH(1,1)	-4.1723	
EGARCH(1,2)	-4.1934		EGARCH(1,2)	-4.1681	
EGARCH(2,1)	-4.2007		EGARCH(2,1)	-4.1753	
EGARCH(2,2)	-4.2029		EGARCH(2,2)	-4.1587	
	LAMDA			LAMDA **with dummies**	
GARCH(1,1)	-4.2924		GARCH(1,1)	-4.2679	
GARCH(1,2)	-4.2883		GARCH(1,2)	-4.2634	
GARCH(2,1)	-4.3016*		GARCH(2,1)	-4.2706	
GARCH(2,2)	-4.3008		GARCH(2,2)	-4.2718*	
GJRGARCH(1,1)	-4.2871	-0.7411	GJRGARCH(1,1)	-4.2625	-0.3889
GJRGARCH(1,2)	-4.2828	-0.2454	GJRGARCH(1,2)	-4.2579	-0.1341
GJRGARCH(2,1)	-4.2965	-1.0333	GJRGARCH(2,1)	-4.2652	0.2839

GJRGARCH(2,2)	-4.2959	-1.4926	GJRGARCH(2,2)	-4.2663	-0.3989
EGARCH(1,1)	-4.2832		EGARCH(1,1)	-4.2524	
EGARCH(1,2)	-4.2789		EGARCH(1,2)	-4.2479	
EGARCH(2,1)	-4.2860		EGARCH(2,1)	-4.2539	
EGARCH(2,2)	-4.2841		EGARCH(2,2)	-4.2528	
	KEKROPS			KEKROPS **with dummies**	
GARCH(1,1)	-3.4072		GARCH(1,1)	-3.3782	
GARCH(1,2)	-3.4029		GARCH(1,2)	-3.3749	
GARCH(2,1)	-3.4038		GARCH(2,1)	-3.3767	
GARCH(2,2)	-3.3986		GARCH(2,2)	-3.3721	
GJRGARCH(1,1)	-3.4178	6.0706**	GJRGARCH(1,1)	-3.3873	5.4084**
GJRGARCH(1,2)	-3.4123	1.9504	GJRGARCH(1,2)	-3.3819	2.3434**
GJRGARCH(2,1)	-3.4214*	8.7768**	GJRGARCH(2,1)	-3.3933*	6.5273**
GJRGARCH(2,2)	-3.3570	-2.6232**	GJRGARCH(2,2)	-3.3878	4.7377**
EGARCH(1,1)	-3.4118		EGARCH(1,1)	-3.3883	
EGARCH(1,2)	-3.4065		EGARCH(1,2)	-3.3833	
EGARCH(2,1)	-3.4122		EGARCH(2,1)	-3.3927	
EGARCH(2,2)	-3.3990		EGARCH(2,2)	-3.3906	

Notes. (*) suggests the model with the smallest Schwarz criterion (BIC)

The GARCH model is nested to the GJR-GARCH. If all leverage coefficients are zero, then the GJR-GARCH model reduces to the GARCH model. This means that we must select the best one using a log likelihood ratio test represented in Table 3 with *d*. The Neyman-Pearson likelihood ratio test will help us to compare the fit of two models, one of which (the null model) is a special case of the alternative model.

Table 3 Likelihood-ratio test (nested GARCH,GJR-GARCH)

	DAP	GRIVALIA	TRASTOR	LAMDA	KEKROPS
	d	d	d	d	d
GARCH(1,1)-GJR(1,1)	-134.7700	14.9380*	5.4640*	0.2480	20.8760*
GARCH(1,2)-GJR(1,2)	0.0220	-10.4200	5.4240*	0.0320	19.2500*
GARCH(2,1)-GJR(2,1)	-274.5660	-3.4020	8.0040*	0.5200	29.9360*
GARCH(2,2)-GJR(2,2)	0.6700	42.0880*	7.9460*	0.8300	-46.5420
with dummy variables					
GARCH(1,1)-GJR(1,1)	3.6860	10.3220*	1.1760	0.0860	18.9140*
GARCH(1,2)-GJR(1,2)	0.0360	7.6520*	1.2240	0.0120	16.2180*
GARCH(2,1)-GJR(2,1)	0.6780	5.9780*	2.2500	0.0540	28.6260*
GARCH(2,2)-GJR(2,2)	12.5340*	11.0920*	2.2340	0.0600	27.5260*

Notes. d=-2ln(likelihood for null model)+2ln(likelihood for alternative model), Ho:GARCH model is more explanatory than TARCH. If d> $\chi^2_{1, 0.05}$=3.841, we reject the null hypothesis. *indicates that the GJR-GARCH model provides more explanatory power compared to GARCH.

Table 4 summarizes the best model selection based on Schwarz criterion for non-nested models (Table 2) and likelihood ratio test for nested models (Table 3) including the analytical presentation of each model's regression coefficients. This led us to conduct our main conclusions about the variables' relationship. Most of our examined variables report asymmetric transition dynamics for positive and negative shocks; except Lamda where the GARCH (2,2) model has a better fit.

Table 4 Best fitted GARCH model - Coefficients

	DAP		GRIVALIA		TRASTOR		LAMDA		KEKROPS	
Variable	Coefficient	z-Statistic	Coefficient	z-Statistic	Coefficient	z-Statistic	Coefficient	z-Statistic	Coefficient	z-Statistic
best model*	GARCH(1,2) model (3)		EGARCH (2,2) model(15)		GJR-GARCH(2,2) model(11)		GARCH(2,1) model(4)		GJR-GARCH(2,1) model(10)	
Mean equation										
β_0	0.0007	-1.3116	-0.0003	-0.5009	0.0010	1.3716	-0.0004	-0.5776	-0.0018	-1.6115
β_1	-0.0484*	-1.9755	-0.1451*	-4.2604	-0.1964*	-6.2308	-0.0937*	-2.81185	0.0045	0.1550
β_2	0.5211*	23.2279	0.0779*	3.0288	0.3179*	8.9100	0.4002*	11.7356	0.5505*	11.2087
Variance equation										
α_0	0.0000*	6.1231	-7.0951*	-8.4384	0.0000*	2.4463	0.0000*	3.2969	0.0000*	3.2921
α_1	0.1522*	11.5978	0.3917*	7.5796	0.2016*	5.1133	0.1910*	9.6472	0.0831*	2.7410
α_2	-0.0059	-0.6794	0.2897*	4.0713	-0.0211*	-2.8996	-0.1643*	-7.7086	0.0663*	7.5318
α_3	0.8239*	51.9850	-0.0851*	-2.5969	-0.1750*	-4.9992	0.9537*	89.0358	-0.0821*	-2.7910
α_4	0.0008*	3.7895	-0.1497	-1.6460	1.3785*	12.0782	-0.0013*	-6.4549	0.9576*	124.308
α_5			0.2450*	2.7733	-0.3986*	-3.6548				
α_6			-10.4509*	-16.0933	-0.0003*	-2.2736				
with dummy variables										
best model*	EGARCH(2,1) model(15)		EGARCH(2,1) model(15)		GARCH(2,2) model(7)		GARCH(2,2) model(7)		GJR-GARCH(2,1) model(12)	
Mean equation										
β_0	0.0012	1.0054	0.0013	0.9827	0.0021	1.1960	-0.0017	-1.0575	-0.0027	-0.9223
β_1	-0.0545*	-2.1099	-0.1154*	-3.6749	-0.2014*	-6.4127	-0.1003*	-2.9615	0.0011	0.0368
β_2	0.5757*	23.8010	0.0676*	2.4146	0.3133*	8.6458	0.4078*	11.7807	0.5407*	10.0311
β_3	-0.0019	-1.1295	-0.0019	-0.9819	-0.0022	-0.8966	0.0023	1.0003	0.0025	0.5952
β_4	-0.0024	-1.4992	0.0011	0.5617	-0.0041	-1.7165	0.0016	0.6748	-0.0027	-0.6781
β_5	-0.0012	-0.7673	-0.0050*	-2.5292	-0.0002	-0.0943	0.0011	0.5106	-0.0007	-0.2046
β_6	-0.0011	-0.6277	-0.0025	-1.1731	0.0006	0.2602	0.0018	0.7397	0.0058	1.5344
Variance equation										
α_0	0.3487*	3.4936	-10.0574*	-12.6264	0.0002*	3.2366	0.0002*	2.7988	0.0006*	4.1205
α_1	0.3851*	8.9905	0.4546*	9.1271	0.2264*	5.1859	0.1903*	8.4269	0.0942*	2.9471
α_2	-0.3862*	-8.7519	0.3444*	4.8715	-0.1996*	-5.1571	-0.1807*	-8.2375	0.0431*	6.5273
α_3	-0.0068	-1.2572	-0.1159*	-3.5112	1.3229*	10.2454	1.3290*	12.3760	-0.0997*	-3.1552
α_4	1.0025*	1169.7	-0.2636*	-2.6133	-0.3603*	-3.0979	-0.3472*	-3.3493	0.9824*	250.301
α_5	-1.5704*	-9.1697	-8.0862*	-7.1248	0.0000	0.4242	-0.0007*	-3.7770	-0.0011*	-2.7778
α_6	-0.6172*	-4.1651	0.3801*	4.5354	-0.0004*	-4.7938	-0.0005*	-5.3250	0.0000	0.1274
α_7	-0.2441	-1.7862	0.2480*	2.5181	-0.0002*	-2.5854	-0.0000	-0.1463	-0.0009*	-3.9766
α_8	-0.3824*	-2.6836	0.2348*	3.0557	-0.0002*	-1.9962	-0.0003*	-2.9306	-0.0008*	-3.3399
α_9	-0.4027*	-2.6836	0.3338*	3.7300	0.0000	0.4417	-0.0000	-0.2141	-0.0011*	-4.7188

Notes. * indicates significance at the 5 percent level or higher.

The parameter estimation for the EGARCH models for Grivalia confirmed the leverage effect because the a_3 coefficient is negative and statistically significant. Positive shocks (good news) generate less volatility than negative shocks (bad news). The positive and statistically significant GJR-GARCH coefficient a_2 for Kekrops indicates asymmetries in the news. Specifically, bad news has larger effects on volatility of the series. None of the Friday coefficients (β_6) is statistically significant in the mean equation. The GD_t coefficient in relation to the mean equation is significant positive for all the series. It is worth mentioning that GD_t affects particularly negative Grivalia's variance equation. The coefficients referring to Friday in the first moment are not significant. The *GD* coefficient in relationship to the mean and the variance equation is significant and positive.

In the next part of our analysis we estimated three pair-wise models using a bivariate GARCH framework and adopting a BEKK representation. The modeled pairs are: the general index (GD) and the real estate index (DAP), Trastor-Piraeus bank (parent company) and Grivalia-Eurobank (parent company). Table 5 reports the results from the conditional variance equation findings for the bivariate BEKK model and help us identify the interrelationships between the examined variables.

Table 5. BEKK GARCH coefficients

BEKK GARCH(1,1)						
Variance-Covariance equation						
	GD-DAP		Trastor-Piraeus bank		Grivalia-Eurobank	
Variable	Coefficient	z-Statistic	Coefficient	z-Statistic	Coefficient	z-Statistic
c_{11}	0.0051*	4.3353	0.0048*	5.1564	0.0183*	12.703
b_{11}	0.9422*	44.210	0.9697*	135.46	0.5030*	5.8652
b_{21}	0.0093	0.2634	-0.0077	-1.5335	-0.0141	-1.3637
α_{11}	0.2469*	6.4131	0.2162*	8.7756	0.5269*	9.0917
α_{21}	-0.0176	-0.4936	0.0084	0.6843	0.0518*	4.0741
c_{21}	0.0114*	8.3516	0.0153*	5.1162	0.0154*	7.4357
c_{22}	0.0051	1.4447	0.0117*	2.4695	0.0001	0.0229
b_{12}	0.0892*	1.9600	0.0059	0.2049	0.1291	0.8765
b_{22}	0.6799*	12.8984	0.8475*	39.647	0.9042*	71.243
α_{12}	-0.0701	-1.3307	-0.0879	-1.3149	-0.1302	-1.3644
α_{22}	0.4654*	9.3330	0.4442*	10.477	0.3597*	11.027
Loglikelihood		6494.36		4868.78		4952.04
Avg. log likelihood		5.0344		3.7742		3.8388
Schwarz criterion		-9.9688		-7.4485		-7.5776

Notes: * indicates significance at the 5 percent level or higher

The impact of an asset's own market effects is represented by subscripts 11 for asset 1, and 22 for asset 2. Similarly, cross-market effects are given by subscripts 21 and 12 for asset 1 and asset 2 respectively. The result that $|\alpha_{ii}| < |b_{ii}|$, suggests that the behavior of current variance and covariance is not so much affected by the magnitude of past innovations as by the magnitude of lagged variances and covariances, except of the pair Grivalia-Eurobank. In the conditional variance equation the α_{ii} coefficients represent ARCH effects, while the b_{ii} coefficients represent GARCH effects. As would be expected in the volatility equation, current returns and volatility are affected from their own past series returns. The coefficients are significant revealing that autocorrelation and volatility clustering is present in the returns with an autocorrelated relationship in the second moment of the distribution. Autoregressive and time dependent volatility effects incur for each series as shown by the α_{11}, α_{22}, b_{11}, b_{22} parameters.

The off-diagonal elements of matrices A and B capture the cross-market effects such as shock and volatility spillover. In documenting the volatility transmission between our variables, we find evidence of unidirectional slightly positive volatility linkage between GD and DAP running from the general index to the real estate index (i.e., only the off-diagonal parameter b_{12} is marginally statistically significant). Further, we find evidence of slightly positive unidirectional linkage between Grivalia and its parent bank running from Eurobank to Grivalia since only the α_{21} coefficient is statistically significant. In other words, Eurobank shocks affected Grivalia's mean returns. Finally, we did not identify any volatility spillover between the two Greek REITs and their parent banks (the off-diagonal parameters of matrix B are statistically insignificant).

5. Conclusions

This is the first quantitative study on the Greek real estate index and its constituents. The results show that the Athens stock exchange general index has a significant impact on real estate stock returns but there is not any significant impact in respect of the day of the week effect. The general index has a positive impact on the Greek real estate index mean equation and slightly positive on the variance equation. All of the index constituents' mean equations are influenced positive (Kekrops has the greatest impact and Grivallia the smallest). In terms of the variance equation the general index has positive impact only on Kekrops. Interestingly, the most negative effect was reported on Grivalia's variance.

Moreover, we found some asymmetries in the news. Specifically, bad news has larger effects on volatility of the series (for Grivalia and Kekrops). The best fitted model for Grivalia is the EGARCH. This model shows that the negative shocks at time t-1 have a greater impact in the variance at time t than positive shocks. This asymmetry is called leverage effect and its parameter is negative and statistically significant for Grivalia. This means that positive shocks (good news) generate less volatility than negative shocks (bad news). GJR-GARCH specification is proved to have the best fit for Kekrops time series. This model assumes a specific parametric form for the conditional heteroskedasticity. This model also proves that negative shocks have a stronger impact in the variance than negative shocks. The effective coefficient associated with the negative shock is statistically significant.

In Greece, REITs are a new investment tool under recent development and due to this the modeling of the Greek real estate index is a useful tool in the observation and understanding of their behavior and characteristics. Moreover, the relationship between the general index and the real estate index has a practical implication in terms of asset allocation of a portfolio in the Greek stock market in terms of diversification potentials between general stocks and real estate companies' stocks. Besides the proposed model specification, another aspect of our analysis is a bivariate BEKK GARCH analysis.

The behavior of current variance and covariance is not so much affected by the magnitude of past innovations as by the magnitude of lagged variances and covariances, except of the pair Grivalia-Eurobank. Concerning interlinkages of our variables, we found evidence of unidirectional slightly positive volatility linkage between GD and DAP running from the general index to the real estate index and slightly positive unidirectional linkage between Grivalia and its parent bank running from Eurobank to Grivalia. In other words, Eurobank shocks affected Grivalia's mean returns. Finally, we did not identify any volatility spillover between the two Greek REITs and their parent banks.

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