An Investor Sentiment Barometer - Greek Implied Volatility Index (GRIV)

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Abstract

In this paper a new measure of Greek stock market volatility based on the implied volatility of FTSE/ATHEX-20 index options is proposed. Greek Implied Volatility Index is calculated using the model-free methodology that involves option prices summations and is independent from the Black and Scholes pricing formula. The specific method is applied for the first time in a peripheral and illiquid market as the Athens Exchange.

The empirical findings of this paper show that there is a statistically significant negative and asymmetric contemporaneous relationship between implied volatility changes and the underlying equity index returns. Finally, the volatility transmission effects on the Greek stock exchange from two leading markets, namely the New York Stock Exchange and the Deutsche Börse, are tested and documented.

Keywords: *Implied volatility indices, Athens Stock Exchange, VIX, VDAX.*
JEL Classification Codes: G13, G14, G15, C53

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1. Introduction

This study develops a new implied volatility index for the Greek stock market, based on the model-free methodology of the new VIX. Implied volatility is the expectation of the market participants for the future volatility of the underlying asset during the maturity of an option and thus, is considered to be the market forecast of future realized volatility.

The concept of a volatility index based on option prices came forward soon after options began trading in organized markets[1]. Gastineau (1977) was the first researcher to create a volatility index by taking the average implied volatility of at-the-money call options on 14 stocks. Galai (1979) developed an option index for each individual underlying stock, while Cox and Rubinstein (1985) improved Gastineau's effort by adding in their calculation more call options for each stock and weighting them in such a way in order to make their index at-the-money and with a constant time to maturity. Separately, Brenner and Galai (1993) proposed a realized volatility index for the currency market.

Yet, the breakthrough in this area was the introduction of VIX by the Chicago Board Options Exchange (CBOE) in 1993. VIX was based on the work of Whaley (1993) and very quickly became the benchmark risk index for the US market. VIX, according to Fleming et al. (1995), extends the previous efforts in two important ways: first, it uses options on an index and not on individual stocks emphasizing on the systematic risk, which is the risk that investors should be interested in. Second, VIX employs both call and put options, while the previous efforts used solely calls, increasing in that way the amount of information captured by the index. Following the example of CBOE, other exchanges introduced their own volatility indices; Deutsche Börse developed in 1994 the VDAX, while French Marchė des Options Nėgociables de Paris (MONEP) introduced in 1997 two indices, the VX1 and VX6. In September 2003, CBOE re-launched VIX (the new VIX) using a new methodology based on the work by Demeterfi et al (1999a) for pricing variance and volatility swaps.

In practice, a volatility index can be used as an underlying asset in derivative products. Deutsche Börse was the first exchange to list, in 1998, a futures contract with an underlying asset an implied

[1] The Chicago Board Options Exchange (CBOE), which was established in 1973, was the first organized market for options. Specifically, on April 26, 1973 began the trading of 911 option contracts on 16 different stocks (source: Chicago Board Options Exchange).

volatility index (the VDAX), while CBOE, on March 26, 2004, listed futures on VIX and on February 24, 2006 introduced options on VIX. Alternatively, an implied volatility index can be employed as an input variable in calculating Value-at-Risk (VaR). In academia, on the other hand, research has focused on implied volatility mainly in three ways: the first class of research deals with various issues related to the difficulties in the determination of implied volatility. For example, there is evidence of a skew pattern in volatility implied by Black and Scholes option pricing model, where deep-in-the-money or out-of-the-money options are associated with higher implied volatility than at-the-money options (e.g. Hull and White, 1987 and Merton, 1976). The second class of finance literature focuses on the relationship of implied with realized volatility; that is the information content of implied volatility and its ability to predict future realized volatility[2]. Interestingly, the third category that deals with the contemporaneous association between implied volatility and underlying index returns is rather limited in finance literature (we can indicatively mention Fleming et al, 1995; Whaley, 2000; Giot, 2005). According to Giot, this could be attributed to the perception that markets are efficient and thus no variable – including implied volatility – can provide abnormal returns.

With respect to the above framework, this paper proposes an implied volatility index for the Greek market – from now onward referred to as GRIV (GReek Implied Volatility) – calculated with the model-free methodology used for the calculation of the new VIX. Additionally, the asymmetric negative relationship between the changes of GRIV and the underlying stock index returns is tested and documented, and finally the linkage of GRIV with the two leading implied volatility indices, VIX and VDAX, is analyzed.

The contribution of the current research is that for the first time, at least to our knowledge, the new model-free methodology is applied to a small market as the Greek one. Indeed, the construction of a volatility index for the Greek stock market is challenging, since it is a relatively new market (the Greek derivatives market was established in August 1999, while the first option contracts were listed

[2] An extended review of forecasting volatility can be found in Poon and Granger (2003) and Andersen et al. (2005).

in September 2000) with limited liquidity[3] and market participants. There are of course, other attempts to create a volatility index for a peripheral market – Skiadopoulos (2004) proposed an index for the Greek market and Shannon and Pillay (2006) for the South African one[4] – but both use the old methodology of VIX, which is based on the Black-Scholes (1973)/ Merton (1973) pricing formula. On the other hand, Gonzalez and Novales (2007) and Ting (2007) propose indices for Spain[5] and Korea[6] respectively, using the new methodology, but deal with substantial markets that cannot certainly qualify as peripheral. Furthermore, the most significant contribution of this study is that its empirical findings prove the suitability of the new VIX methodology for less developed and illiquid markets.

The second contribution of the current paper is that it studies the stock market integration using implied volatility and not realized returns and variances, which is the method that the overwhelming number of researchers have implemented (indicatively, other studies that use implied volatility are Aboura and Villa, 1999; Nikkinen and Sahlström, 2004; Äijö, 2008). The use of implied volatilities means that market participants' expectations about future volatility/ uncertainty are tested rather than the actual stock price movements.

The rest of the paper is organized as follows: the next section includes the definition of implied volatility and a brief review of the two oldest and most influential implied volatility indices, VIX and VDAX. Section three describes the calculation methodology of GRIV and its statistical properties, while section four examines its relationship with the underlying index. Section five analyzes its association with the corresponding US and German volatility indices and section six includes the concluding remarks.

[3] The daily average volume of the future on FTSE/ATHEX-20, which is the most liquid product, was 9.833 contracts for 2006, while the daily average volume of the options on the same index was 2.520 contracts (source: Athens Exchange).

[4] South African Futures Exchange (SAFEX) disseminates an implied volatility index (SAVI) from the second quarter of 2007.

[5] In 2006, the annual and average daily trading volumes of the Ibex -35 futures were 6,4 million and 25.000 contracts respectively and the annual and average daily trading volumes of the Ibex 35 options were 5,5 million contracts and 22.000 contracts respectively (Source: Madrid Stock Exchange).

[6] In 2006, the annual and average daily trading volumes of the KOSPI 200 futures were 46,6 million contracts and 188.688 contracts, respectively and the annual and average daily trading volumes of the KOSPI 200 Options were 2.414,4 million contracts and 9,8 million contracts (Source: The Korea Exchange).

2. Implied Volatility

2.1 Definition

An analogy between interest rates and volatility contributes in the understanding of the latter. The role of interest rates in the pricing of the bonds is comparable to the role of volatility in the pricing of options (Derman et al, 1998). Initially, volatility was just an input variable in the Black-Scholes option pricing formula. As every bond has its own yield to maturity (YTM), every option has its own implied volatility; in essence, YTM is the implied return of each bond. In the same way as each YTM is converted into a particular bond price, through the discounting of the corresponding cash flows, each implied volatility is translated, through the Black-Scholes formula, into a particular option price.

The Black-Scholes is, without a doubt, the predominant option-pricing model, even though its assumptions[7] don't hold completely. According to Black-Scholes, the theoretical price of an option is a function of five variables: the underlying price, the strike price, the time to maturity, the interest rate and the volatility of the underlying asset during the maturity of the option. Since many options are listed in organized exchanges, besides their theoretical price, they also have a market price determined by demand and supply, which could be considered as the "fair" price. In this case, using the Black-Scholes formula and the market price, and since the other inputs are objectively known, we can imply the volatility that market participants are expecting for the period until the expiration of the option.

2.2 Implied Volatility Indices

2.2.1 The Original VIX

The calculation of the original VIX (from now on we will refer to the old VIX as VXO, which is the ticker that CBOE currently uses) is based on the Black-Scholes (1973)/ Merton (1973) option valuation model[8]. In particular, it is constructed from the implied volatility of four pairs of call and put options on the S&P100. Those specific options are four near-the-money options for the nearby expiry

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[7] In particular, the assumptions of Black-Scholes are the following: lognormal distribution of stock returns, constant volatility, constant interest rates, full usage of the short selling proceeds, no taxes and transaction costs, infinite divisible securities, continuous trading and risk neutral investors.

[8] The construction of VXO is described in detail in Whaley (1993, 2000) and Fleming et al. (1995).

and four near-the-money options for the second nearby expiry. The nearby options series are considered as the series with the shortest time to expiration (with at least eight days to expiration) and the second nearby option series, as the series of the following expiry. The prices used to compute implied volatilities are the midpoints of the bid and ask prices. VXO is constructed in a way to represent the implied volatility of a hypothetical at-the-money option on S&P100 with a constant maturity of thirty calendar days (22 trading days). The index uses a fixed maturity because implied volatility changes as the expiration of the underlying options changes (Fleming et al., 1995).

2.2.2 The new VIX[9]

The new VIX differs from VXO in two ways: first, the two indices use different underlying assets; the new VIX calculation is based on options written on the S&P 500 index instead of the S&P 100 that the original VIX was using. Of course the two indices are well correlated, but the S&P 500 is considered to be the primary U.S. stock market benchmark. Second, the two indices use a different method of calculation for the implied volatility. The new VIX is independent of any model, as it no longer relies on the Black-Scholes/ Merton model. The mathematical base of the calculation of the new VIX is no longer the implied volatility, but the implied variance. It is based on the concept of fair value of future variance developed by Demeterfi et al. (1999a) and is calculated directly from market observables, which are independent of any pricing model, such as the prices of out-of-the-money call and put options and interest rates. Furthermore, the new VIX calculates expected implied volatility from the prices of a strip of options with a wide range of strike prices and not just at-the-money strikes as the original VIX did.

The concept of a model-free implied variance initiated from the introduction and growth of variance swaps. It made its first appearance in Dupire (1994) and Neuberger (1996) and subsequently, it was enhanced by various researchers, including Carr and Madan (1998), Demeter et al. (1999a, 1999b), Britten-Jones and Neuberger (2000), Bakshi, Kapadia and Madan (2003), Carr and Wu (2005) and Jiang and Tian (2005a). The calculation of the new VIX is based on the work of Demeterfi et al.

[9] A detailed description of the new methodology of the implied volatility index can be found in Chicago Board Options Exchange publication: “The VIX white paper”.

(1999a), but, as Jiang and Tian (2005b) show, its methodology is theoretically equivalent to the model-free implied variance formulated in Britten-Jones and Neuberger (2000).

2.2.3 VDAX

In 1994, the Deutsche Börse launched a family of implied volatility indices based on the DAX index options. In particular, it created eight volatility sub-indices, one for each DAX options expiry date (from 2 to 24 months). Each sub-index is calculated through 2 pairs of options, each with the same exercise price, one above and one below the calculated final forward price for the respective expiry date. The concept of the volatility sub-indices has been designed in order to allow for easier utilization as an underlying asset for a derivative product and the fact that just four ATM options are used per maturity, allows the replication of the indices. The VDAX, the main German implied volatility index, is calculated through a linear interpolation of the two sub-indices which are nearest to a remaining life of 45 days. The calculation of VDAX is quite similar to the original VIX, but differs in two respects: First, the reference period is 45 calendar days, instead of 30 that are used in the former; there is no adjustment to trading days as being done in the VIX. Second, the underlying price for calculating the ATM position is the forward price of the underlying to maturity considered.

Deutsche Börse, following the example of CBOE, on April 20, 2005, replaced VDAX with VDAX-new, which uses the same model-free methodology of the new VIX, and additionally has a rolling fixed maturity of 30 days instead of the original 45 days.

3. Construction of the Greek Implied Volatility Index (GRIV)

3.1 Construction methodology of GRIV

For the calculation of GRIV we use the daily closing prices of the options on the FTSE/ATHEX-20 index, from January 2004 to December 2007, retrieved from the official website of the exchange (www.adex.ase.gr). FTSE/ATHEX-20[10] index was the first Greek equity index that was used as an underlying asset in the derivatives market; options on the particular index were first listed in September 2000. There are totally six European option series trading in Athens Exchange (ATHEX) corresponding to the three months of the quarter cycle (March, June, September, December) and the remaining three nearest months; the expiration date is set on the third Friday of each expiry month.

The closing prices are selected – instead of the price of last trade or the midpoint of the bid and ask prices (the calculation of VIX uses the mid-price of the bid-ask spread) – firstly, because the liquidity of the derivatives market of ATHEX is limited and the daily volume of the options is small and secondly, because the closing price is not simply a last trade price; it is rather a settlement price calculated based on an algorithm (in essence a weighted average) and hence, closing prices are less prone to manipulation or imprecision. The advantage of the closing prices, compared to the mid bid-ask spread, for the illiquid Greek market is also verified by Skiadopoulos.

It is noteworthy that the existence of market making offsets, at least partly, the limited liquidity and depth of the Greek derivatives market, since market makers are obliged to offer continuously bid and ask prices for three pairs of near-the-money options (for the ATM strike and one strike above and below) for the two nearest expiries and for other options upon request (quote request). However, sometimes, prices are not available for an adequate number of options; in that case using the put-call parity we calculate the theoretical price of the deep in-the-money options, which, in fact, don't affect the value of the implied volatility index, since, most of the times, they are not used directly in the actual calculation[11], given that only the call options with strike price higher than K_0 and the put options

[10] FTSE/ATHEX-20 index consists of the twenty larger, in terms of market capitalization, companies, of various sectors, listed in the Athens Exchange.

[11] The reason for calculating them has to do more with the practical function of the model.

with strike price lower than $K_{0,}$ that is, only the OTM options, are used. Nevertheless, in the rare cases that these deep in-the-money options are used in the calculation of GRIV, because of shortage of actual prices, the output should not be considered flawed, since the common practice (Petsas and Porfiris, 2002) of the market participants in ATHEX, especially of the market makers, is to quote bid and ask prices based on the conversion and reversion relationships of the future with the options on FTSE-ATHEX 20[12].

It is worth mentioning that one modification of the typical methodology of implied volatility indices, and indeed a computation weakness of GRIV, has to do with the rollover of the option series used in the calculation as its expiration arrives[13]. For the Greek volatility index[14], the options of the first month are used until the very last day of their life, since there are no available prices for the options of the third month to replace them in the calculations. In this point, we should point out that, since the implied volatilities of each expiry are linearly interpolated in order to calculate GRIV, the weightings, and thus the importance, of the volatility implied by the option series of the first month weaken gradually as their expiration day comes. Thus, the nearest expiration options, as time goes by, have a diminishing effect on the value of GRIV.

The general formula for the model-free calculation of GRIV, which is based solely on observable variables, such as option prices and interest rate, is as follows:

$$\sigma^2 = \frac{2}{\mathrm{T}} \sum \frac{\Delta \mathrm{K}_i}{K_i^2} e^{KT} W(K_i) - \frac{1}{T} \left(\frac{F}{K_0} - 1 \right)^2 \qquad (1)$$

where:

σ GRIV /100 $\Longrightarrow$ GRIV = σ * 100

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[12] Reversion consists of selling the future and simultaneously buying a call and selling a put, while conversion consists of buying the future and simultaneously selling a call and buying a put.

[13] That is, as the expiration of the options of the first month is coming, the calculation of the index should be based on the option series of the second month, which remains, and the option series of the third month, which replace the first month.

[14] In the VIX calculation, the options with eight days to expiry are dropped and the third-month options are added.

$$T = (M_{today} + M_{settlement\_day} + M_{remaining\_day}) / Total\_number\_of\_\min utes\_in\_the\_year$$

Where: M_{today} = number of minutes until midnight today

$M_{settlement\ day}$ = number of minutes from midnight until 14:00 on the settlement day[15]

$M_{remaining\ days}$ = total minutes between today and the settlement day

F Forward index price based on the options prices

$$F = strike\_price + e^{RT} \times (Call - Put)$$

K_i Strike price of out-of-the-money option i - For calls, when $K_i > F$ and for puts, when $K_i < F$

ΔK_i The difference between strike prices[16] (half the distance of the strike prices above and below K_i): $\Delta K_i = \frac{K_{i+1} - K_{i-1}}{2}$

K_o The nearest (round down) strike price to the forward price F

R the risk-free rate[17]

$W(K_i)$ the settlement price for every option with a strike price K_i

In contrast, Skiadopoulos (2004) also proposed an implied volatility index (GVIX) for the Greek market, but his proposed calculation method is based on the Black's (1976) model. Furthermore, due to liquidity issues, he differentiates from original Whaley's method, as he uses four options, instead of eight – two for each of the two expiries. Furthermore, he takes into consideration only the first OTM call and the first OTM put for each expiry and calculates, through linear interpolation, the ATM option implied volatility. Then, the thirty-day rolling fixed maturity implied volatility is derived by interpolating between the implied volatility of the two expiries.

[15] For the last day of trading, that is the third Friday of the expiry month, the final closing/ settlement price is calculated for 2004 and 2005 at 16:00 and for 2006 and 2007 at 14:00.

[16] ΔK for the lower strike price is simply the difference between the lowest strike price and the following higher one and respectively, for the higher strike price, is the between the highest strike price and following lower one.

[17] The risk-free rate used is the appropriate EURIBOR (Euro Interbank Offered Rate), which is published every day by the Fédération Bancaire Européenne (http://www.euribor.org).

3.2 Properties of the Greek Implied Volatility Index (GRIV)

The daily evolution of the GRIV level price from the first trading day of 2004 to the last one of 2007 is shown in Figure 1. The highest price, 30,12%, was reached on May 26, 2006 and the lowest one, that is 14,19%, on November 11, 2005, a total range of 15,93%.

Regarding the descriptive statistics of the index (Table 1), the mean is 19,97% and the median is 19,70%. The positive skewness is implying a longer right tail and the kurtosis, which is above 3 – the value of the normal distribution – implies fatter tails. Furthermore, the fact that the mean of the daily change in GRIV is virtually zero, suggests that there is no trend in GRIV prices. The autocorrelations for the levels of implied volatility are positive, signifying that the autocorrelation function decays exponentially to zero, and suggesting a long-memory process. On the other hand the evidence of negative autocorrelations for daily changes in implied volatility suggests a mean reversion process. The first and second order coefficients are -0,16 and –0,027 respectively. The significance of autocorrelations is tested with the Ljung-Box Q-statistic (Table 2). In order to investigate whether the implied volatility time-series are stationary, the augmented Dickey-Fuller (ADF) unit root tests are conducted. The results of the ADF test statistic at four lags (the number of lags is determined using the Schwarz criterion) and without a time trend[18] are reported in Table 3. Using a 1% significance level, the null hypothesis of a unit root is rejected both in the cases of the level and the changes of the Greek volatility index.

In an effort to detect the normal level for GRIV, we examine the mean value and the range of the index, for the whole period under examination, as well as for every single year (Table 4). It is quite obvious that calendar years 2004 and 2005 were pretty calm, as they were characterized by a tight range in the implied volatility levels and rather low maximum prices. In contrast, years 2006 and 2007 can be described as pretty volatile, as both the maximum price and the range of GRIV are much larger. It is worth mentioning that almost 50% of the daily data points of GRIV in 2006 are larger than the maximum price of 2005, while in 2007, the respective percentage was 25%. In addition, the 16 largest

[18] Due to the nature of volatility, it is plausible to assume that there is no time trend in volatility series in the long run. Nonetheless, the ADF tests were also performed with a time trend and the results are similar; furthermore, the results are not sensitive to the number of lags used.

observations (27,53% - 30,12%) in the four-year period are reported in the global market crisis of May-June 2006. In conclusion, we could comment that it is quite difficult to determine a normal price for the Greek Implied Volatility index, since every period is quite different. However, it should be reported that during the four-year period, GRIV lied between 18,28% and 21,53% half of the times, while on 90% of the total 1.004 trading days closed between 15,47% and 24,87%.

4. Relationship of the implied volatility index with the underlying stock market

The relationship of stock market returns and expected risk/ volatility is well documented in academic research. The pioneers were Markowitz (1952) and Tobin (1958) who were the first to relate the expected return of a portfolio with its standard deviation, establishing the modern portfolio theory, which seeks the maximization of return for a given level of risk. Sharpe (1964) presented a model for measuring portfolio risk along with the return that investors should expect for bearing that risk, the celebrated Capital Asset Pricing Model (CAPM). In the following years, numerous researchers have recorded the empirical relationship between stock market returns and expected volatility. Among others, Black (1976), Christie (1982) and French, Schwert and Stambaugh (1987) provided evidence of a strong negative relationship of market returns and ex post calculated expected volatility. Furthermore, Black (1976) and Schwert (1989, 1990) documented the asymmetry of the return – volatility relationship; that is the increase in expected volatility related to a given decrease of the stock market price is larger than a respective decrease in expected volatility related to an equal increase of the stock market price.

In the implied volatility indices literature, the evidence on a strongly asymmetric negative contemporaneous correlation between the implied volatility index and the underlying index returns, although limited, is overwhelming. In particular, Fleming et al (1995), Whaley (2000), Giot (2005) and Carr and Wu (2006) all identify the statistically significant negative contemporaneous relationship between VIX and S&P100 returns, also confirming the asymmetric effect. With reference to studies dealing with other volatility indices – Simon (2003) and Giot (2005) for the Nasdaq 100 Volatility Index (VXN), Skiadopoulos (2004) for the Greek GVIX, Gonzalez and Novales (2007) for the Spanish VIBEX-NEW and finally Ting (2007) for the Korean KIX – the findings are consistent.

Guo (2002) shows how the negative risk-return relation documented in these studies can be reconciled with the positive risk-return trade-off derived from the above stated theories of modern portfolio theory. According to Guo, due to the fact that volatility is serially correlated, returns relate positively to past volatility and negatively to contemporaneous volatility. In particular, past variance is positively related to returns because it contains information about conditional variance or risk. On the other hand, the contemporaneous relation between returns and risk is negative because of a volatility feedback effect; that happens because a positive innovation in variance at present implies higher expected future variance and, thus, higher expected future returns. In order for future expected returns to be higher though, the innovation in variance must be accompanied by a drop in the stock index level today.

4.1 Data

In this study, the Greek Implied Volatility index is considered the proxy for expected risk and the FTSE/ATHEX-20 index proxies the stock market, in an effort to examine the relationship between volatility and stock returns. Figure 2 shows the daily evolution of the two indices for the period 2004 – 2007. For the empirical analysis the logarithmic returns are calculated:

$$r_t = \ln\left(\frac{FTSE/ATHEX\,20_t}{FTSE/ATHEX\,20_{t-1}}\right) \qquad (2)$$

We note that besides the daily returns (1.003 observations), we also calculate the weekly returns (207 observations) of FTSE/ATHEX-20 from Wednesday to Wednesday, in order to avoid any miscalculation issues regarding on the one hand, the expiration of options on every third Friday of the month and on the other, any pricing anomalies in stock prices related to the week of the day or weekend effect[19].

The mean daily return of the underlying index is 0.0833% and its standard deviation is 1,07%, while the mean weekly return and standard deviation are 0,385% and 2,42% respectively. The return time series exhibits negative skewness, that is longer left tail and the kurtosis suggests fatter tails as it exceeds the value for the normal distribution (Table 1). The Jarque-Bera statistic robustly rejects the

[19] Weekend effect is the reported phenomenon in stock markets according to which stock returns in Mondays are significantly lower than the returns of the preceding Friday.

normal distribution hypothesis for both daily and weekly returns. The autocorrelation is close to zero, but the Ljung-Box Q statistic isn't statistical significant and thus, we cannot reject the no-serial correlation hypothesis (Table 2). Also, the results of the unit-root tests, using again the augmented Dickey-Fuller test (Table 3) indicate that the time-series of both daily and weekly stock market returns are stationary.

4.2 Methodology

Three methods are employed in order to test the relationship of stock market returns and implied volatility, specifically correlation and regression analysis and the Granger causality test. For the empirical analysis, we follow the example of Fleming et al. (1995), and we use the changes on the value of GRIV[20] rather than its level. According to Fleming et al., this selection is based on three reasons: first, both academics and practitioners are interested in the changes or innovations of expected volatility. Second, if stock prices follow a random walk, assessing the relationship stock and volatility indices in levels may prove to be spurious. At last, implied volatility indices' levels also appear to be near random walk.

Initially, we check the correlation of the daily returns of the underlying index, FTSE/ATHEX-20, with the daily changes of GRIV. In the regression analysis, we test the relationship of the weekly returns of FTSE/ATHEX-20 with the weekly changes of GRIV ($\Delta GRIV_t$)[21].

$$R_t \text{ FTSE/ATHEX-20} = c + b\,\Delta GRIV_t \qquad (3)$$

Subsequently, the asymmetric relationship of FTSE/ATHEX-20 and GRIV is examined, by separating the changes of GRIV into positive ($\Delta^+ GRIV_t$) and negative ($\Delta^- GRIV_t$) and regressing them against the returns of the underlying index.

$$R_t \text{ FTSE/ATHEX-20} = a\,\Delta^+ GRIV_t + b\,\Delta^- GRIV_t \qquad (4)$$

An additional statistical measure for evaluating the relationship of implied volatility with the underlying index returns is the Granger causality test. A time series y is said to cause another time

[20] $\Delta GRIV_t = GRIV_t - GRIV_{t-1}$, where GRIV is the value of the index.

[21] Weekly returns and changes from Wednesday to Wednesday.

series x, if past values of y improve the prediction of the current value of x. The concept of "causality" is much more limited than that of the common use of the term. According to Hamilton (1994), "a variable y fails to Granger cause x if for all s > 0 the mean squared error (MSE) of a forecast of x_{t+s} based on (x_t, x_{t-1}, . . .) is the same as the MSE of a forecast of x_{t+s} that uses both (x_t, x_{t-1}, . . .) and (y_t, y_{t-1}, . . .)". The Granger causality test assumes that variables are generated by a stationary process, that means that the properties of a time series are not affected by the time origin.

4.3 Empirical Results

For the total 1003 daily observations, the correlation coefficient is equal to –0,09. This number is lower than the reported coefficient of Skiadopoulos (-0,17). Nevertheless, the correlation coefficient increases significantly if, instead of daily data points, weekly observations are used; in this case, using 207 observations, the coefficient reaches -0,32.

Regarding the regression analysis, the results confirm the existing literature, as there is a statistical significant negative relationship between FTSE/ATHEX-20 and GRIV. The regression output (Table 5) is as follows:

$$R_t \text{ FTSE/ATHEX-20} = 0.003944 + -0.598515\ \Delta GRIV_t$$

The positive coefficient of the constant is considered reasonable given the fact that the period under review was extremely positive for the Athens Exchange stock returns[22]. The negative coefficient of $\Delta GRIV_t$ can be interpreted as follows; if, for example, GRIV loses 100 basis points (1%), the incremental return of FTSE/ATHEX-20 (without considering the constant c) will be +0,5985%. The opposite applies in case of a positive change of GRIV.

Next, the asymmetric relationship of FTSE/ATHEX-20 and GRIV is examined. The findings suggest that a positive change in the implied volatility index results in a larger negative return of the stock index, than an equivalent negative change:

$$R_t \text{ FTSE/ATHEX-20} = -0.668748\,\Delta^{+} GRIV_t + -0.482015\,\Delta^{-} GRIV_t$$

[22] FTSE/ATHEX-20 index stood at 1.194,23 on 02/01/2004 and on 31/12/2007 stood at 2.752,48 (total return +230%).

The meaning of the above regression is that if GRIV declines by 100 b.p. (-1%), the return of the underlying stock index will be +0.482%, while, if GRIV goes up by 100 b.p. (+1%), the return will be –0.6687% (Table 6).

The asymmetry of volatility[23], in stock markets, according to Black (1976), is caused by a leverage effect, that is, when the stock price of company decreases, the debt-to-equity ratio increases, leading to higher volatility of equity returns. The opposite holds, when stock prices rise. It is noteworthy, that the new model-free construction of implied indices uses a wider range of call and put options and thus deals more effectively with volatility asymmetry.

In concluding, Table 7 includes the results of the Granger causality test for two lags; the change of GRIV Granger causes the returns of FTSE/ATHEX-20 (the null hypothesis is rejected) and the opposite also holds, that is the returns of FTSE/ATHEX-20 cause the change of GRIV. The results are consistent even when the time lags increase. Our findings contradict Skiadopoulos, who reported that only the returns of FTSE/ATHEX-20 Granger cause the change in volatility and the opposite isn't true.

5. Volatility spillover effects

5.1 Data

In this section, we examine the transmission effects of the volatility of the New York Stock Exchange (NYSE), as proxied by VIX, and the volatility of the Deutsche Börse, as proxied by VDAX, on the volatility of the Greek market, as proxied by GRIV[24]. Figure 3 shows the daily evolution of GRIV, VIX and VDAX for the period 2004-2007; to the extent that the spread between the two volatility indices measures the difference of the riskiness of the two countries, it is normal to record that the average price for GRIV, for the period under review, lies is higher than the average prices of VIX and VDAX. In particular, as shown in Table 8, the mean value of GRIV is 19,97% (median 19,70%), while the respective number for the VIX is 14,65% (13,63%) and for the VDAX 17,83% (17,27%).

[23] A negative stock return leads to higher volatility, than an equivalent positive return.

[24] All three indices are calculated based on the same model-free methodology.

In order to investigate whether the implied volatility time-series are stationary, the augmented Dickey-Fuller (ADF) unit root tests are conducted. The results of the ADF test statistic at four lags and without a time trend show that, using the 1% significance level, the null hypothesis of a unit root is rejected only in the case of the Greek volatility index, whereas a unit root is not rejected for the other series[25]. However, after differencing, all the series are stationary, as the null of a unit root is soundly rejected for all three time-series (at 1% significance level).

As a preliminary analysis of the cross-dynamics of the implied volatility indices the contemporaneous and one-lag cross correlation coefficients for both the levels and the daily changes are calculated. In particular, the correlation coefficient of the level of GRIV with the contemporary level of VIX is +0,28, while with the level of the previous day, is +0,30. Respectively, the correlation of the daily changes of the two indices is +0,08 and +0,12[26]. On the other hand, the correlation of the level of GRIV with the contemporary level of VDAX is higher, that is +0,38 – very close to the correlation with the level of the previous day, which is +0,39. The daily changes correlations are +0,116 και +0,125 respectively. Thus, the results indicate that the implied volatility indices are correlated.

In concluding this section, we should note that due to the time difference, the U.S. underlying market opens for trading exactly at the same time that the continuous trading stops in ATHEX, that is at 16:30 Greek time[27] – which is also the ending time for the calculation of the options closing prices – therefore the prices and returns of the two indices for the same calendar day, cannot be technically characterized as contemporaneous. That's why, in the context of this paper, we mainly take into consideration the price of VIX of the previous day (one time lag). Certainly, due to the dual listings of US stocks in the European bourses and the virtually continuous operation of the US derivatives exchanges[28], we also consider the prices and changes of the two indices of the same calendar day. On

[25] The null hypothesis of a unit root for the levels of the US and the German volatility index is rejected using the 5% significance level.

[26] The respective coefficients in Skiadopoulos are smaller, that is +0,13 for the levels and –0,02 for the daily changes.

[27] After 16:30, the call auctions take place; the trading on the closing price is allowed until 17:00, when the stock exchange closes for the day.

[28] The electronic trading platform of Chicago Merchantille Exchange, known as GLOBEX, operates 23 hours in the day.

the other hand, the German market closes at 18:30 Greek time, thus there are no implications regarding the time differences.

5.2 Methodology

In order to examine the relationship between the markets, the vector autoregressive analysis (VAR) and the Granger causality test are used. The econometric analysis of implied volatility crossovers could be done either in levels or in changes. Given that the time series of implied volatility changes are stationary, vector autoregressive (VAR) modeling and Granger causality test are performed for the differenced series, in order to examine the cross-dynamics of implied volatilities. Furthermore, the levels of the indices incorporate idiosyncratic aspects, like the specific country risk, and additionally, it makes intuitively and logically more sense to assume that the change in the level of VIX or VDAX will lead to a change in the level of the Greek implied index (Aboura and Villa, 1999). Finally, implied volatility is not an unbiased measure of realized volatility (Poon and Granger, 2003) and thus, using the changes in the implied volatility levels, reduces the effect of this bias.

The vector autoregression (VAR), popularized by Sims (1980), is commonly used for capturing the dynamic structure of interrelated time series. VAR analyzes every endogenous variable as a function of the lagged values of all the endogenous variables in the system. The mathematical form of the used VAR system is:

$$\Delta GRIV = a^{GRIV} + \sum_{i=1}^{n} b_i^{GRIV} \Delta VIX_{t-1} + \sum_{i=1}^{n} c_i^{GRIV} \Delta VDAX_{t-1} + \sum_{i=1}^{n} d_i^{GRIV} \Delta GRIV_{t-1} + \varepsilon^{GRIV} \tag{5}$$

$$\Delta VIX = a^{VIX} + \sum_{i=1}^{n} b_i^{VIX} \Delta VIX_{t-1} + \sum_{i=1}^{n} c_i^{VIX} \Delta VDAX_{t-1} + \sum_{i=1}^{n} d_i^{VIX} \Delta GRIV_{t-1} + \varepsilon^{VIX}$$

$$\Delta VDAX = a^{VDAX} + \sum_{i=1}^{n} b_i^{VDAX} \Delta VIX_{t-1} + \sum_{i=1}^{n} c_i^{VDAX} \Delta VDAX_{t-1} + \sum_{i=1}^{n} d_i^{VDAX} \Delta GRIV_{t-1} + \varepsilon^{VDAX}$$

Where, ΔGRIV, ΔVIX and ΔVDAX, the daily changes of the implied volatility indices, are the endogenous variables, α, b_i and c_i are matrices of coefficients to be estimated, and e is a vector of innovations that are not serially correlated – they might be contemporaneously correlated with each other – and are also uncorrelated with the past prices of the endogenous variables.

To define appropriate lag lengths of the VAR model, final prediction error (FPE), Akaike's information criterion (AIC), Hannan-Quinn's information criterion (HQ), Schwarz's criterion (SC) and likelihood ratio tests (LR) are used. A VAR(4) model is chosen since the results from both FPE and AIC suggest a lag length of four, while according to Schwarz's and Hannan-Quinn's criteria a lag length of two and three respectively is appropriate. Likelihood ratio test, on the other hand, selects a lag length of ten. Furthermore, the adequacy of the lag length is confirmed by the fact that there is no autocorrelation in the residual terms.

In the following section, the empirical findings of the VAR analysis and the Granger causality test are reported. Furthermore, the speed at which the volatility movements are transmitted from the leading markets, that is the US and Germany, to the Greek market is tested and the extent that a movement in the American or German market can explain the shock in the Greek market is examined.

5.3 Empirical Results

In Table 9, the summary statistics of the estimation results of VAR system are reported. The F-statistics show that the VAR(4) model is highly significant, the adjusted R^2 ranges from 0.041 to 0.127. The coefficients, when analysing the daily change of GRIV, varies from 0,019 to 0,75. We notice that the changes of VIX are, in general, statistically more robust and have the higher coefficients.

The contemporaneous correlations of the residuals[29] of the daily changes of the three implied volatility indices are presented in Table 10 and demonstrate instantaneous causality between the markets, that is the degree that new information that generates an abnormal return in one market is shared within the same period by the other two markets. The empirical results are totally consistent with the previously reported correlation coefficients.

[29] The residuals or innovations characterize abnormal volatility index changes not forecasted despite the available past information (Aboura and Villa, 1999).

Subsequently, we apply two empirical uses of the VAR, namely the impulse response analysis and the variance decomposition. An impulse response function, in general, traces the reaction of an endogenous variable to one of the innovations. In particular, it tracks down the effect of a one standard deviation shock to one of the innovations on current and future values of the daily changes of the other two implied volatility indices. The results (Table 11) show the interaction of the three indices, proving that there is, of course, no effect either on VIX or VDAX from a Greek shock; on the other hand, the answer of the GRIV to a shock on VIX escalates in the second day and, quite surprisingly, the Greek response lasts for five days before it disappears. Regarding the relationship with the biggest Eurozone market, we notice that the Greek response is much smaller – almost half compared to the response in the US shock – and moreover it only lasts for two days.

Variance decomposition, on the other hand, provides a different method of describing the system dynamics. Specifically, it separates the variation in an endogenous variable into the component shocks to the endogenous variables and thus, it gives information about the relative importance of each random innovation to the three variables in the VAR. The empirical findings of the variance decomposition indicate the negligible influence of the Greek Implied Volatility index to the US and German one, but also show that almost five percent of the Greek error variance can be explained by the VIX innovations and a much lower percentage, that is 1,5 percent, can be explained by the VDAX innovations (Table 12).

The results of the Granger causality test are reported in (Table 13). Regarding VIX and GRIV, the Granger test for four time lags, proves that the daily change of VIX causes the change of GRIV, that is, the null hypothesis is rejected, but the opposite doesn't stand, that is, the null hypothesis that ΔGRIV doesn't Granger cause ΔVIX cannot be rejected. These findings contradict Skiadopoulos, proving that the correlation of the volatility of stock market returns across the globe have increased dramatically. Similarly, regarding the relationship of VDAX and GRIV, the Granger causality test again for four time lags, proves that the daily change of VDAX causes the change of GRIV, but the opposite doesn't stand, that is, the null hypothesis that ΔGRIV doesn't Granger cause ΔVIX cannot be rejected.

6. Conclusion

This article describes the construction of an implied volatility index for the Greek stock market based on a model-free methodology that uses option prices summations. This is the methodology used for the calculation of the new VIX and differs significantly from the "traditional" volatility implied by the Black and Scholes formula, which assumes that stock market returns follow a lognormal distribution and that volatility remains constant throughout the maturity of the option. Additionally, this methodology is computationally less intensive and theoretically more sound for the illiquid and immature Greek derivatives market.

After calculating the Greek Implied Volatility index (GRIV) and describing its basic descriptive statistics, we analysed its information content regarding the returns of the underlying stock index, namely the FTSE/ATHEX-20. In particular, the three methods employed – cross correlations, regression analysis and Granger causality test – proved the statistically significant negative relationship between the changes of GRIV and the returns of FTSE/ATHEX-20. Furthermore, we also confirmed the asymmetry of this relationship, as we showed that a positive innovation in GRIV has a larger negative effect on the underlying index return, than an analogous negative innovation has. The fact that the results are consistent with existing literature verifies that the new model-free methodology is also successfully applicable to less developed and liquid markets as the Greek one.

In the last section of the paper, we analyzed the relationship among GRIV, VIX and VDAX, which are the implied volatility proxies of two of the most influential global markets. The econometric analysis included a vector autoregression (VAR) analysis and Granger causality tests. The empirical findings showed a spillover effect from the leading markets to the developing Greek one with the influence of the US volatility index to be more pronounced. The findings suggest that forecasting the change of GRIV is enhanced by the inclusion of the daily change of VIX and VDAX.

Finally, future research regarding the Greek implied volatility index could include testing its ability to forecast the future realized volatility of FTSE/ATHEX-20. Additionally, the forecast ability of a potential combination of historical and implied volatility could be tested.

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APPENDIX

Table 1 – Summary Statistics GRIV, ΔGRIV and FTSE/ATHEX 20 returns

	GRIV	ΔGRIV	Daily returns	Weekly returns
Mean	0.199715	2.34E-05	0.000833	0.003853
Median	0.197020	-2.00E-05	0.001261	0.007905
Maximum	0.301160	0.060980	0.052403	0.048296
Minimum	0.141930	-0.049590	-0.058094	-0.089796
Std. Dev.	0.027232	0.006736	0.010770	0.024247
Skewness	0.578047	0.446838	-0.446822	-0.899185
Kurtosis	3.813703	20.26011	5.022973	3.951469
Observations	1004	1003	1003	207

Table 2 – Autocorrelation of GRIV, ΔGRIV and FTSE/ATHEX 20 returns

Autocorrelations	1	2	3
GRIV	0.969**	0.948**	0.929**
ΔGRIV	-0.160**	-0.027**	0.112**
Daily returns	0.061	0.003	-0.039
Weekly returns	0.042	-0.132	0.024

** Identifies correlation significant at the 1% level
* Identifies correlation significant at the 5% level

Table 3 – Unit root tests of GRIV, ΔGRIV and FTSE/ATHEX 20 returns

Augmented Dickey-Fuller (ADF) test	
GRIV	-3.741**
ΔGRIV	-13.37**
Daily returns	-29.77**
Weekly returns	-13.76**

Critical Value for 1% significance level: -3.44**
5% significance level: -2.86*

Table 4 – Percentiles of GRIV

	Mean	Median	Range	Minimum Price	Maximum Price	# of Observations
2004-2007	19.97%	19.70%	15.92%	14.19%	30.12%	1004
2004	19.70%	19.36%	6.40%	17.42%	23.81%	253
2005	17.59%	17.74%	7.48%	14.19%	21.67%	250
2006	21.91%	21.59%	14.77%	15.35%	30.12%	249
2007	20.69%	20.55%	12.30%	15.18%	27.48%	252

Percentiles						
99.00%	**95.00%**	**75.00%**	**50.00%**	**25.00%**	**5.00%**	**1.00%**
27.81%	24.87%	21.53%	19.70%	18.28%	15.47%	14.58%
22.56%	22.19%	20.76%	19.36%	18.44%	17.82%	17.56%
21.11%	20.65%	18.94%	17.73%	16.11%	14.61%	14.40%
29.93%	27.63%	23.50%	21.59%	20.14%	17.95%	15.88%
26.94%	25.70%	21.63%	20.19%	18.89%	15.92%	15.45%

Table 5 – R FTSE/ATHEX-20 = c + b ΔGRIV

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.003944	0.001525	2.586720	0.0104
ΔGRIV	-0.598515	0.168749	-3.546785	0.0005

R-squared	0.099683	Mean dependent var	0.003853
Adjusted R-squared	0.095291	S.D. dependent var	0.024247
S.E. of regression	0.023063	Akaike info criterion	-4.691559
Sum squared resid	0.109040	Schwarz criterion	-4.659359
Log likelihood	487.5764	F-statistic	22.69764
Durbin-Watson stat	1.948361	Prob(F-statistic)	0.000004

Table 6 – R FTSE/ATHEX-20 = α Δ^{+}GRIV + β Δ^{-}GRIV

Variable	Coefficient	Std. Error	t-Statistic	Prob.
$\Delta^{+}GRIV_t$	-0.668748	0.163779	-4.083224	0.0001
$\Delta^{-}GRIV_t$	-0.482015	0.202330	-2.382322	0.0181

R-squared	0.075416	Mean dependent var	0.003853
Adjusted R-squared	0.070906	S.D. dependent var	0.024247
S.E. of regression	0.023372	Akaike info criterion	-4.664962
Sum squared resid	0.111979	Schwarz criterion	-4.632762
Log likelihood	484.8236	Durbin-Watson stat	1.864150

Table 7 – Granger Causality Test (ΔGRIV and return of FTSE/ATHEX-20)

Null Hypothesis (Lags: 2)	Obs	F-Statistic	Probability
ΔGRIV does not Granger Cause R FTSE/ATHEX20	205	6.00952	0.00292
R FTSE/ATHEX20 does not Granger Cause ΔGRIV		5.91287	0.00320

Table 8 – Summary Statistics of implied volatility indices (Jan 2004 – Dec 2007)

	VIX	VDAX	GRIV	ΔVIX	ΔVDAX	ΔGRIV
Mean	0.146509	0.178381	0.199715	8.02E-05	-1.28E-05	2.34E-05
Median	0.136300	0.172700	0.197020	-0.000550	-0.000600	-2.00E-05
Maximum	0.310900	0.314200	0.301160	0.071600	0.043400	0.060980
Minimum	0.098900	0.116500	0.141930	-0.069900	-0.045500	-0.049590
Std. Dev.	0.037127	0.037060	0.027232	0.010701	0.009443	0.006736
Skewness	1.564687	0.726608	0.578047	0.278645	0.511586	0.446838
Kurtosis	5.597914	3.070032	3.813703	11.01142	6.021508	20.26011
Observations	979	1000	1004	978	999	1003

Table 9 – Vector Autoregression Estimates

Sample (adjusted): 6 1000 Standard errors in ( ) & t-statistics in [ ]

	ΔVIX	ΔVDAX	ΔGRIV
ΔVIX(-1)	-0.189164	0.372588	0.070952
	(0.04007)	(0.03382)	(0.02513)
	[-4.72094]	[11.0182]	[2.82296]
ΔVIX(-2)	-0.153603	0.174928	0.072650
	(0.04601)	(0.03883)	(0.02886)
	[-3.33839]	[4.50492]	[2.51724]
ΔVIX(-3)	0.012355	0.145811	0.038360
	(0.04621)	(0.03900)	(0.02899)
	[0.26736]	[3.73883]	[1.32337]
ΔVIX(-4)	-0.050385	0.042272	0.032199
	(0.04312)	(0.03639)	(0.02705)
	[-1.16860]	[1.16173]	[1.19058]
ΔVDAX(-1)	0.063577	-0.304239	0.055235
	(0.04761)	(0.04018)	(0.02987)
	[1.33526]	[-7.57133]	[1.84940]
ΔVDAX(-2)	0.079733	-0.105029	0.019051
	(0.05018)	(0.04234)	(0.03147)
	[1.58907]	[-2.48031]	[0.60530]
ΔVDAX(-3)	-0.010444	-0.111410	0.075231
	(0.04942)	(0.04171)	(0.03100)
	[-0.21132]	[-2.67117]	[2.42680]
ΔVDAX(-4)	-0.006762	-0.088952	0.025127
	(0.04510)	(0.03806)	(0.02829)
	[-0.14996]	[-2.33731]	[0.88831]
ΔGRIV(-1)	-0.115777	-0.014625	-0.206700
	(0.05550)	(0.04684)	(0.03481)
	[-2.08618]	[-0.31225]	[-5.93777]
ΔGRIV(-2)	-0.073742	0.009736	-0.087663
	(0.05648)	(0.04767)	(0.03543)
	[-1.30561]	[0.20426]	[-2.47439]
ΔGRIV(-3)	0.009061	-0.049059	0.092654
	(0.05595)	(0.04722)	(0.03510)
	[0.16193]	[-1.03895]	[2.63998]
ΔGRIV(-4)	-0.051998	0.004406	0.025758
	(0.05763)	(0.04863)	(0.03615)
	[-0.90231]	[0.09059]	[0.71258]
C	-9.97E-05	-0.000216	-7.00E-05
	(0.00036)	(0.00030)	(0.00023)
	[-0.27726]	[-0.71107]	[-0.31065]
R-squared	0.054314	0.139415	0.096096
Adj. R-squared	0.040994	0.127294	0.083365
Sum sq. resids	0.095029	0.067682	0.037390
S.E. equation	0.010561	0.008913	0.006625
F-statistic	4.077736	11.50203	7.548189
Log likelihood	2715.421	2862.194	3118.850
Akaike AIC	-6.248372	-6.587731	-7.181157
Schwarz SC	-6.176793	-6.516153	-7.109579
Mean dependent	-0.000108	-0.000199	-4.35E-05
S.D. dependent	0.010784	0.009541	0.006919
Determinant resid covariance (dof adj.)		2.74E-13	
Determinant resid covariance		2.62E-13	
Log likelihood		8847.175	
Akaike information criterion		-20.36572	
Schwarz criterion		-20.15099	

Table 10 – Residual correlations of VAR(4)

	ΔVIX	ΔVDAX	ΔGRIV
ΔVIX	1.000000	0.530366	0.113348
ΔVDAX	0.530366	1.000000	0.120989
ΔGRIV	0.113348	0.120989	1.000000

Table 11 – Impulse response analysis

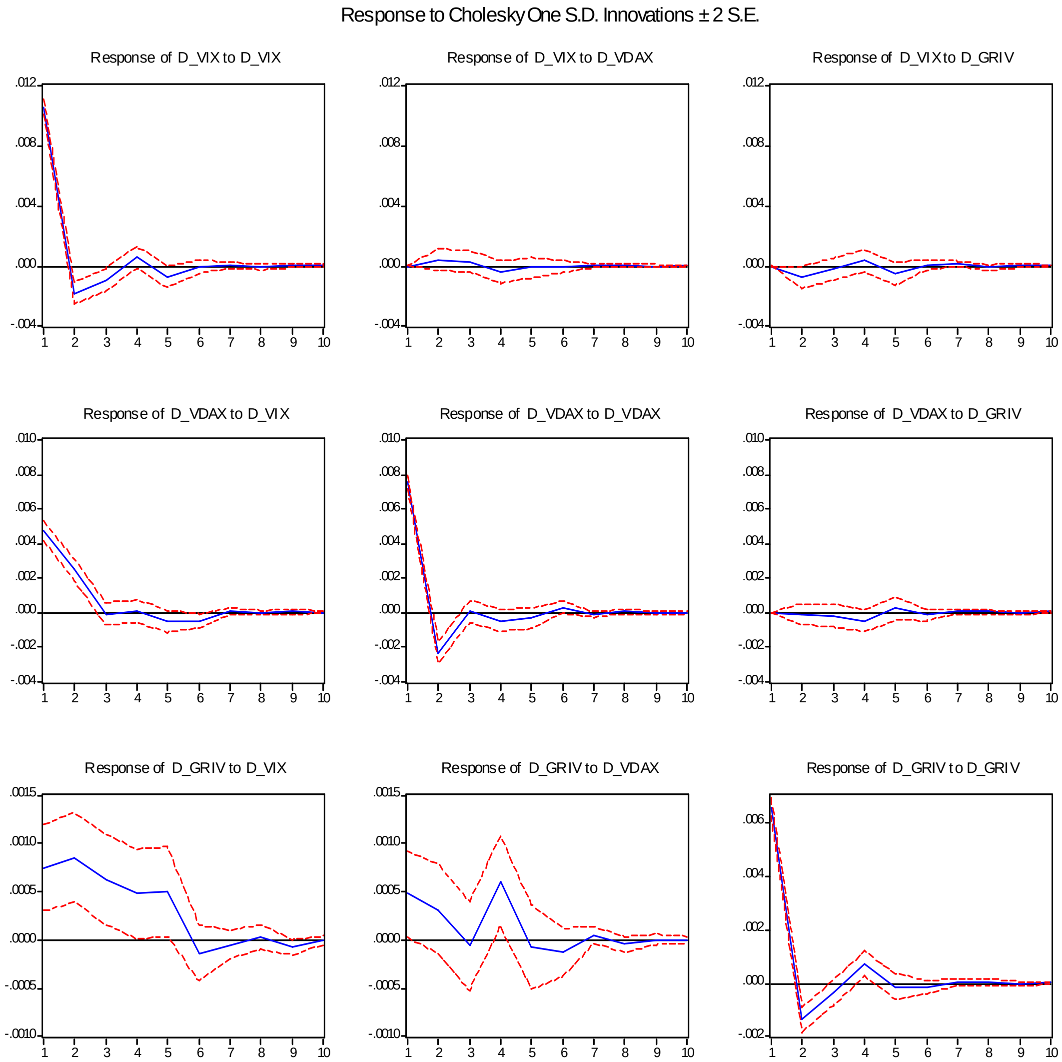

Table 12 – Variance decomposition

Variance Decomposition of Δ_GRIV:				
Period	**S.E.**	**ΔVIX**	**ΔVDAX**	**ΔGRIV**
1	0.006625	1.284775	0.515572	98.19965
2	0.006823	2.781889	0.704572	96.51354
3	0.006861	3.581998	0.704656	95.71335
4	0.006942	3.968133	1.458623	94.57324
5	0.006962	4.466678	1.462146	94.07118
6	0.006966	4.498938	1.493188	94.00787
7	0.006967	4.503280	1.498322	93.99840
8	0.006967	4.505045	1.502450	93.99250
9	0.006968	4.516205	1.502289	93.98151
10	0.006968	4.516203	1.502334	93.98146

Cholesky Ordering: ΔVIX, ΔVDAX, ΔGRIV

Table 13 – Granger Causality Tests

Null Hypothesis (Lags: 4):	**Obs**	**F-Statistic**	**Probability**
ΔVDAX does not Granger Cause ΔVIX	865	0.90640	0.45955
ΔVIX does not Granger Cause ΔVDAX		31.3840	2.0E-24
ΔGRIV does not Granger Cause ΔVIX	874	1.69041	0.15010
ΔVIX does not Granger Cause ΔGRIV		10.9812	1.1E-08
ΔGRIV does not Granger Cause ΔVDAX	985	0.20229	0.93715
ΔVDAX does not Granger Cause ΔGRIV		11.0078	9.8E-09

Figure 1 – Daily price of GRIV (period 2004 – 2007)

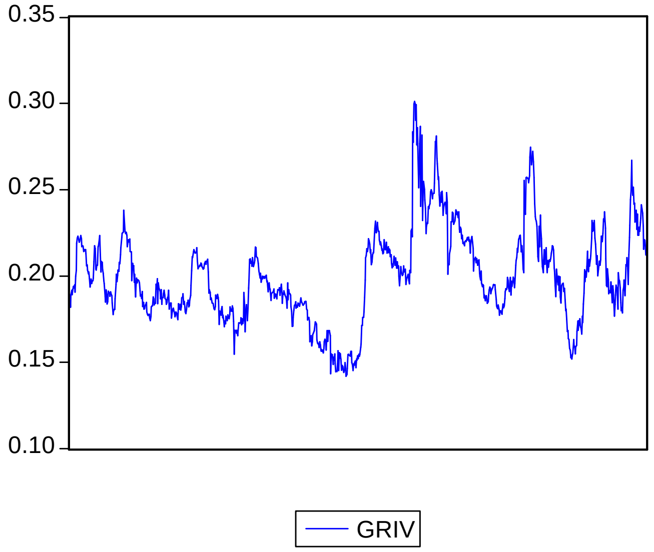

Figure 2 – Daily price of GRIV and FTSE/ASE 20 (period 2004 – 2007)

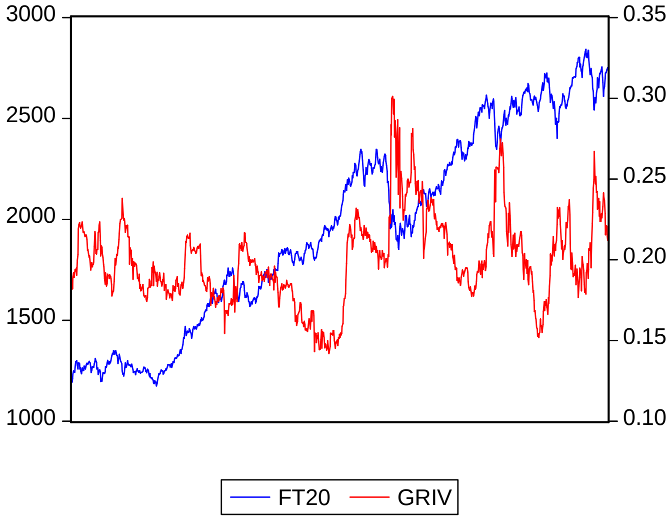

Figure 3 – Daily price of GRIV, VIX and VDAX (period 2004 – 2007)