The Greek Implied Volatility Index: Construction and Properties

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Forthcoming in Applied Financial Economics

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Abstract

There is a growing literature on implied volatility indices in developed markets. However, no similar research has been conducted in the context of emerging markets. In this paper, an implied volatility index (GVIX) is constructed for the fast developing Greek derivatives market. Next, the properties of GVIX are explored. In line with earlier results, GVIX can be interpreted as a gauge of the investor's sentiment. In addition, we find that the underlying stock market can forecast the future movements of GVIX. However, the reverse relationship does not hold. Finally, a contemporaneous spillover between GVIX and the US volatility indices VXO and VXN is detected. The results have implications for portfolio management.

JEL Classification: G10, G11, G13, G15.

Keywords: Granger Causality Tests, Implied Volatility Indices, Implied Volatility Spillover, Volatility Derivatives.

1. Introduction

There is a growing literature on the construction and the properties of implied volatility indices in developed markets (Fleming et al., 1995, Moraux et al., 1999, Whaley, 1993, and 2000, Simon, 2003, and Wagner and Szimayer, 2004). However, no research has been conducted in the context of emerging derivatives markets. The objective of this paper is twofold. First, it constructs an implied volatility index for the fast growing Greek derivatives market. Second, the properties of the constructed index are studied. This allows examining for the first time some "aggregate" properties of the implied volatilities of this rapidly evolving market.

The study of the construction and of the properties of implied volatility indices has been primarily motivated by the increasing need to create derivatives on volatility (volatility derivatives, see Brenner and Galai, 1989, 1993). These are instruments whose payoffs depend explicitly on some measure of volatility. Hence, they are the natural candidates for speculating and hedging against changes in volatility (volatility risk). Volatility risk has played a major role in several financial disasters in the past 25 years (e.g., Barings Bank, Long-Term-Capital Management). Many traders also profit from the fluctuations in volatility (see Carr and Madan, 1998, for a review on the volatility trading techniques); Guo (2000), and Poon and Pope (2000) find that profitable volatility trades can be developed in the currency and index option markets, respectively. In March 2004, the Chicago Board Options Exchange (CBOE) introduced volatility futures, and it announced the imminent introduction of volatility options.

A volatility index can serve as the underlying asset to volatility derivatives; it would play the same role as the market index plays for options and futures on the index[1]. The volatility index can also be used for Value-at-Risk purposes (Giot, 2002b), to identify buying/selling opportunities in the stock market (Stendahl, 1994, Whaley, 2000), and to forecast the future market volatility (see Fleming et al., 1995, Moraux et al., 1999, Giot, 2002b, Simon, 2003).

Gradually, the derivatives exchanges have started constructing implied volatility indices. In 1993, CBOE introduced an implied volatility index, named VIX (currently renamed to VXO; hereafter we will use the latter ticker) that is based on the S&P 100 index options. In 1994, the German Futures and Options Exchange launched an implied volatility index (VDAX) based on DAX index options. In 1997, the French Exchange market MONEP created two volatility indices (VX1, VX6) that reflect the synthetical at-the-money implied volatilities of the CAC-40 index options. In 2000, CBOE introduced the Nasdaq Volatility Index (VXN) that is derived from the implied volatility of Nasdaq-100 Index (NDX) options.

The methodology used to construct the above mentioned volatility indices, is similar to this of VXO. However, the construction technique of VXO is quite data demanding. It requires two option series trading every day. Two pairs of options are used from each series; each pair consists of one call, and one put with the same strike. In total, eight options must be used. The implementation of the method assumes a very liquid market. These constraints may not be met in emerging option markets that are less liquid than CBOE[2].

In this paper, first an implied volatility index is constructed for the Greek option market (Athens Derivatives Exchange, ADEX). The construction is based on an alternative to the VXO method so as to respect the liquidity constraints typically encountered in emerging markets. Next, the properties of the constructed Greek Volatility Index (GVIX) are studied. The focus is on the relationship of GVIX with the underlying stock index (FTSE/ASE-20) rather than on the power of GVIX to forecast the realized volatility. Finally, the relationship of the GVIX to VXO and VXN is studied (implied volatility spillovers). Despite the voluminous literature on the linkages and interactions between international stock prices/volatilities (see for example, Malliaris and Uruttia, 1992, Arshanapali and Doukas, 1993, and Koutmos, 1996, among others), there has not been much attention paid to the transmission of implied volatilities across markets. Gemmill (1996) explored whether the changes in the implied volatility smile in England are correlated with those of U.S. over the period 1985-1990. Gemmill and Kamiyama (1997) examined whether the implied volatility transmits across the Japanese, British, and American markets over the period 1992-95. Implied volatility propagation is of particular importance to option portfolio managers; it affects option prices and hedge ratios, and it may indicate changes in expected volatility.

The construction of an implied volatility index for the Greek market and the study of its properties deserve attention for a number of reasons. The Greek option market was founded in 2000, and it can be characterized as an emerging market. Despite it's short life, it has experienced a tremendous growth; the volume has increased from 2,381,260 to 7,387,574 contracts from 2000 to 2002 (an increase of 210%!). The relationship of the Greek volatility index with the spot market may be of particular importance to investors with positions in stocks. This is because the Greek stock market has experienced a remarkably continuous crisis from mid 1999 to the beginning of 2003; it has declined about 4,000 index points. Finally, given the nature of the Greek market, it is worth investigating the implied volatility spillover between an emerging and a developed market. To the best of our knowledge, this is the first study that examines the properties of a measure of implied volatility in the Greek option market, and it's potential use for portfolio management purposes.

An inverse relationship between changes in GVIX and the FTSE/ASE-20 return is documented. Furthermore, in line with Whaley (2000), Giot (2002a), and Simon (2003) who studied the properties of VXO and VXN, this relationship is asymmetric. This has an important implication: the GVIX can be interpreted as a gauge of the investor's fear; an increase in GVIX affects the stock return (negatively) more than a decrease does. On the other hand, in contrast to Malz (2000), we find that the implied volatilities of the Greek market cannot provide an early warning of market stress. However, the reverse relationship does hold: the results indicate that the FTSE/ASE-20 can be used to predict future movements of GVIX. Finally, a spillover of implied volatility between the US implied volatility indices VXO / VXN and GVIX is found. These results have important implications for portfolio management.

The rest of the paper is structured as follows. In Section 2, the construction of GVIX is explained; the data set is described, as well as the calculation of the implied volatilities. In Section 3, the properties of the GVIX are examined. Section 4 examines the transmission of implied volatility between the Greek and the US markets. Section 5 concludes and suggests some topics for future research.

2. The Greek Volatility Index (GVIX): Construction and Data

Following the standard practice in constructing implied volatility indices, the Greek Volatility Index (GVIX) represents the implied volatility of a synthetic at-the-money (ATM) option with twenty-two trading days to maturity (or equivalently, thirty calendar days to maturity). ATM implied volatilities are used so as to minimize the measurement errors in estimating implied volatilities. This is because most of the options trading activity is concentrated close-to-the-money. A constant maturity is used because it has been found that implied volatilities change as the time to maturity changes (see e.g., Fleming et al., 1995). Maintaining a constant time to expiration minimizes the effect that this consideration may have on VXO. Next, the construction method and the employed data set are described.

2.1 Construction

The suggested construction method of GVIX requires four option prices, for any day. More specifically, for any day, two expiries are used: one is longer and the other is shorter than the constant maturity date we aim to create. In any expiry, the first out-of-the-money (OTM) call, and the first OTM put are identified. Then, the implied volatilities are extracted. Next, for any expiry, the ATM option implied volatility is calculated by interpolating linearly between the implied volatilities of the OTM call and put. Finally, the constant maturity implied volatility is derived by interpolating linearly between the ATM implied volatility of the two expiries.

The proposed method differs from the VXO one. The latter uses both in-the-money (ITM) and OTM options. An additional constraint is that pairs of calls and puts with the same strike need to be traded for the nearest and second-nearest series. In total, eight options should be used (see also Whaley 1993, 2000, for more details on the construction of VXO). In our case, application of the VXO construction technique is not possible due to liquidity considerations. However, there is no loss of information by excluding ITM options. This is because an OTM (ITM) put should have the same implied volatility with an ITM (OTM) call, provided that the put-call parity relationship holds (there is a simple arbitrage if it does not hold). Moreover, using only OTM options has the advantage that it minimizes the effect of measurement errors on the calculation of implied volatilities (see Skiadopoulos et al., 1999, Bliss and Panigirtzoglou, 2004, Panigirtzoglou and Skiadopoulos, 2004)[3].

GVIX is constructed separately from the average of the bid-ask option prices, and from the settlement option prices. This allows us to investigate which type of option price should be preferred in order to construct the index with as little noise as possible (see Section 3.1). In the implied volatility literature both types of option prices have been used.

For example, the average of the bid-ask option quotes is used to construct the VXO since it reduces the bid-ask bounce (see e.g., Whaley, 1993). On the other hand, using settlement prices that are calculated by some algorithm (usually as a weighted average) makes the derived index less prone to possible manipulation.

2.2 The Data Set and the Calculation of Implied Volatilities

Daily data of index options and futures traded in the Athens Derivatives Exchange (ADEX) from 10/10/2002 to 30/12/2002 are used (554 observations). The raw data set consists of the last bid-ask quotes and settlement prices of options on the FTSE/ASE-20 index, and the settlement prices of the FTSE/ASE-20 future[4]. Options and futures with time-to-maturity less than five working days, with volume less than five contracts, and with zero option price were discarded from our database. The VXO and VXN implied volatilities are downloaded from the CBOE web site (www.cboe.com).

The FTSE/ASE-20 index is a capitalization index comprising the twenty most liquid Greek stocks trading in the electronic system known as OASIS. The Greek stock market operates from 11:00-16:00. Trading in ADEX started in August 1999. The FTSE/ASE-20 future was the first contract that was launched. The FTSE/ASE-20 option was launched in September 2000. These are the two most liquid derivative contracts: over the period 2000-2002, the volume in the future contract increased from 968,486 to 4,170,146 contracts. In the option contract, the volume increased from 52,740 to 2,034,126 contracts.

On every day, there are six series trading for both the option and the future contract. The three series correspond to the three nearest consecutive months, and the other three correspond to the three months of the March-June-September-December cycle. The expiration day is the third Friday of the contract month. Options and futures trade from 10:45-16:15. Their contract size is 5 EUROS per index point. The FTSE/ASE-20 option is a cash settled European option[5]. For every new option series, there are initially eleven strike prices; new strike prices are introduced as the index moves. The strike prices differ by 50 index points. The depth of the options bid-ask quotes is five contracts. This volume constraint holds for the two shortest expiries and the three options that are nearest to-the-money.

Given that the FTSE/ASE-20 pays dividends, a European option-pricing model that takes into account the dividends payment should be used in order to calculate the implied volatilities. We circumvent the problem of estimating a dividend yield by using Black's model (1976) that prices European future options. This is a standard approach followed in the academic literature, provided that the option and the future have the same underlying asset and the same expiry date (see for example, Pena et al., 1999). It is also in line with the practice of the Greek market makers who hedge using the futures rather than a portfolio of stocks that replicates the index. In addition, pricing options off the futures reduces any biases in the calculated implied volatilities due to non-synchronous trading since the Greek derivative market does close at the same time with the spot market. At time t, the Black's European call and put prices c_t and p_t are given by

$$c_t = e^{-r_{t,T}(T-t)}[F_{t,T}N(d_1) - XN(d_2)], \tag{1}$$

$$p_t = e^{-r_{t,T}(T-t)}[XN(-d_2) - F_{t,T}N(-d_1)] \tag{2}$$

where

$$d_1 = \frac{\ln(F_{t,T}/X) + (v^2/2)(T-t)}{v\sqrt{T-t}}, \quad d_2 = d_1 - v\sqrt{T-t} \tag{3}$$

and $N(x)$ is the standard cumulative normal distribution evaluated at point x, $F_{t,T}$ is the price at time t of a future expiring at time T ($t \leq T$), X is the strike price, $r_{t,T}$ is the maturity T risk-free interest rate at time t, v is the volatility, and T is the option's expiry date.

EURIBOR interest rates obtained from Datastream are used to proxy for the risk-free interest rate. Daily interest rates for one, two, three weeks, one, two, and three months were used, while those for other maturities were calculated by linear interpolation. The effect of any measurement errors in the interest rate is small since the rho of OTM options is small. GVIX was not constructed for the days where there was only one series trading (39 such days were met) and/or there were not four option prices available. Eventually, the GVIX could be constructed in the 303 out of the 554 days.

3. Properties of the Greek Volatility Index

3.1 Summary Statistics

Figure 1 shows the evolution of GVIX calculated from the average bid-ask quote and from the settlement option prices. It also shows the evolution of the FTSE/ASE-20 over the same period. We can see that even though most of the time the two volatility indices tend to move together, the GVIX calculated from settlement prices seems to be more volatile. Furthermore, in certain periods there seems to be a negative correlation between the changes in the FTSE/ASE-20 and the changes of the two volatility indices. This has been termed as leverage effect (see Figlewski and Wang, 2000, for a detailed review and an empirical study on the leverage effect).

In order to study the time series properties of the constructed indices formally, we proceed as follows. Table 1 shows the summary statistics (mean, median, maximum, minimum, standard deviation, skewness, kurtosis, and the results from the Jarque-Bera test with it's *p*-value in the brackets) of the FTSE/ASE-20 and the two volatility indices. We can see that the three series are distributed non-normally. Both measures of GVIX reach their highest value on 24/09/01. The constructed from bid-ask (settlement) quotes GVIX reaches it's minimum value on 18/05/01 (11/06/02). Finally, FTSE/ASE-20 reaches it's maximum value on 11/10/01, and it's minimum value on 30/12/02.

Table 2 shows the summary statistics of the (continuously compounded) returns of the FTSE/ASE-20 and the *changes* $\Delta GVIX = GVIX_t - GVIX_{t-1}$ of the two indices, as well as their cross-correlations. The sample mean for both volatility indices is zero indicating that there is no trend. The standard deviation for the volatility index constructed from the bid-ask quotes is greater. Both volatility indices are distributed non-normally; hence, extreme movements in the volatility changes are more probable than under the normal distribution.

The cross-correlations confirm the existence of the leverage effect, even though this is rather weak. In the case that bid-ask option prices are used, the correlation between the FTSE/ASE-20 return and the changes in GVIX is found to be –0.16. Using settlement prices yields a slightly higher correlation of –0.17. The correlation between the changes of the two volatility indices is 0.71.

Finally, regarding the autocorrelation coefficients, the standard 5% significance bound is $2/\sqrt{T} = 2/\sqrt{302} = 0.115$. We can see that the first order autocorrelation for both measures of ΔGVIX is statistically significant, and it is negative. This can be interpreted as evidence of mean reversion in the implied volatility index. Alternatively, the negative serial autocorrelation can be interpreted as a signal for the presence of measurement errors in the calculation of implied volatilities (Harvey and Whaley, 1991). This negative autocorrelation is much stronger in the case that ΔGVIX is constructed by the average of the bid-ask quotes (-0.227 compared to –0.167). Hence, this suggests that the volatility index constructed from bid-ask quotes is more prone to noise. Therefore, settlement prices should be preferred. For the rest of the analysis we use the constructed from settlement prices GVIX.

The presence of extra noise in the last bid-ask quotes can be explained by the fact that it is very likely that these are not quoted simultaneously with the spot index; in the

Greek options market, the market makers are not obliged to provide quotes within the last fifteen minutes of the daily trading session. In addition, it is worth mentioning that the GVIX autocorrelation results are lower than the ones found for other European indices; for example, Moraux et al. (1999) found a value of –0.27 for the first order autocorrelation of the changes in VX1. This indicates that the presented here method may be a potential candidate to construct volatility indices in less liquid than the U.S. markets.

3.2 Investor's Gauge of Fear

The capital asset pricing model theories (e.g., Sharpe, 1964) predict that the expected return depends on the expected volatility. In addition, within the implied volatility index literature, Whaley (2000), Giot (2002a) and Simon (2003) have found a negative relationship between returns and VXO/ VXN. A possible explanation of this is that the demand for puts increases when the market declines. Increased demand means higher put prices, and hence higher implied volatilities. Furthermore, this relationship is asymmetric: an equal size positive/negative shock on implied volatility does not have the same effect on the index return[6]. Hence, they interpret the VXO as "the investor's fear gauge"; the further VXO increases in value, the more panic there is in the market. The further VXO decreases in value, the more complacency there is in the market[7].

To investigate whether this interpretation can also be attributed to GVIX, we follow Whaley's (2000) methodology in that we regress the daily returns R_t of the FTSE/ASE-20 on the daily changes $\Delta GVIX$ of the GVIX, and the change $\Delta GVIX^+$ of GVIX when the change is positive i.e. $\Delta GVIX^+ = \Delta GVIX$ if $\Delta GVIX > 0$, and $\Delta GVIX^+ = 0$, otherwise[8]

$$R_t = a_1 \Delta GVIX_t + a_2 \Delta GVIX^+{}_t + u_t \tag{4}$$

The regression results (t-values in brackets) are

$$R_t = -0.088\Delta GVIX_t - 0.125\Delta GVIX^+{}_t, \quad R^2 = 0.05$$
$$(-3.302) \qquad (-3.382)$$

All regression coefficients are significantly different from zero at a 1% significance level. The interpretation of the coefficients is the following: if GVIX falls by one percent, then the FTSE/ASE-20 return will increase by $-0.088 \times (-0.01) = 0.00088$ units. On the other hand, if GVIX rises by one-percent, the FTSE/ASE-20 return will decrease by $-0.088 \times 0.01 - 0.125 \times 0.01 = -0.002$ units. Therefore, the Greek stock market is affected (negatively) more by an increase in GVIX than it is affected (positively) by an equal size decrease in GVIX.

Finally, we checked whether the 11th of September attack affected the risk-return relationship. Towards this end, a multiplicative dummy variable D was included in the regression model of equation (4), i.e.

$$R_t = a_1\Delta GVIX_t + a_2\Delta GVIX^+{}_t + b_1 D\Delta GVIX_t + b_2 D\Delta GVIX^+{}_t + u_t \qquad (5)$$

where D=1 if t>11/09/2001 and D=0, otherwise. We found that

$$R_t = -0.083\Delta GVIX_t - 0.157\Delta GVIX^+{}_t - 0.014D\Delta GVIX_t + 0.064D\Delta GVIX^+{}_t$$
$$(-2.010) \qquad (-2.920) \qquad (-0.254) \qquad (0.851)$$

where the t-statistics are reported within brackets. We can see that the coefficients b_1 and b_2 are statistically insignificant. This implies that the attack did not affect the risk-return relationship in the Greek options market. Therefore, the risk-return relationship remains stable during the period under scrutiny. This is in accordance with Giot (2002a) and Simon (2003) who found that the risk-return relationship is stable in the VXO (VXN) and the S&P 100 (Nasdaq-100) markets.

3.3 Granger Causality Test

We perform a Granger causality test in order to check whether *ΔGVIX* (*R*) helps to predict *R* (*ΔGVIX*). The Granger causality test consists of running bivariate regressions of the form

$$\Delta GVIX_t = c + \sum_{l=1}^{K} a_l \Delta GVIX_{t-l} + \sum_{l=1}^{K} b_l R_{t-l} + u_t \tag{6}$$

$$R_t = c + \sum_{l=1}^{K} a_l R_{t-l} + \sum_{l=1}^{K} b_l \Delta GVIX_{t-l} + u_t \tag{7}$$

The null hypothesis is $H_0 : b_1 = ... = b_K = 0$.

The interpretation of the null is that *R* does *not* Granger-cause *ΔGVIX* in the first regression and that *ΔGVIX* does *not* Granger-cause *R* in the second regression[9].

Table 3 shows the results from the Granger causality test using two lags (*K*=2). We can see that *R* Granger-causes *ΔGVIX* (i.e., rejection of the null) while the reverse does not hold. This result is robust to the choice of *K*. Moreover, it is in contrast to Malz (2000). He also ran similar Granger causality tests, and he found that several measures of volatility (constant maturity implied, historical, exponentially weighted moving average) could predict the future (squared) returns of various assets[10]. Our findings are of particular importance to an investor who has a position in FTSE/ASE-20 options. They suggest that he can use the returns of the underlying asset in order to forecast the future movement of the implied volatility, and hence of the option price. On the other hand, the Greek implied volatility index does not contain information regarding the direction of future returns.

Towards identifying the power of lagged values of *ΔGVIX* and of *R* to forecast the future movements of *ΔGVIX,* we run the following regression

$$\Delta GVIX_t = \sum_{l=1}^{2} a_l \Delta GVIX_{t-l} + \sum_{l=1}^{2} b_l R_{t-l} + u_t \tag{8}$$

The R^2 of the regression is 10%. Table 3 also shows the coefficient estimates, and their *t*-values (in brackets) and *p*-values. We can see that the α_l, b_l $(l=1,2)$ coefficients are statistically significant and negative. The negative sign in the coefficients of the lagged values of $\Delta GVIX$ confirms that GVIX follows a mean-reverting process. Following a general-to-specific approach, we have also run similar regressions with higher order lags and by including an intercept. We found that these do not have any additional forecasting power. Therefore, the investor can use the information contained in the values of $\Delta GVIX$ and R of the past two periods in order to develop the appropriate option strategy.

4. Spillover Effects

In this section, we examine whether there is a transmission of implied volatility across the CBOE and the ADEX markets. Towards this end, the relationship between VXO, VXN, and GVIX is studied. Figure 2 shows the evolution of VXO, VXN, and GVIX over the period 2000-2002. Application of the augmented Dickey-Fuller test reveals that the series are non-stationary.

Table 4 shows the cross-correlations between VXO, VXN, and GVIX in their first differences. We can see that the correlation between the changes of VXO and GVIX, and VXN and GVIX is almost zero (0.06, and –0.02, respectively). The small correlation values indicate that the correlations between emerging and developed derivative markets are low; so far, there was evidence on low cross-correlations between emerging and developed *stock* markets (see Howell, 1998). The correlation between the changes of VXO and VXN is 0.7.

Next, we test whether there is a Granger causality relationship between changes in GVIX and each one of the US volatility indices; four lags are used (see also Malliaris and Uruttia, 1992, for an application of Granger causality tests in the context of lead-lag relationships for stock market indices). Table 5 shows that in general, there is no such Granger causality relationship; there is some weak evidence for the case where lagged values of VXN are used to forecast the changes in GVIX. This implies that the changes in the US indices cannot forecast the changes in GVIX (and vice-versa).

Finally, in line with Gemmill and Kamiyama (1997), the following unidirectional regressions are performed in order to study further the presence of any spillover effects:

$$\Delta GVIX_t = c_1 + a_1 \Delta VXO_t + a_2 \Delta VXN_t + u_t \tag{9}$$

$$\Delta GVIX_t = c_2 + b_1 \Delta VXO_{t-1} + b_2 \Delta VXN_{t-1} + u_t \tag{10}$$

$$\Delta GVIX_t = c_3 + a_1 \Delta VXO_t + a_2 \Delta VXN_t + b_1 \Delta VXO_{t-1} + b_2 \Delta VXN_{t-1} + u_t \tag{11}$$

Equation (9) tests whether there is a contemporaneous relationship between ΔGVIX and the changes in the US volatility indices. Equation (10) checks whether the US indices lead the Greek volatility index. Equation (11) examines whether there is both a contemporaneous and lead relationship between the Greek and the US indices.

In order to understand the meaning of “contemporaneous” and “lead” effect, the time zones within which the indices are reported, need to be identified. The US indices trade from 8:30-15:15 (Chicago time), or 16:30-23:15 Greek time. Given that closing prices are used to construct the volatility indices, “contemporaneous” refers to the same calendar date *t,* even though the time at which the US and Greek indices are measured differs.

Table 5 shows the estimated coefficients, the *t*-statistics in brackets and the *p*-values. The R^2 for equations (9) and (10) is 1% and for equation (11) is slightly greater (3%). We can see that there is a contemporaneous spillover effect between the changes in VXO and GVIX (significant α_1 in equation (9)). In addition, there is a contemporaneous spillover effect between GVIX and *both* US indices in the case that the previous period values of both indices are also taken into account (equation (11)). The coefficients of the lagged values are insignificant though; this is consistent with the earlier rejection of the Granger causality hypothesis between the indices. On the other hand, the change in the U.S. implied volatility indices does not lead the next day's change in GVIX [equation (10)].

The empirical evidence on the implied volatility spillovers literature is mixed. Gemmill (1996) found that contemporaneous changes in the shape of the English and U.S. smiles are uncorrelated over the period 1985-1990. Gemmill and Kamiyama (1997) found that the S&P 500 implied volatilities lead the FTSE and Nikkei ones over the period 1992-95. Our results on the lead/lag relationship may be attributed to the anecdotal evidence that Greek option traders tend to be affected by the previous day movements of the European rather than those of the US option markets (Gemmill, 1996, explains his findings as a result of the different kinds of participants in the various markets).

5. Conclusions

We have constructed an implied volatility index for the rapidly evolving Greek derivatives market using the FTSE/ASE-20 future and option contracts. The construction method may be used in emerging markets that are less liquid than the U.S. option markets. To construct the Greek implied volatility index (GVIX), settlement option prices are found to be preferred from the average bid-ask option price.

Next, the properties of GVIX have been studied. They shed light on the behavior of an aggregate measure of implied volatilities in an emerging market and they have important implications for portfolio management. In line with Whaley (2000), Giot (2002a) and Simon (2003), we found that the index can be used as a gauge of the investor's fear. This measure is stable over time and it is not affected by the 11th of September crash. Moreover, the results from Granger causality tests imply that the investor can use the information contained in the values of GVIX and the FTSE/ASE-20 of the past two periods in order to develop a profitable option strategy. On the other hand, GVIX cannot forecast the future FTSE/ASE-20 returns. Therefore, it *cannot* be treated as a leading indicator for the stock market. This finding is in contrast to the results found in the literature, so far. Finally, a contemporaneous spillover of change in the implied volatility between the GVIX and the U.S. volatility indices was detected. However, no lead-lag effects are present.

This paper creates at least three strands for future research. First, the ability of GVIX to forecast the future market volatility should be investigated. This can be done by means of a statistical analysis, or under a more practical metric such as Value-at-Risk by performing the appropriate backtesting. Second, it may be worth examining the presence of common factors in GVIX and US indices using alternative methodologies. Towards this end, a non-linear vector autoregression approach may be used (see, e.g., Lekkos and Milas, 2004, for an application on the interest rate swap markets). Finally, the GVIX methodology could be applied to US data and compared against the VXO technique. These issues are beyond the scope of this paper, but they deserve to become topics for future research.

Acknowledgments

I am particularly grateful to Nikos Porfiris who kindly provided the data set for this study, and to Carol Alexander, Chris Brooks, Harris Linaras, Stewart Mayhew, Nikolaos Panigirtzoglou, Peter Pope, Mark Shackleton, and Robert Whaley for many helpful discussions. I would also like to thank Christos Dadamis, Athanasios Episkopos, Dimitris Flamouris, Gikas Hardouvelis, Iakovos Iliadis, Katerina Panopoulou, Dimitris Papas, Costas Petsas, and the participants at the 2003 University of Piraeus-ADEX Research Seminar

Series, and at the 2003 Hellenic Finance and Accounting Association Meeting for useful discussions and comments. This paper was part of the project "Volatility Derivatives" funded by the Athens Derivatives Exchange (ADEX). Financial support from the Research Centre of the University of Piraeus is also gratefully acknowledged. The views expressed herein are those of the author and do not necessarily reflect those of ADEX. Any remaining errors are my responsibility alone.

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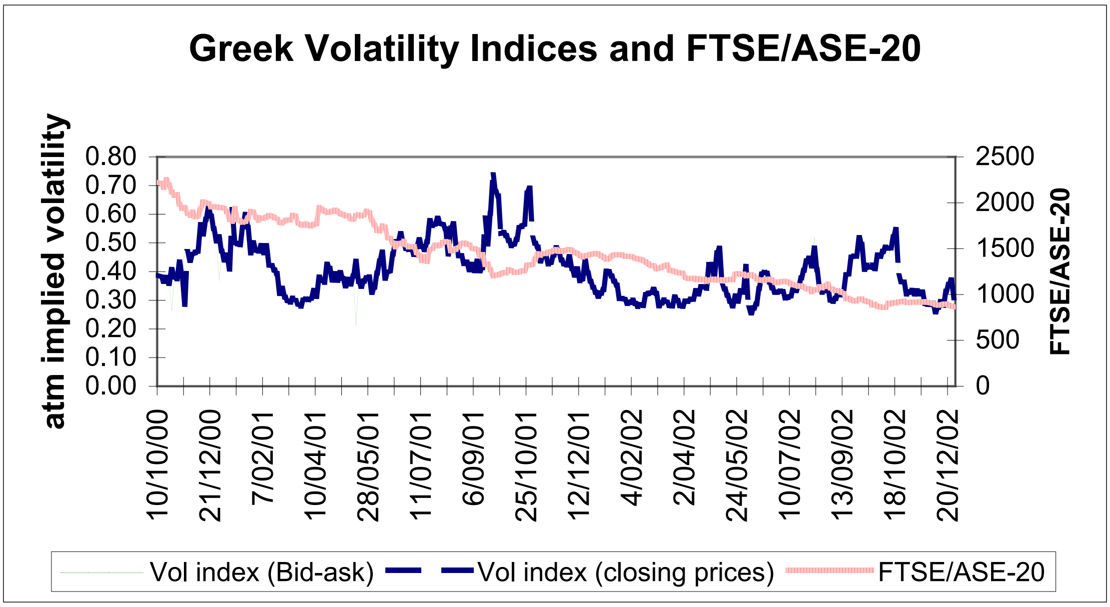

Figure 1: The Greek implied volatility index (GVIX) and the FTSE/ASE-20 over the period 10/10/2002 – 30/12/2002. The GVIX is calculated from the average bid-ask option quote and from the settlement option prices, separately.

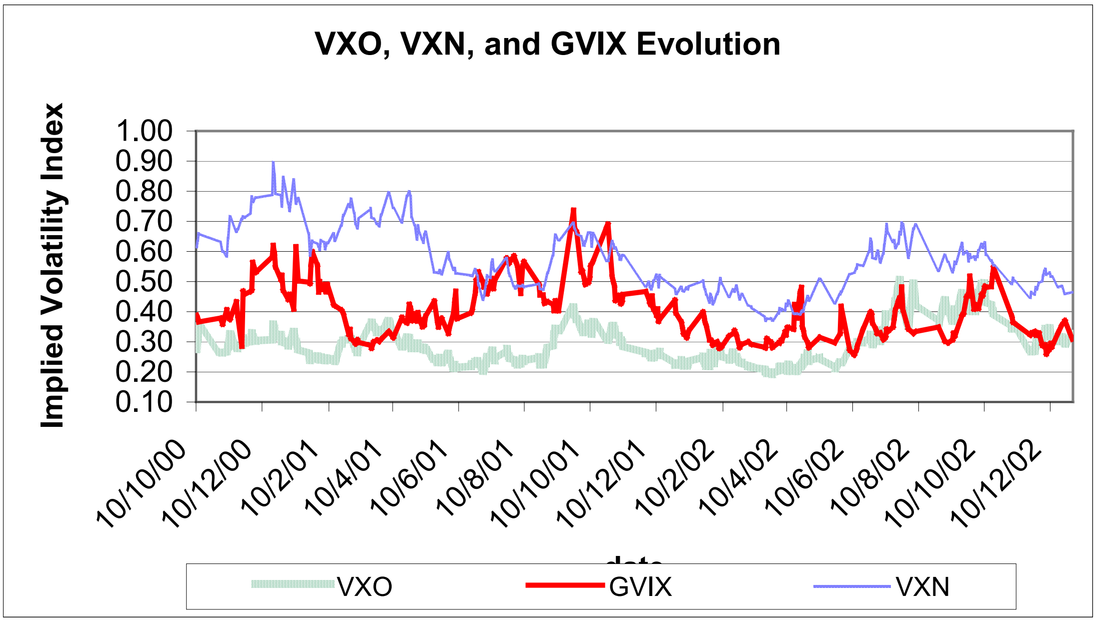

Figure 2: Evolution of VXO, VXN, and GVIX implied volatility indices over the period 10/10/2002 – 30/12/2002.

	FTSE/ASE-20	GVIX (Bid-Ask)	GVIX (Settlement)
Mean	1421.98	0.40	0.41
Median	1414.57	0.39	0.39
Maximum	2251.17	0.74	0.74
Minimum	856.95	0.21	0.26
Std. Dev.	351.77	0.09	0.09
Skewness	0.22	0.63	0.69
Kurtosis	2.03	2.94	3.06
Jarque-Bera	14.51 (0.00)	20.36 (0.00)	24.25 (0.00)

Table 1: Summary Statistics of the FTSE/ASE-20 and of GVIX. The GVIX has been constructed separately from the average bid-ask option quotes and from the settlement option quotes.

	Return FTSE/ASE-20	ΔGVIX (Bid-Ask)	ΔGVIX (Close)
Mean	0.00	0.00	0.00
Median	0.00	0.00	0.00
Maximum	0.09	0.21	0.21
Minimum	-0.08	-0.16	-0.17
Std. Dev.	0.02	0.05	0.04
Skewness	0.34	0.08	0.25
Kurtosis	6.69	6.44	7.68
Jarque-Bera	177.39 (0.00)	149.11 (0.00)	278.30 (0.00)
Cross-Correlations			
Return FTSE/ASE-20	1	-0.16	-0.17
ΔGVIX (Bid-Ask)	-0.16	1	0.71
ΔGVIX (Close)	-0.17	0.71	1
Autocorrelations			
$\hat{\rho}(1)$	0.038	-0.227*	-0.167*
$\hat{\rho}(2)$	0.077	0.018	-0.088
$\hat{\rho}(3)$	-0.011	0.044	0.101

Table 2: Summary Statistics of the returns of FTSE/ASE-20 and the changes of GVIX constructed separately from the average bid-ask option quotes and the closing option quotes. Cross-Correlations and the autocorrelations up to three lags are reported. The asterisk indicates significance of the autocorrelation coefficient at 5% level of significance.

Null Hypothesis	F-Statistic	Probability
R does not Granger Cause $\Delta GVIX$	8.42*	0.0003
$\Delta GVIX$ does not Granger Cause R	2.3748	0.0948
Regression Results		
Coefficient	**Estimate (t-value)**	**Probability**
$\boldsymbol{a_1}$	-0.23* (-4.04)	0.0001
$\boldsymbol{a_2}$	-0.15** (-2.54)	0.0117
$\boldsymbol{b_1}$	-0.25** (-2.07)	0.0389
$\boldsymbol{b_2}$	-0.40* (-3.29)	0.0011

Table 3: Granger Causality Test between $\Delta GVIX$ and R using two lags (K=2). Results from the regression $\Delta GVIX_t = \sum_{l=1}^{2} a_l \Delta GVIX_{t-l} + \sum_{l=1}^{2} b_l R_{t-l}$ are also reported. One asterisk denotes significance at a 1% significance level, and two asterisks denote significance at 5% significance level.

	ΔGVIX	**ΔVXO**	**ΔVXN**
ΔGVIX	1	0.06	-0.02
ΔVXO	0.06	1	0.7
ΔVXN	-0.02	0.7	1

Table 4: Cross-Correlations between VXO, VXN, GVIX in the first differences over the period 10/10/2002 – 30/12/2002.

Null Hypothesis	F-Statistic	Probability
ΔVIX does not Granger cause *ΔGVIX*	1.43	0.23
ΔGVIX does not Granger cause *ΔVXO*	0.28	0.89
ΔVXN does not Granger cause *ΔGVIX*	2.45***	0.05
ΔGVIX does not Granger cause *ΔVXN*	0.84	0.5
Regression Results: Equations (9) **and** (10), R^2**=0.01**		
Coefficient	**Estimate (t-value)**	**Probability**
c_1	0.00 (-0.16)	0.87
a_1	0.29*** (1.88)	0.06
a_2	-0.18 (-1.66)	0.10
c_2	0.00 (-0.06)	0.95
b_1	-0.01 (-0.06)	0.95
b_2	0.15 (1.34)	0.18
Regression Results: Equation (11), R^2**=0.03**		
c_3	0.00 (-0.12)	0.91
a_1	0.37** (2.30)	0.02
a_2	-0.20*** (-1.76)	0.08
b_1	0.05 (0.31)	0.75
b_2	0.15 (1.32)	0.19

Table 5: Granger Causality Test between *ΔGVIX* and *ΔVIX (ΔVXN)* using four lags (*K*=4). The results from the regressions $\Delta GVIX_t = c_1 + a_1 \Delta VXO_t + a_2 \Delta VXN_t + u_t$, $\Delta GVIX_t = c_2 + b_1 \Delta VXO_{t-1} + b_2 \Delta VXN_{t-1} + u_t$, and $\Delta GVIX_t = c_3 + a_1 \Delta VXO_t + a_2 \Delta VXN_t + b_1 \Delta VXO_{t-1} + b_2 \Delta VXN_{t-1} + u_t$ are also reported. One asterisk denotes significance at a 1% significance level, two asterisks denote significance at a 5% significance level, and three asterisks significance at a 10% significance level.

Footnotes

[1] A volatility derivative can also be written on an asset that has a payoff closely related to the volatility swings, e.g., a straddle. See Brenner et al. (2002) who propose an option on a straddle.

[2] For example, MONEP constructs it's volatility indices using only call prices that trade more frequently. However, this may introduce severe biases in the construction of the implied volatility index since it is well documented that the implied volatilities of calls and puts may differ significantly (see for example, Gemmill, 1996). See also Moraux et al. (1999) for a discussion of the measurement errors in the construction of the French volatility indices.

[3] In September 2003, CBOE introduced two new volatility indices, termed VIX and VXN, respectively. These are based on an alternative to the "old" VIX and VXN construction method. Among other differences, the new method also uses only OTM options.

[4] The option prices quoted as "closing" in ADEX are not the last-traded prices. They are settlement prices in the sense that ADEX uses an algorithm to calculate them. For the shortest expiry, the three nearest-to-the-money call and puts are used. For the second expiry series only the closest-to-the-money call and put is required. Then, Black's (1976) model is used to back out the implied volatility using the last traded future price and a constant interest rate of 3%. In the next step, the arithmetic average of the implied volatility is obtained. Finally, the settlement option price is calculated using the average implied volatility and the future settlement price.

[5] A distinguishing characteristic of the Greek derivatives market is that the settlement and margining are performed at an end-client level allowing a transparent monitoring of the transactions that facilitates risk management. This is in contrast to the "omnibus" practice followed by other exchanges.

[6] Figlewski and Wang (2000) confirm this asymmetric relationship by treating the changes (of the logarithm) of implied volatility as the dependent variable, and the index returns as the independent variable, in a linear regression setup.

[7] As such a measure of fear, VXO can help to determine whether OEX options are undervalued or overvalued (see Stendahl, 1994, for a discussion on using VXO for volatility trading purposes).

[8] Whaley (2000) uses also an intercept in his regression formulation. We found that the intercept component was insignificant and thus we omitted it.

[9] Y is said to be Granger-caused by X if X helps in the prediction of Y, or equivalently if the coefficients on the lagged X's are statistically significant. It is important to note that the statement "X Granger causes Y" does not imply that Y is the effect or the result of X. Granger causality measures precedence and information content but does not by itself indicate causality in the more common use of the term (see Hamilton, 1994, for a detailed description of the Granger causality test).

[10] We applied the Granger-causality test to squared returns, as well. However, the results did not change.