

**MARGIN CHANGES AND FUTURES TRADING ACTIVITY: A NEW
APPROACH**

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Abstract

The paper examines the impact of margins, adjusted for underlying price risk proxied by market volatility, on trading volume and at the same time incorporates the relationship between trading volume, and price volatility documented in equities and futures markets. The study estimates bivariate GARCH-M models to take account of the inter-relationships and applies them to the Greek derivatives market over the period 1999-2005. The results show that when adjusting margins for market risk there is no impact on trading volume, casting doubts on the results of previous research, and providing support for the view that margin requirements are used only as a mechanism to prevent trader default.

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1. Introduction

In futures contracts traders are not required to put up the entire value of a contract but to post a margin that is typically between 2% and 10%. Unlike stock margins, margins in the futures markets are not down payments, but are performance bonds that are designed to ensure that traders can meet their financial obligations.¹ A substantial amount of research on margin requirements has been on the relationship between margin requirements and trading volume. The empirical evidence however has generally failed to document a strong inverse association as theory suggests. According to Dutt and Wein (2003) the reason for that is because previous research has failed to consider empirically, although discussed the rationale for it,² that exchange margin committees change margins when they believe that market risk has changed. For example, if price volatility increases, the exchange margin committee will raise margins in response to the increase in market risk³ and that will have a negative impact on volume since margins are a cost to the trader.⁴ However, the increase in price volatility is likely to increase trading volume at the same time (see e.g. Jacobs & Onochie, 1998). Since the two effects on volume are of opposite sign, the predicted impact of a margin increase will be ambiguous.

The aim of this study is to provide further empirical evidence on the effects of margin changes on trading volume. The main contribution of the paper to the literature is that it adjusts margins for underlying price risk proxied by market volatility as suggested by Dutt and Wein (2003), and at the same time incorporates the relationship between trading volume and price volatility, which is widely documented in equities and futures markets. The study is novel in that it employs a new econometric methodology to allow for these inter-relationships, which was not considered in previous empirical research. It

estimates bivariate GARCH-M models,⁵ which allow for autocorrelation in the first and second moments, for nonlinearities in the second moments, provide a means for estimating a risk premium and have the advantages of avoiding simultaneity bias with regard to the relationship between volume and price volatility.

The tests are also conducted on the stock index futures of the Greek derivatives market, a newly established market, which has been rapidly expanding to match that of its European counterparts during a time when the Greek economy and financial markets were experiencing important developments and undergoing significant changes.⁶ This issue has never been examined before in the context of the Greek derivatives market. In particular, the study conducts the tests on a large-capitalisation index futures contract (i.e. FTSE/ASE 20 Index) comprising of the 20 largest stocks in terms of market capitalisation and liquidity. Previous studies, such as Adrangi and Chatrath (1999), Chatrath, Adrangi and Allender (2001), and Dutt and Wein (2003), have primarily focused on individual financial and/or commodity futures contracts.

In summary, our investigation has the following main objectives: (i) to examine whether changes in margin requirements have significantly affected trading volume; (ii) to investigate the effects of margin changes on trading volume, after adjusting margins for underlying price risk, and (iii) to incorporate in the analysis of the effects of margin changes on trading volume the empirical regularity of a positive contemporaneous correlation between trading volume and price volatility.

The remaining of the paper is organised as follows. Section 2 reviews the literature on the effects of margin requirements on trading volume in the futures markets, and the relationship between trading volume and price volatility. Section 3 provides a

brief discussion of the establishment and development of the Greek derivatives market. Section 4 describes the univariate and bivariate GARCH-M models, which are employed to examine the effects of margin changes on trading volume. This section also sets up the hypotheses to be tested. Section 5 describes the data and presents the empirical results. The final section summarises the empirical findings and presents the main policy conclusions.

2. Literature review

Previous literature has found little evidence of an inverse association between margins and volume although it has documented a small inverse relationship with respect to open interest. Fische and Goldberg (1986) examined the effect of margin changes on both open interest and volume around a 3- to 5-day window of such changes of futures contracts trading on the CBOT, like corn, iced broilers, wheat, gold, silver, oats, plywood, soybean meal, soybean oil, and soybean over the period 1972 to 1978. They found, on the one hand, that a 10% increase in margin requirements would reduce open interest by approximately one-third of 1%, and on the other hand, they found that a 10% increase in margins would increase volume traded by 14.62%. This finding was explained by the fact that as margin requirements increase, volume increases as well, as traders move to unwind their futures positions in order to avoid the higher costs imposed, eventually causing a net reduction in open interest.⁷

Other empirical studies have also failed to identify statistically significant inverse relationships between margins and volume. For example, Hartzmark (1986) investigated 13 contract days calculating whether volume changed significantly from 15 days before

to 15 days following the change. He found that in only 4 of 13 occurrences did volume move negatively and significantly in the opposite direction. As a result, the association between margins and volume is also weak over the longer period and does not support the assertion that increased margin requirements will reduce trading volume.

More recently Dutt and Wein (2003) when examining 3 financial futures contracts (gold, Dow Jones and 10-year Treasury Notes) and 3 agricultural futures contracts (wheat, corn and oats) over a 17-year time period found statistically positive and/or insignificant relationships between volume and margin changes, as it was the case in previous research. However, after adjusting margins for underlying price risk, using variability estimates calculated as the variance of the daily settlement price changes for 20 days before and 20 days after each margin change, they find a statistically significant inverse relationship between margin changes and trading volume in all 6 futures contracts. Furthermore, the effect is more evident in financials than in the more traditional agricultural futures contracts.

Our study draws also from another strand of literature, which examined the relationship between trading volume and volatility. Several studies have documented a positive contemporaneous correlation including the seminal paper by Karpoff (1987), Schwert (1989), and Lamoureux and Lastrapes (1991), who were the first to use GARCH-type volatility specifications, and Gallant, Rossi and Tauchen (1992), who used nonparametric methods. In the Greek context Phylaktis, Kavussanos and Manalis (1996) investigated the relationship between volume and volatility in the Athens Stock Exchange (ASE) in Greece and found a positive conditional volume-volatility relationship, when they applied a GARCH-type volatility specification and introduced lagged volume in the

variance equation. More recently however, Darrat, Rahman and Zhong (2003), who examine the contemporaneous correlations, as well as the lead-lag relations, between trading volumes and return volatility in all 30 stocks comprising the DJIA using intraday data and an EGARCH-M process, find that correlations are positive and statistically significant in only 3 of the 30 DJIA stocks. All remaining stocks of the DJIA exhibit no significant positive correlation between trading volumes and return volatility.⁸

The positive relationship between trading volume and price volatility is also documented in the futures markets. For example, Cornell (1981) studied 17 commodity futures markets and found a positive correlation between changes in both the average trading volume and the standard deviation of log-relatives at two-month intervals. Tauchen and Pitts (1983) found a similar relationship when examining futures on Treasury bills. Grammatikos and Saunders (1986) studied 5 foreign currency contracts at daily intervals with Granger-causality tests and documented significantly positive results that reveal no maturity effect on price variability. Najand and Yung (1991) applied univariate GARCH methodology, with volume as an explanatory variable in the conditional variance, examining futures on U.S. Treasury bonds. They found both significant GARCH and volume effects in the second moments of futures returns. Bessembinder and Seguin (1993) examined 8 U.S. futures contracts using OLS, and found that unexpected volume shocks have a significant positive effect on volatility. Jacobs and Onochie (1998) applied bivariate EGARCH-M modelling and looked at a cross-section of financial futures trading on LIFFE. They found a positive relationship between trading volume and price volatility, as measured by the conditional heteroscedasticity of price change.

In view of this widespread evidence on the relationship between trading volume and volatility, the current study takes it into account in its investigation of the effects of margin requirements adjusted for market volatility on trading activity.

3. The Greek derivatives market

The Athens Derivatives Exchange S.A. (ADEX) and the Athens Derivatives Exchange Clearing House S.A. (ADECH) were established in 1997 when Law 2533 was enacted to provide the necessary legal framework for the establishment of the derivatives market in Greece.⁹ Trading operations were officially inaugurated on August 27, 1999 and since then interest to acquire membership to ADEX and ADECH has remained strong. The dynamic course of growth of the derivatives market is shown in Table 1.

The range of derivative products traded in ADEX continued to expand and at present ADEX investors are able to choose from a range of liquid, EUR-denominated products, including futures and options on the blue-chip FTSE/ASE 20 and mid-cap FTSE/ASE Mid-40 indices of the ASE. Summary statistics for the most heavily traded contract the FTSE/ASE 20 are provided in Table 2. Information on FTSE/ASE 40 is also shown for comparison.¹⁰

All futures market participants – buyers and sellers – must deposit money with their brokers in futures margin accounts to guarantee contract obligations. As far as ADECH's daily operation is concerned, the mark-to-market of the futures position, which is known as daily settlement, is done separately from the margining. Specifically, every day, for each clearing account, two numbers are issued by ADECH. One number is the daily settlement amount that can be either positive or negative, depending on the outcome

of the mark-to-market of the futures position, whether it results in profit or loss. The other number is the minimum required balance of the margin account, for example a 10% margin of the nominal value of the futures position. It is the responsibility of each futures trader, every day, through the clearing member, to both pay for the daily settlement amount, if this is negative resulting from a loss-making position, and also maintain the minimum balance of a 10% margin of the futures position, on his or her margin account that ADECH requires.

The FTSE/ASE 20 Index futures were initially introduced with a 20% margin on August 27, 1999. Subsequently, FTSE/ASE Mid-40 Index futures were launched with an 18% margin on January 28, 2000, and at that time the margin requirement for the FTSE/ASE 20 Index futures was modified to 14% by ADECH. ADECH has the right to increase or decrease the margin required for deposit, under extreme market conditions or at any time it deems as appropriate to act. For example, ADECH had increased the margins for both index futures contracts from 12% to 16% on September 12, 2001, as a result of the terrorist attacks that occurred in the U.S. the day before. Many such changes in the margin requirements have been performed in the past, since the launch of these products. However, since October 7, 2002, when margins had increased from 12% to 15%, there has been a gradual reduction to the margins, with the last decrease taking place on February 5, 2004, from 11% to 10%. The margins have remained unchanged ever since. A list comprising all the margin changes that occurred since the introduction of the stock index futures contracts in the Greek derivatives market is shown in Table 3.¹¹

4. Methodological issues

This section discusses the univariate and bivariate GARCH-M(p, q) models, which are used to examine the effects of margin changes on trading volume, by taking into account, on the one hand, the effect of conditional volatility of stock returns on margin changes, and on the other hand, the relationship between conditional volatility of stock returns and trading volume. The best univariate GARCH-M(p, q) models are initially selected and these are subsequently used to construct the bivariate GARCH-M(p, q) model. This section also sets up the hypotheses to be tested.

4.1. Univariate GARCH-M(p, q) models

The conditional mean and conditional variance equations describing the univariate GARCH-M(p, q) models of stock index returns and the level of trading volume are specified in the following two subsections.

4.1.1. Conditional mean and variance of stock returns

The conditional mean of stock returns equation is specified below as follows:

$$\Delta f_t = a_{0\text{uni}} + \sum_{i=1}^p b_{i\text{uni}} \Delta f_{t-i} + \sum_{j=1}^q c_{j\text{uni}} u_{t-j}^f + d_{1\text{uni}} h_t^f + u_t^f, \quad (1)$$

where $f_t = \ln(F_t)$ is the natural logarithm of the contract's settlement futures price, F_t ; $\Delta f_t = f_t - f_{t-1}$ is the price log-relative, Δf_{t-i} are past returns, u_{t-j}^f are MA terms, h_t^f is the conditional variance of Δf_t , and u_t^f are random disturbance terms.

Equation (1) models the futures return as having a deterministic constituent, $a_{0\text{uni}}$ and $d_{1\text{uni}} h_t^f$, and a stochastic constituent, u_t^f , which is conditionally heteroscedastic and correlated with volume. The normal futures return constituent is also modelled as an

ARMA(p, q) process to take into account the possible market inefficiencies. α_{0uni} is the unconditional expected rate of price change, $d_{1uni}h_t^f$, is the risk premium where h_t^f is the conditional heteroscedasticity of the futures return process (see Domowitz & Hakkio, 1985, and Engle, Lilien & Robbins, 1987). This is a representation for the systematic risk associated with unanticipated movements in interest rates. Greater systematic risk related with unanticipated shifts in the yield curve is reflected in innovations to the futures price change process, which, as a result, directly influences conditional variance in the GARCH equation. Thus, the conditional heteroscedasticity proxies for systematic risk and it is expected that the estimated coefficient, d_{1uni} , would be negative.

The conditional variance of stock returns equation is specified below as follows:

$$h_t^f = \alpha_{0uni} + \sum_{i=1}^p \beta_{iuni} h_{t-i}^f + \sum_{j=1}^q \gamma_{juni} u_{t-j}^f + \delta_{1uni} v_{t-1}, \quad (2)$$

where $\alpha_{0uni} \geq 0$, and $\beta_{iuni}, \gamma_{juni} \geq 0$ to ensure $h_t^f > 0$. The sum of the coefficients β_{iuni} and γ_{juni} , denote the degree of persistence in the conditional variance given a shock to the system.

The coefficient, δ_{1uni} , shows the impact of volume and represents the effect of information flow upon price change through the volatility of return, which is in traders' information sets and, as such, is separate from the contemporaneous correlation of the innovations. Consistent with the MDH and many models of sequential information transmission and noisy rational expectations equilibrium, the coefficient, δ_{1uni} , is

expected to have a positive sign.¹ Therefore, the first hypothesis to be tested is set up as follows:

$$H1: \delta_{1uni} > 0$$

We use lagged volume as an instrument for contemporaneous volume to avoid the problem of simultaneity since lagged values of endogenous variables are classified as predetermined (see e.g. Harvey, 1989).

4.1.2. Conditional mean and variance of trading volume

The conditional mean of trading volume equations are specified below as follows:

$$v_t = e_{0uni} + \sum_{i=1}^p g_{iuni} v_{t-i} + \sum_{j=1}^q k_{juni} u_{t-j}^v + l_{1uni} t + n_{1uni} h_t^v + w_{1uni} m_t + \dots \\ \dots + y_{1uni} r_t + z_{1uni} x_t + u_{t,}^v, \quad (3a)$$

$$v_t = e_{0uni} + \sum_{i=1}^p g_{iuni} v_{t-i} + \sum_{j=1}^q k_{juni} u_{t-j}^v + l_{1uni} t + n_{1uni} h_t^v + w_{2uni} (m_t / h_{t-1}^f) + \dots \\ \dots + y_{1uni} r_t + z_{1uni} x_t + u_{t,}^v, \quad (3b)$$

where $v_t = \ln(V_t)$ is the natural logarithm of the level of trading volume, V_t ; v_{t-i} are past terms, u_{t-j}^v are MA terms, h_t^v is the conditional variance of v_t , and $u_{t,}^v$ are random disturbance terms.

¹ For an elaboration of the MDH, see e.g. Clark (1973), Harris (1987), and Andersen (1996); for several sequential equilibrium models of speculative markets, see Copeland (1976), and Smirlock and Starks (1985), and for certain newer classes of noisy rational expectations equilibria, see Blume, Easley and O'Hara (1994), and Easley, Keifer and O'Hara (1997).

Volume has deterministic and stochastic constituents as well. The normal volume constituent is modelled as an ARMA(p,q) process with the margin level, m_t , either unadjusted (see equation (3a), or adjusted for underlying price risk, denoted by h_{t-1}^f (see equation (3b), a short-term interest rate, r_t , time to contract maturity, x_t , and a time-trend variable, t .

The innovation, u_t^v , is interpreted as abnormal volume. We include lagged terms to accommodate possible persistence in abnormal volume following an information event as noted in several asymmetric information models of trading volume (see Karpoff, 1986). The use of the conditional volatility (h_t^v) in volume allows one to separate increases in volume due to informed market participants from the uninformed traders as well as from surprises. If the arrival of new information is associated with increased asymmetry of information among traders and an increase in trading volume and is proxied by h_t^v , the estimated coefficient, n_{uni} , is expected to be positive.

The margin level, m_t , on day t , is included to examine the effects of margin requirements on trading volume. As explained in Section 1 if m_t is not adjusted for market risk proxied by market volatility, its impact on trading activity will be ambiguous. This is so for increases in market volatility cause an increase in margins, which are a cost to the trader and consequently reduce volume. At the same time, the increases in volatility are likely to lead to increases in volume traded as it is empirically documented in the literature for the futures markets.

In equation (3b) we follow Dutt and Wein (2003) and adjust margins to expected changes in market risk. Dutt and Wein (2003) used the variance of the daily settlement price changes for 20 days before and 20 days after, for each margin change as a proxy for

risk. In our study margins are adjusted for market risk, using the lagged conditional variance of the change in daily settlement prices, denoted by h'_{t-1} . According to Dutt and Wein's (2003), Fische and Goldberg's (1986), and Telser's (1981) interpretations, it is changes in margins at given levels of risk that would inversely affect volume. Based on this rationale, the coefficient, w_{2uni} , in equation (3b), which examines the effects of margins, when adjusted, on trading volume, is predicted to be negative. Thus, our second hypothesis is set up as follows:

$$H2: w_{2uni} < 0$$

A short-term interest rate, the Euro Overnight Index Average (EONIA) rate, r_t , is included to represent the short-term changes in storage and holding costs and may therefore affect volume.¹² The coefficient, y_{1uni} , is expected to have a negative sign, since an increase in the cost of holding inventories would lead to a reduction in futures market activity.

Time to contract maturity, x_t , that is, the number of days until expiration of the contract on day t , affects contract volume and it is therefore included in the model. The coefficient, z_{1uni} , is expected to have a positive sign, that is as the contract approaches its expiry trading volume increases as futures traders begin to close out their positions to avoid receiving the physical commodity and at the same time open new positions in other contracts with longer expiry dates.

Finally, a time-trend variable, t , is included to control for long-term changes in contract interest.

The conditional variance of trading volume equation is specified below as follows:

$$p \qquad q$$

$$h_t^v = \varepsilon_{0\text{uni}} + \sum_{i=1} \zeta_{i\text{uni}} h_{t-i}^v + \sum_{j=1} \eta_{j\text{uni}} u_{t-j}^v + \theta_{1\text{uni}} \Delta f_{t-1}, \quad (4)$$

where $\varepsilon_{0\text{uni}} \geq 0$, and $\zeta_{i\text{uni}}, \eta_{j\text{uni}} \geq 0$ to ensure $h_t^v > 0$.

The coefficient, $\theta_{1\text{uni}}$, the lagged return in the conditional variance of volume models the informational impact of price on volume. To the extent that price increases signal lower systematic risk, so that there is less hedging and/or speculative activity relative to informationally motivated trade, the expectation is that the coefficient estimate of $\theta_{1\text{uni}}$ will be positive. The third testable hypothesis is therefore set up as follows:

$$\text{H3: } \theta_{1\text{uni}} > 0$$

4.2. Bivariate GARCH-M(p, q) model

This section discusses the bivariate GARCH-M(p, q) model, which is constructed using the best selected univariate GARCH-M(p, q) models. The conditional mean, the conditional variance and conditional covariance equations describing the bivariate GARCH-M(p, q) model are specified below as follows:¹³

$$\Delta f_t = a_{0\text{biv}} + \sum_{i=1}^p b_{i\text{biv}} \Delta f_{t-i} + \sum_{j=1}^q c_{j\text{biv}} u_{t-j}^f + d_{1\text{biv}} h_t^f + u_t^f, \quad (5)$$

$$v_t = e_{0\text{biv}} + \sum_{i=1}^p g_{i\text{biv}} v_{t-i} + \sum_{j=1}^q k_{j\text{biv}} u_{t-j}^v + l_{1\text{biv}} t + n_{1\text{biv}} h_t^v + w_{1\text{biv}} m_t + \dots \\ \dots + y_{1\text{biv}} r_t + z_{1\text{biv}} x_t + u_t^v, \quad (6a)$$

$$v_t = e_{0\text{biv}} + \sum_{i=1}^p g_{i\text{biv}} v_{t-i} + \sum_{j=1}^q k_{j\text{biv}} u_{t-j}^v + l_{1\text{biv}} t + n_{1\text{biv}} h_t^v + w_{2\text{biv}} (m_t/h_{t-1}^f) + \dots \\ \dots + y_{1\text{biv}} r_t + z_{1\text{biv}} x_t + u_t^v, \quad (6b)$$

$$(u_t^f, u_t^v)^T \sim N((0,0)^T, H_t), \quad (7)$$

$$(h_t^f, h_t^{fv}, h_t^v)^T = \text{vech}(H_t), \quad (8)$$

$$h_t^f = \alpha_{0\text{biv}} + \sum_{i=1}^p \beta_{i\text{biv}} h_{t-i}^f + \sum_{j=1}^q \gamma_{j\text{biv}} u_{t-j}^f + \delta_{1\text{biv}} v_{t-1}, \quad (9a)$$

$$h_t^v = \varepsilon_{0\text{biv}} + \sum_{i=1}^p \zeta_{i\text{biv}} h_{t-i}^v + \sum_{j=1}^q \eta_{j\text{biv}} u_{t-j}^v + \theta_{1\text{biv}} \Delta f_{t-1}, \quad (9b)$$

$$h_t^{fv} = \iota_{0\text{biv}} + \sum_{i=1}^p \kappa_{i\text{biv}} h_{t-i}^{fv} + \sum_{j=1}^q \lambda_{j\text{biv}} u_{t-j}^{fv} + \mu_{1\text{biv}} \sqrt{|\Delta f_{t-1} v_{t-1}|}, \quad (9c)$$

$$L(\theta|Y,u) = -1/2 \sum_{t=0}^T (\ln(2\pi) + \ln|H_t| + u_t^T H_t^{-1} u_t). \quad (10)$$

As previously stated, $f_t = \ln(F_t)$ is the natural logarithm of the contract's settlement futures price, F_t ; $\Delta f_t = f_t - f_{t-1}$ is the price log-relative; $v_t = \ln(V_t)$ is the natural logarithm of the level of trading volume, V_t ; and $u_t = (u_t^f, u_t^v)^T$ is the vector of random disturbance terms for log-relative price and log volume at time, t , respectively, with zero mean vector, 0 , and conditional variance-covariance matrix, H_t , with elements, $\text{vech}(H_t) = (h_t^f, h_t^{fv}, h_t^v)^T$, as the respective conditional variances and covariance. Y, u are time series of observations and disturbances, respectively, and $L(\cdot)$ is the log-likelihood of the parameter vector, θ , conditional on the observations.

Equations (5-6b) describe a bivariate GARCH-M(p, q) structure for the first moments, similar to the univariate GARCH-M(p, q) models presented in the previous subsections. Equations (9a-c) describe a bivariate GARCH-M(p, q) structure for the second moments. The cross-equation structure restricts the conditional moments to depend only upon their past levels, mean equation innovations, and lagged levels of the

other variable.² Equations (9a-b) are similar to the univariate GARCH-M(p,q) models as previously presented.

The contemporaneous correlation between price change and volume is measured by the coefficient, $\iota_{0\text{biv}}$, in the conditional covariance equation, that is, equation (9c). The MDH, several sequential information, and noisy rational expectations models suggest that this coefficient should be positive. The majority of both the empirical and theoretical literature also documents a positive correlation. Based on this, the fourth testable hypothesis is set up as follows:

$$H4: \iota_{0\text{biv}} > 0$$

We estimate the models using an iterative procedure based upon the method of Broyden, Fletcher, Goldfarb and Shanno (BFGS) to maximise the log-likelihood function. The quasi-maximum likelihood procedure of Bollerslev and Wooldridge (1992) is also applied, in order to estimate robust standard errors and covariance.

5. Empirical analysis

5.1. Data

The data set comprises daily observations of settlement prices and trading volume, that is, the number of contracts traded, for the nearby futures contract of the FTSE/ASE 20 Index, from August 27, 1999 to December 31, 2005, giving us in total 1,584 observations. The data is collected from the ADEX records. The FTSE/ASE 20 Index comprises of the 20 largest in market capitalisation and most highly traded stocks

² Including contemporaneous variables results in difficulty of interpretation, more complex asymptotics and less tractable estimation (see Hamilton, 1994).

of all the companies listed on the ASE. It represents over 50% of ASE's total capitalisation and currently has a heavier weight on banking, telecommunication and energy stocks.

Table 4 reports descriptive statistics of the daily stock index returns and trading volume. As it can be seen the returns series is positively skewed and highly leptokurtic compared to the normal distribution. It also displays significant first order autocorrelation. The Ljung-Box (1978) $Q(20)$ statistic for 20th order autocorrelations is statistically significant, while the Ljung-Box test statistic $Q^2(20)$ (for the squared data) indicates the presence of conditional heteroskedasticity.

The volume series is negatively skewed and leptokurtic compared to the normal distribution. It displays significant autocorrelations, which remain large for the ten lags reported. Significant autocorrelations in trading activity series have also been found in many earlier studies including Kavussanos and Phylaktis (2001) in their investigation of the volatility-volume relationship in the Greek capital market. The Ljung-Box (1978) $Q(20)$ statistic for 20th order autocorrelations is statistically significant, while the Ljung-Box test statistic $Q^2(20)$ (for the squared data) indicates the presence of conditional heteroskedasticity. The Augmented Dickey-Fuller (ADF) test statistic for unit roots indicates that the trading volume series is $I(0)$.

The empirical results of the univariate and bivariate GARCH- $M(p,q)$ models for the FTSE/ASE 20 Index nearby futures contract from August 27, 1999 to December 31, 2005, are presented in the next subsections.

5.2. Estimates of univariate GARCH- $M(p,q)$ models

The following two subsections present the maximum likelihood estimates of the univariate GARCH-M(p,q) models for stock index returns and trading volume. The results of different univariate GARCH-M(p,q) models of stock index returns are reported in Table 5, while those of trading volume are reported in Tables 6 and 7. Each table has three panels. Panel A presents the estimates of the conditional mean equation, Panel B presents the estimates of the conditional variance equation, and Panel C presents the model diagnostics.

The appropriate univariate GARCH-M(p,q)-ARMA(p,q) models are selected using mainly the Akaike (AIC) and Schwarz (SIC) information criteria, but also taking into account the significance of the coefficients, the Ljung-Box test statistics $Q(20)$ and $Q^2(20)$, and the sum of the coefficients of lagged squared returns and lagged conditional variances. Moreover, if our modelling is correctly specified, the value of the coefficients of skewness and kurtosis of the standardised residuals should be smaller than the value of skewness and kurtosis of the returns series and volume series respectively.

5.2.1. Results of conditional mean and variance of stock returns

Table 5 reports the estimated results of different univariate GARCH-M(p,q) models of stock index returns. In Panel A of Table 5, the results for the conditional mean of stock index returns are presented, modelled with various ARMA processes. The coefficient estimate of d_{1uni} , which measures the sensitivity of price change to time variation in the risk premium, is negative but statistically insignificant in all four models.

Panel B of Table 5 presents the results for the conditional variance of returns. The sum of coefficients β_{iuni} and γ_{juni} , the past conditional variances and past squared returns

respectively, is close to unity, indicating high persistence of volatility over time. The coefficient, δ_{1uni} , the lagged volume in the conditional variance of returns, is negative and statistically significant at the 5% level in models 1 and 4, and significant at the 10% level in models 2 and 3.¹⁴ This is contrary to our predictions of a positive coefficient, and inconsistent with the MDH and several models of sequential information transmission and noisy rational expectations equilibrium. Therefore, the first hypothesis tested, H1, is rejected. Jacobs and Onochie (1998) find positive and significant coefficients in all 6 futures contracts examined.

Panel C of Table 5 contains the model diagnostics. The Ljung-Box statistics $Q(20)$ and $Q^2(20)$ of the standardised and squared standardised residuals respectively exhibit no serial correlation, in all four models, implying that the models are well specified. Moreover, the coefficients of skewness (m_3) and kurtosis (m_4) of the standardised residuals exhibit a smaller value, than the skewness and kurtosis of the returns series respectively, further implying that the models are correctly specified.

Based primarily on the AIC and SIC information criteria, but also taking into account all the other conditions described above, model 1, the GARCH-M(1,1)-ARMA(1,0) model was considered as the most appropriate model.¹⁵ This univariate model is subsequently used to construct the bivariate GARCH-M(p,q) model.

Before we proceed to the results of the conditional mean and variance of trading volume, it is worth noting, that we also attempted an EGARCH-M specification to capture possible asymmetric shocks to volatility [see Nelson (1991)]. The estimated results of different univariate EGARCH-M(p,q) models of stock index returns for the period August 27, 1999 to December 31, 2005, are reported in Table A of the Appendix.

The first three models in Table A (models 1-3) demonstrate that the conditional variance equation is not well specified, as the Ljung-Box statistic $Q^2(20)$ of the squared standardised residuals exhibits serial correlation. By adding an extra GARCH term in the conditional variance equation, it rectifies this misspecification. Consequently, as it is shown in model 4, the EGARCH-M(2,1)-ARMA(1,0) model, the conditional variance equation becomes well specified, as the Ljung-Box statistic $Q^2(20)$ exhibits no serial correlation.

Although the leverage effect coefficient, ξ_{uni} , is found to be negative and statistically significant at the 5% level, indicating the existence of an asymmetric effect in returns, model 4, the EGARCH-M(2,1)-ARMA(1,0) model, is not superior to GARCH-M(1,1)-ARMA(1,0) model, using the AIC and SIC information criteria. In addition, the estimation of trading volume using the univariate EGARCH-M specification failed to converge, and as a result we could not employ an EGARCH-M specification for the bivariate model.

5.2.2. Results of conditional mean and variance of trading volume

Table 6 reports the results of different univariate GARCH-M(p,q) models of trading volume. The first three models in Table 6 (models 1-3) demonstrate that the conditional mean equation is not well specified, as the Ljung-Box statistic $Q(20)$ of the standardised residuals exhibits serial correlation. By adding more ARMA terms in the conditional mean equation, which are found to be statistically significant, it rectifies this misspecification and GARCH-M(1,1)-ARMA(3,2) model, i.e. model 4, is now well specified.

We were able to further improve on model 4 by adding an extra MA term and including only one AR term in the conditional mean equation, as it is depicted by the smaller AIC and SIC information criteria. Therefore model 5, the GARCH-M(1,1)-ARMA(1,3) model was considered as the most appropriate model. This univariate model is subsequently used to construct the bivariate GARCH-M(p,q) model.

Panel A of Table 6 presents the results for the conditional mean of trading volume. In model 5, the selected model, the coefficient, n_{1uni} , of the conditional variance, h^v_t , is found to be positive and statistically significant at the 10% level confirming Jacobs and Onochie's (1998) results. The coefficient, w_{1uni} , which examines the effects of margin requirements on trading volume, is negative and statistically significant at the 5% level. As discussed in the methodological issues section, the coefficient, w_{1uni} , can be either positive, negative, or zero. For example, Fische and Goldberg (1986) find that a 10% increase in margins would increase volume traded by 14.62%, using a 3- to 5-day window around margin changes. On the other hand, Hartzmark (1986) find that in only 4 of 13 contract days did volume move negatively and significantly in the opposite direction, using a 15-day window around margin changes. Dutt and Wein (2003) find statistically positive and/or insignificant relationships between volume and margins, using a 20-day window around margin changes.

The coefficient, y_{1uni} , the EONIA rate, r_t , is found to be negative but statistically insignificant, failing to support the view that an increase in the cost of holding inventories would lead to a reduction in futures market activity. This result might reflect the relatively low interest rates that prevailed in the Eurozone during the sample period. Looking at the results of earlier studies Dutt and Wein (2003) find negative and

statistically significant coefficients in 5 of 6 futures contracts, while Fishe and Goldberg (1986) find positive but insignificant values.

The coefficient, z_{1uni} , time to contract maturity, x_t , is found to be positive and statistically significant. This finding supports the view that as the contract approaches its delivery futures traders begin to close out their positions to avoid receiving the physical commodity and at the same time they open new positions in other contracts with longer expiry dates, consequently causing an increase in trading volume. This is a stronger result compared to Dutt and Wein (2003), who find mixed results, and Fishe and Goldberg (1986) who find positive and significant values only for the distant futures contract.

Finally, a time-trend variable, t , included to control for long-term changes in contract interest is found to be statistically insignificant.

Panel B of Table 6 presents the results for the conditional variance of volume. The sum of coefficients ζ_{iuni} and η_{juni} , the past conditional variances and past squared returns respectively, is less than 1, and therefore has a stationary variance.

The coefficient, θ_{1uni} , the lagged return in the conditional variance of volume, is negative, contrary to our expectations of a positive coefficient, but it is statistically insignificant. The lagged return models the informational impact of price on volume, and to the extent that price increases signal lower systematic risk, there is less hedging and/or speculative activity relative to informationally motivated trade. Therefore, the third hypothesis tested, H3, is rejected. This result is in contrast to Jacobs and Onochie (1998), who find positive and significant coefficients in all futures contracts examined.

Panel C of Table 6 contains the model diagnostics, which confirm that the conditional mean and variance equations of volume are well specified.

The same procedure was followed as above, for the selection of the most appropriate model, when margin requirements are adjusted for underlying price risk, using the lagged conditional variance of the change in daily settlement prices, denoted as h_{t-1}^f , in the conditional mean equation of trading volume. Table 7 reports the estimated results of different univariate GARCH-M(p,q) models of trading volume.

Models 1 and 2 in Table 7 demonstrate that the conditional mean equation is not well specified, as the Ljung-Box statistic Q(20) of the standardised residuals exhibits serial correlation. By adding more ARMA terms in the conditional mean equation, which are found to be statistically significant, it rectifies this misspecification. Consequently, as it is shown in models 3 and 4, the conditional mean equation becomes well specified, as the Ljung-Box statistic Q(20) exhibits no serial correlation.

We were able to further improve on models 3 and 4, and as previously shown, model 5, the GARCH-M(1,1)-ARMA(1,3) model was considered as the most appropriate model, based mainly on the values of the AIC and SIC information criteria, but also taking into consideration all the other conditions. Panel C of Table 7, which contains the model diagnostics, shows that model 5 is well specified. This univariate model is subsequently used to construct the bivariate GARCH-M(p,q) model.

There are few differences regarding the coefficients between model 5, the preferred model in Table 6 where m_t is unadjusted and model 5, the preferred model in Table 7, where m_t is adjusted. In the latter the coefficient, n_{1uni} , the conditional variance, h_{t-1}^v , is positive but statistically insignificant, unlike the significant coefficient found in the unadjusted model. What is of interest however is that the coefficient, w_{2uni} , which examines the effects of margin requirements adjusted for underlying price risk, using the

lagged conditional variance of the change in daily settlement prices, denoted by h_{t-1}^f , is positive and statistically insignificant, against the expectations of a negative coefficient. Thus, by adjusting margins for market risk we find them not to have an impact on trading volume. Thus, the second hypothesis tested, H2, is rejected. This is in contrast to the results of Dutt and Wein (2003), who document a statistically significant inverse relationship between margin changes and trading volume for all futures contracts examined.

5.3. Estimates of bivariate GARCH-M(p,q) model

Table 8 reports the estimated results of different versions of the bivariate GARCH-M(1,1) model of stock index returns and trading volume. The bivariate GARCH-M(1,1) model is constructed using the selected univariate models, that is, the GARCH-M(1,1)-ARMA(1,0) model and the GARCH-M(1,1)-ARMA(1,3) model, for the stock index returns and trading volume respectively.

Model 1 in Table 8 examines the effects of margin requirements on trading volume and compares the results to the findings of previous research. Model 2 examines the effects of margin requirements on trading volume, but margins are adjusted for underlying price risk, using the lagged conditional variance of the change in daily settlement prices, denoted by h_{t-1}^f . The results are compared to Dutt and Wein's (2003) findings, who also adjust margins for market risk. Model 3 also examines the effects of margin requirements on trading volume, but margins are adjusted by the conditional variance of the change in daily settlement prices lagged twice, denoted by h_{t-2}^f . This is done to check the robustness of our results. Finally, model 4 repeats model 2 but includes

lagged conditional variance of returns separately in the conditional mean of volume, in order to capture the direct effect of volatility on trading volume, which might have been wrongly accounted for when adjusting margin requirements for risk. The results in models 3 and 4, are similar to the results of the initial model 2, providing further evidence on the robustness of the bivariate GARCH-M(1,1) model.¹⁶

In Panel A of model 1, the results for the conditional mean of stock index returns and trading volume are presented. The conditional mean of returns is modelled as an ARMA(1,0) process, and the conditional mean of volume is modelled as an ARMA(1,3) process. The presence of serial correlation is evident, since the ARMA processes modelled, present statistically significant terms.

The coefficient estimate of d_{biv} , which measures the sensitivity of price change to time variation in the risk premium, is negative but statistically insignificant, as in the univariate model. The coefficient, n_{biv} , which measures the impact of the arrival of new information on trading volume as proxied by the conditional variance, h^v_t , is found to be positive and statistically significant at the 5% level, while in the univariate model it is significant at the 10% level.

The results on the remaining coefficients, that is, the margin level variable, m_t , the EONIA rate variable, r_t , time to contract maturity variable, x_t , and time-trend variable, t , are similar to the results reported for the univariate model, and therefore we will not repeat the comments. In effect, m_t , the variable of most interest to our examination, is found to be negative and statistically significant at the 5% level, when margins are not adjusted for underlying price risk.

Panel B of model 1 presents the results for the conditional variances of returns and volume and the conditional covariance between returns and volume. The sum of the coefficients of the past conditional variances and past squared returns, for both the conditional variances of returns and volume, is less than 1.

The coefficient, δ_{1biv} , the lagged volume in the conditional variance of returns, is negative and statistically insignificant, unlike the negative and significant coefficient found in the univariate model, but still inconsistent with our expectations of a positive coefficient. The coefficient, θ_{1biv} , the lagged return in the conditional variance of volume, is also negative and statistically insignificant, as in the univariate model, but still inconsistent to our predictions of a positive coefficient. Therefore, the two hypotheses tested, H1 and H3, are both rejected.

The coefficient, i_{0biv} , in the conditional covariance, which measures the contemporaneous correlation between price change and volume, is negative and statistically significant at the 5% level, inconsistent with the MDH, several sequential information, and noisy rational expectations models, which suggest that this coefficient should be positive. Therefore, the fourth hypothesis tested, H4, is rejected. This is in contrast to Jacobs and Onochie (1998), who find positive and statistically significant coefficients in all futures contracts examined. However, similar results to ours have also been found in the equities markets in Darrat, Rahman and Zhong (2003), who examined the contemporaneous correlations between volumes and return volatility in all 30 stocks comprising the DJIA, and found positive statistically significant correlations in only 3 stocks and negative correlation in 8 stocks.

The negative relationship found in the Greek market might be due to excessive noise trading compared to informed trading in the futures market. According to Liu (2007), who examined the different roles played by the two components of trading volume, informed trading and liquidity trading, in the volume-volatility relation using a marketwide private information arrival rate based on Easley et al. (1995) model, the liquidity component is the underlying driving force for the positive volume-volatility relation. The lack of substantial informed trading in the Greek capital market is supported by the low proportion of institutional trading. For example, in 2004, the proportion of institutional investors in Greece was 15%, significantly lower compared to other markets, such as the UK market, where the proportion was 51%.¹⁷

Panel C of model 1 contains the model diagnostics, which confirm that the conditional mean and variance equations of returns and volume and the conditional covariance equation between returns and volume are well specified.

The results of model 2 are similar to the results of model 1 and therefore we will not repeat the comments. As in the univariate model, coefficient, w_{2biv} , which examines the effects of margin requirements on trading volume, after margins are adjusted for underlying price risk, using the lagged conditional variance of returns, denoted as h_{t-1}^f , is found to be positive and statistically insignificant, failing to find an inverse association between margins and volume traded. This is in contrast to Dutt and Wein's (2003) findings who document a statistically significant inverse relationship between margin changes and trading volume. Thus, the second hypothesis tested, H2, is rejected.

As mentioned at the beginning of this subsection, the results in model 3, when margins are adjusted by the conditional variance of returns lagged twice, denoted as h_{t-2}^f ,

are similar to the results of the initial model 2. In model 4, the lagged conditional variance of returns, denoted as h_{t-1}^f , is separately included in the conditional mean of volume, in order to capture the differential effect of margin changes on volume. Although the lagged conditional variance of returns coefficient, s_{1biv} , is found to be negative and statistically significant, contrary to the expectations of a positive coefficient (see e.g. Cornell, 1981), the coefficient, w_{2biv} , is found to be negative but still statistically insignificant. The remaining of the results are similar to those of the initial model 2.

6. Summary and main policy conclusions

The effects of margin requirements on financial markets are not only of interest to academics, but are of practical concern to policy makers. Empirical studies carried out so far have not been able to conclusively resolve the debate on the effects of margin requirements on financial markets.

The current study has added two different dimensions to the examination of margin requirements on trading volume, which should make one treat the results of previous studies with caution. On the one hand, previous research, has generally neglected to consider that margin requirements change in response to changes in price volatility, and on the other hand, they did not take into account the relationship between price volatility and trading volume.

In our analysis, we employ a bivariate GARCH-M(p,q) model, which is constructed using the best selected univariate GARCH-M(p,q) models. We examine the effects of margin changes on trading volume, using the most liquid futures contract

traded in the Greek derivatives market, the FTSE/ASE 20 Index nearby futures contract, for the period August 27, 1999 to December 31, 2005.

The empirical results can be summarised as follows: An association between margin changes and trading volume is not found, when margins are adjusted for underlying price risk, using the lagged conditional variance of stock returns, and against the expectations of a negative relationship. This association remains also statistically insignificant, when margins are adjusted by the conditional variance of stock returns lagged twice, and when separately incorporating the lagged conditional variance of stock returns in the conditional mean of trading volume. This highlights the importance of adjusting margin requirements for risk and casts doubts on the results of previous studies which did not allow for these inter-relationships. Regarding the relationship between volatility of stock returns and trading volume, we find a contemporaneous correlation which is negative and statistically significant. As we have explained this could be due to the lack of substantial informed trading in the market.

Finally, it seems that margin requirements are used only as a mechanism to prevent trader default, at least in the case of the Greek derivatives market, and any decisions associated with the changes in margins, did not have a significant effect on trading volume. The findings further support what Roll (1989) stated in his comprehensive review on the implications for regulatory policy, that there is little evidence in favour of the efficacy of margin requirements, price limits and transaction taxes.

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Table 1
The Growth of the Greek Derivatives Market

| Year End | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 |
|--------------------------------|-------|-------|--------|--------|--------|--------|
| Trading Members (ADEX) | 40 | 65 | 70 | 67 | 60 | 55 |
| Clearing Members (ADECH) | 36 | 42 | 47 | 47 | 41 | 36 |
| - Direct Clearing Members | 29 | 33 | 35 | 35 | 29 | 24 |
| - General Clearing Members | 7 | 9 | 12 | 12 | 12 | 12 |
| Terminals | 171 | 333 | 419 | 429 | 405 | 310 |
| API Service Member Subscribers | 21 | 28 | 34 | 35 | 33 | 30 |
| Investor Accounts | 3,181 | 9,133 | 15,482 | 21,256 | 24,373 | 27,399 |
| Products | 5 | 7 | 8 | 10 | 11 | 11 |

Source: ASE Fact Book 2006.

Table 2
Summary Trading Statistics for Stock Index Futures

| Year | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 |
|-------------------------------|--------|----------|-----------|-----------|-----------|-----------|-----------|
| FTSE/ASE 20 Index Futures | | | | | | | |
| Total Traded Volume | 48,190 | 484,246 | 1,326,089 | 2,085,056 | 2,809,211 | 2,792,168 | 2,380,010 |
| Daily Average Trading Vol. | 554 | 1,922 | 5,283 | 8,442 | 11,373 | 11,036 | 9,520 |
| Traded Value (Mil. EUR) | 815.88 | 6,514.23 | 10,464.48 | 11,181.61 | 13,374.84 | 18,146.57 | 19,189.00 |
| FTSE/ASE Mid-40 Index Futures | | | | | | | |
| Total Traded Volume | N/A | 428,985 | 527,726 | 344,476 | 76,939 | 130,751 | 132,453 |
| Daily Average Trading Vol. | N/A | 1,702 | 2,099 | 1,395 | 311 | 517 | 530 |
| Traded Value (Mil. EUR) | N/A | 2,792.44 | 1,758.49 | 819.99 | 306.59 | 1,442.02 | 1,733.00 |

Source: ASE Fact Book 2006. N/A refers to non-applicable.

Table 3
Margin Requirements on Stock Index Futures

| Effective Date | FTSE/ASE 20 Index | FTSE/ASE Mid-40 Index |
|----------------|-------------------|-----------------------|
| 27/08/1999 | 20% | - |
| 07/01/2000 | 14% | - |
| 28/01/2000 | - | 18% |
| 24/10/2000 | 12% | 16% |
| 12/02/2001 | - | 12% |
| 12/09/2001 | 16% | 16% |
| 12/10/2001 | 12% | 12% |
| 07/10/2002 | 15% | 15% |
| 16/12/2002 | 14% | 14% |
| 14/01/2003 | 13% | 13% |
| 16/05/2003 | 12% | 12% |
| 20/06/2003 | 11% | 11% |
| 05/02/2004 | 10% | 10% |

Notes: The above list including the margin changes of the stock index futures was provided by the Risk Management Department of ADECH.

Table 4
Summary Statistics of FTSE/ASE 20 Index Nearby Futures Contract
(27/08/1999-31/12/2005)

| | Stock Index Returns | Trading Volume |
|---------------------|---------------------|----------------|
| Mean | -0.000 | 8.090 |
| Std. Deviation | 0.016 | 1.171 |
| Minimum | -0.106 | 3.045 |
| Maximum | 0.097 | 10.164 |
| Skewness | 0.098 | -1.143* |
| Kurtosis (excess) | 4.080* | 0.608* |
| ρ_1 | 0.080* | 0.932* |
| ρ_2 | -0.013 | 0.905* |
| ρ_3 | -0.016 | 0.894* |
| ρ_4 | 0.041 | 0.888* |
| ρ_5 | -0.002 | 0.885* |
| ρ_6 | 0.007 | 0.877* |
| ρ_7 | 0.011 | 0.875* |
| ρ_8 | -0.005 | 0.877* |
| ρ_9 | -0.014 | 0.875* |
| ρ_{10} | -0.022 | 0.869* |
| Q(20) | 35.41* | 24529.93* |
| Q ² (20) | 275.78* | 23890.28* |
| ADF(7) | | -3.813 |

Notes: Stock index return is calculated as $\Delta f_t = (f_t - f_{t-1})$ the price log-relative, where $f_t = \ln(F_t)$ is the natural logarithm of the contract's settlement futures price, F_t . Trading volume is calculated as $v_t = \ln(V_t)$, the natural logarithm of trading volume, V_t . ρ_i , where $i = 1, \dots, 10$ are sample autocorrelations. * denotes significance of diagnostic statistics at the 5% level. Q(20) and Q²(20) for the squared data, are Ljung-Box statistics of 20th order. ADF(7) is the Augmented Dickey-Fuller test statistic with lag length 7 chosen using SIC; the critical value is -3.413.

Table 5
Univariate GARCH-M(p,q) Estimation of Stock Index Returns
FTSE/ASE 20 Index Nearby Futures Contract (27/08/1999-31/12/2005)

| Coefficients | Model 1 | Model 2 | Model 3 | Model 4 |
|-------------------------------|--------------------|---------------------|---------------------|--------------------|
| Panel A. Conditional mean | | | | |
| a_{0uni} | 0.000 (0.604) | 0.000 (0.592) | 0.000 (0.636) | 0.000 (0.490) |
| b_{1uni} | 0.079* (2.861) | 0.080* (2.660) | -0.001 (-0.006) | 0.080* (2.672) |
| b_{2uni} | | -0.009 (-0.328) | | |
| c_{1uni} | | | 0.081 (0.429) | |
| d_{1uni} | -0.751 (-0.334) | -0.733 (-0.322) | -0.910 (-0.379) | -0.465 (-0.203) |
| Panel B. Conditional variance | | | | |
| α_{0uni} | 0.000* (2.084) | 0.000* (2.032) | 0.000** (1.801) | 0.000* (2.165) |
| β_{1uni} | 0.856* (18.368) | 0.855* (19.135) | 0.856* (16.626) | 1.111* (5.604) |
| β_{2uni} | | | | -0.235 (-1.227) |
| γ_{1uni} | 0.111* (3.357) | 0.111* (3.469) | 0.111* (3.209) | 0.094* (3.442) |
| δ_{1uni} | 0.000* (-2.010) | 0.000** (-1.952) | 0.000** (-1.751) | 0.000* (-2.090) |
| Panel C. Model diagnostics | | | | |
| m_3 | -0.088 | -0.093 | -0.090 | -0.098 |
| m_4 | 1.519* | 1.524* | 1.524* | 1.536* |
| $X^2(2)$ | 154.13* | 155.31* | 155.41* | 158.14* |
| Q(20) | 19.100 | 19.686 | 19.481 | 18.997 |
| Q ² (20) | 22.633 | 22.712 | 22.651 | 19.963 |
| AIC | -8.2580 | -8.2564 | -8.2569 | -8.2568 |
| SIC | -8.2343 | -8.2292 | -8.2298 | -8.2297 |

Notes: For the specification of the univariate GARCH-M(p,q) model refer to equations (1) and (2) in text. The subscript *uni* refers to univariate. The figures in parentheses are *t*-statistics. m_3 and m_4 are coefficients of skewness and kurtosis of the standardised residuals respectively. $X^2(2)$ is the Jarque-Bera-normality test. Q(20) and Q²(20) are 20th order Ljung-Box statistics of the standardised and squared standardised residuals respectively. AIC and SIC are the Akaike and Schwarz information criteria respectively. * and ** denotes significance at the 5% and 10% level respectively.

Table 6
Univariate GARCH-M(1,1) Estimation of Trading Volume-Margins Unadjusted
FTSE/ASE 20 Index Nearby Futures Contract (27/08/1999-31/12/2005)

| Coefficients | Model 1 | Model 2 | Model 3 | Model 4 | Model 5 |
|-------------------------------|---------------------|---------------------|----------------------|----------------------|----------------------|
| Panel A. Conditional mean | | | | | |
| e_{0uni} | 1.100* (3.790) | 0.783* (3.302) | 0.009 (0.065) | -0.139* (-2.584) | -0.107 (-1.035) |
| g_{1uni} | 0.819* (50.527) | 0.611* (22.636) | 0.975* (83.754) | 0.620* (45.610) | 0.996* (458.733) |
| g_{2uni} | | 0.252* (10.678) | | 0.628* (40.892) | |
| g_{3uni} | | | | -0.253* (-59.668) | |
| k_{1uni} | | | -0.602* (-10.046) | -0.136* (-5.743) | -0.529* (-20.294) |
| k_{2uni} | | | | -0.649* (-33.227) | -0.188* (-6.016) |
| k_{3uni} | | | | | -0.085* (-3.098) |
| l_{1uni} | 0.000* (4.660) | 0.000* (3.261) | 0.000 (0.621) | 0.000 (-0.461) | 0.000 (-0.558) |
| n_{1uni} | 1.812 (1.285) | 1.805 (1.301) | 1.577* (6.017) | 1.501* (8.440) | 1.217** (1.681) |
| w_{1uni} | -2.271* (-2.661) | -1.890* (-3.428) | -0.683 (-1.494) | -0.320* (-2.219) | -0.262* (-2.958) |
| y_{1uni} | 2.387 (1.167) | 1.771 (1.045) | 0.035 (0.037) | -0.131 (-0.360) | -0.194 (-0.574) |
| z_{1uni} | 0.003* (2.460) | 0.004* (3.625) | 0.002* (2.696) | 0.001* (2.322) | 0.001* (2.209) |
| Panel B. Conditional variance | | | | | |
| ε_{0uni} | 0.146* (4.560) | 0.124* (4.394) | 0.142* (11.921) | 0.137* (13.911) | 0.112* (6.086) |
| ζ_{1uni} | 0.009 (0.063) | 0.102 (0.701) | -0.077 (-1.105) | -0.082 (-1.157) | 0.092 (0.787) |
| η_{1uni} | 0.112 (1.180) | 0.102 (1.144) | 0.105* (10.634) | 0.096* (16.066) | 0.102* (3.155) |
| θ_{1uni} | -0.524 (-0.995) | -0.324 (-0.384) | -0.459** (-1.702) | -0.343 (-1.213) | -0.338 (-1.188) |
| Panel C. Model diagnostics | | | | | |
| m_3 | -0.094 | -0.115** | -0.155* | -0.213* | -0.225* |
| m_4 | 0.853* | 0.944* | 0.954* | 0.923* | 0.929* |
| $X^2(2)$ | 50.33* | 62.18* | 66.42* | 68.08* | 70.33* |
| Q(20) | 189.678* | 114.195* | 73.968* | 20.744 | 25.061 |
| Q ² (20) | 15.569 | 14.448 | 18.703 | 22.544 | 21.725 |
| AIC | -1.7818 | -1.8409 | -1.8975 | -1.9469 | -1.9494 |
| SIC | -1.7445 | -1.8002 | -1.8568 | -1.8960 | -1.9018 |

Notes: For the specification of the univariate GARCH-M(1,1) model refer to equations (3a) and (4) in text. For the rest see Notes to Table 5.

Table 7
Univariate GARCH-M(1,1) Estimation of Trading Volume-Margins Adjusted
FTSE/ASE 20 Index Nearby Futures Contract (27/08/1999-31/12/2005)

| Coefficients | Model 1 | Model 2 | Model 3 | Model 4 | Model 5 |
|-------------------------------|--------------------|--------------------|----------------------|---------------------|----------------------|
| Panel A. Conditional mean | | | | | |
| e_{0uni} | 0.672* (2.372) | 0.378** (1.723) | -0.206* (-4.244) | -0.239* (-4.020) | -0.159 (-1.108) |
| g_{1uni} | 0.812* (38.531) | 0.615* (24.334) | 0.630* (30.018) | 0.601* (5.114) | 0.999* (297.860) |
| g_{2uni} | | 0.249* (9.913) | 0.634* (20.248) | 0.159 (1.454) | |
| g_{3uni} | | | -0.249* (-65.188) | 0.426* (9.530) | |
| g_{4uni} | | | -0.016 (-0.803) | -0.188* (-4.735) | |
| k_{1uni} | | | -0.155* (-5.055) | -0.129 (-1.125) | -0.531* (-18.728) |
| k_{2uni} | | | -0.654* (-20.785) | -0.142* (-2.419) | -0.190* (-5.672) |
| k_{3uni} | | | | -0.464* (-9.393) | -0.086* (-2.966) |
| l_{1uni} | 0.001* (7.243) | 0.000* (5.816) | 0.000 (-0.173) | 0.000 (-0.087) | 0.000 (-0.065) |
| n_{1uni} | 2.104 (1.258) | 1.922 (1.501) | 1.357* (4.867) | 1.463* (5.918) | 1.061 (1.027) |
| w_{2uni} | 0.000* (-2.240) | 0.000 (-0.867) | 0.000 (1.442) | 0.000 (1.074) | 0.000 (0.918) |
| y_{1uni} | 5.427* (2.661) | 4.183* (2.263) | 0.113 (0.438) | 0.243 (0.571) | 0.089 (0.290) |
| z_{1uni} | 0.003* (2.076) | 0.004* (3.282) | 0.001* (2.560) | 0.002* (2.460) | 0.001* (2.297) |
| Panel B. Conditional variance | | | | | |
| ε_{0uni} | 0.159* (3.139) | 0.129* (4.228) | 0.132* (8.078) | 0.130* (8.067) | 0.106* (2.681) |
| ζ_{1uni} | -0.070 (-0.280) | 0.076 (0.463) | -0.050 (-0.447) | -0.039 (-0.348) | 0.134 (0.506) |
| η_{1uni} | 0.107 (1.229) | 0.101** (1.867) | 0.098* (10.814) | 0.105* (11.446) | 0.104* (2.127) |
| θ_{1uni} | -0.567 (-1.518) | -0.355 (-0.924) | -0.287 (-1.092) | -0.276 (-1.055) | -0.279 (-0.628) |
| Panel C. Model diagnostics | | | | | |
| m_3 | -0.073 | -0.099 | -0.216* | -0.212* | -0.224* |
| m_4 | 0.758* | 0.907* | 0.952* | 0.980* | 0.949* |
| $X^2(2)$ | 39.32* | 56.80* | 72.02* | 75.03* | 72.71* |
| Q(20) | 183.660* | 113.111* | 20.506 | 20.661 | 25.798 |
| Q ² (20) | 15.387 | 13.767 | 20.731 | 18.134 | 19.601 |
| AIC | -1.7790 | -1.8370 | -1.9476 | -1.9443 | -1.9471 |
| SIC | -1.7417 | -1.7962 | -1.8933 | -1.8866 | -1.8995 |

Notes: For the specification of the univariate GARCH-M(1,1) model refer to equations (3b) and (4) in text. For the rest see Notes to Table 5.

Table 8
Bivariate GARCH-M(1,1) Estimation of Stock Index Returns and Trading Volume
FTSE/ASE 20 Index Nearby Futures Contract (27/08/1999-31/12/2005)

| Coefficients | Model 1 | Model 2 | Model 3 | Model 4 |
|--|----------------------|----------------------|----------------------|----------------------|
| Panel A. Conditional mean | | | | |
| a_{0biv} | 0.000 (0.706) | 0.000 (0.744) | 0.000 (0.732) | 0.001 (1.215) |
| b_{1biv} | 0.081* (3.834) | 0.083* (2.422) | 0.083* (2.666) | 0.078* (3.383) |
| d_{1biv} | -1.238 (-0.512) | -1.135 (-0.510) | -1.133 (-0.491) | -1.771 (-1.026) |
| e_{0biv} | -0.111* (-35.757) | -0.155* (-9.168) | -0.161* (-9.319) | -0.119 (-1.444) |
| g_{1biv} | 0.996* (397.327) | 0.998* (271.928) | 0.998* (407.049) | 0.996* (243.650) |
| k_{1biv} | -0.527* (-29.229) | -0.528* (-23.219) | -0.528* (-21.741) | -0.533* (-20.247) |
| k_{2biv} | -0.188* (-6.631) | -0.190* (-7.005) | -0.190* (-6.637) | -0.189* (-6.715) |
| k_{3biv} | -0.092* (-3.680) | -0.093* (-3.377) | -0.093* (-3.674) | -0.093* (-4.177) |
| l_{1biv} | 0.000 (-0.499) | 0.000 (-0.029) | 0.000 (0.002) | 0.000 (0.101) |
| n_{1biv} | 1.215* (61.982) | 1.040* (12.509) | 1.081* (6.492) | 1.123* (2.049) |
| s_{1biv} | | | | -44.164* (-2.005) |
| w_{1biv} | -0.242* (-2.692) | | | |
| w_{2biv} | | 0.000 (0.689) | 0.000 (1.017) | 0.000 (-0.866) |
| y_{1biv} | -0.176 (-0.579) | 0.087 (0.279) | 0.092 (0.326) | 0.041 (0.144) |
| z_{1biv} | 0.001* (2.623) | 0.001* (2.281) | 0.001* (2.589) | 0.001* (2.288) |
| Panel B. Conditional variance and covariance | | | | |
| α_{0biv} | 0.000** (1.728) | 0.000** (1.692) | 0.000** (1.747) | 0.000** (1.665) |
| β_{1biv} | 0.854* (17.512) | 0.855* (18.832) | 0.855* (17.887) | 0.867* (18.972) |
| γ_{1biv} | 0.110* (3.646) | 0.109* (3.671) | 0.109* (3.535) | 0.102* (3.523) |
| δ_{1biv} | 0.000 (-1.631) | 0.000 (-1.576) | 0.000 (-1.636) | 0.000 (-1.599) |
| ϵ_{0biv} | 0.108* (20.731) | 0.103* (6.224) | 0.104* (6.601) | 0.103* (4.136) |
| ζ_{1biv} | 0.124* (7.226) | 0.163 (1.306) | 0.152 (1.283) | 0.154 (0.952) |
| η_{1biv} | 0.094* (5.376) | 0.098* (4.785) | 0.096* (4.333) | 0.101* (3.840) |
| θ_{1biv} | -0.363 (-1.521) | -0.316 (-1.332) | -0.321 (-1.210) | -0.316 (-1.327) |
| ι_{0biv} | 0.000* | 0.000* | 0.000* | 0.000* |

| | | | | |
|----------------------------|----------|----------|----------|----------|
| | (-2.277) | (-2.321) | (-2.797) | (-2.186) |
| κ_{1biv} | 0.849* | 0.852* | 0.852* | 0.847* |
| | (10.289) | (11.005) | (11.613) | (11.606) |
| λ_{1biv} | 0.041** | 0.040 | 0.040 | 0.041** |
| | (1.762) | (1.469) | (1.572) | (1.817) |
| μ_{1biv} | 0.001* | 0.001* | 0.001* | 0.001* |
| | (2.333) | (2.363) | (2.833) | (2.275) |
| Panel C. Model diagnostics | | | | |
| m_{3sr} | -0.080 | -0.079 | -0.079 | -0.078 |
| m_{3tv} | -0.224* | -0.223* | -0.224* | -0.227* |
| m_{4sr} | 1.543* | 1.552* | 1.552* | 1.545* |
| m_{4tv} | 0.924* | 0.943* | 0.941* | 0.889* |
| $X^2_{sr}(2)$ | 158.52* | 160.45* | 160.44* | 159.04* |
| $X^2_{tv}(2)$ | 69.47* | 71.78* | 71.52* | 65.59* |
| $Q_{sr}(20)$ | 18.861 | 18.780 | 18.782 | 18.876 |
| $Q_{tv}(20)$ | 25.154 | 25.814 | 25.845 | 26.107 |
| $Q^2_{sr}(20)$ | 22.484 | 22.863 | 22.860 | 23.458 |
| $Q^2_{tv}(20)$ | 20.481 | 18.541 | 18.571 | 18.961 |
| AIC _{sr} | -8.2552 | -8.2552 | -8.2552 | -8.2516 |
| AIC _{tv} | -1.9508 | -1.9484 | -1.9487 | -1.9521 |
| SIC _{sr} | -8.2314 | -8.2315 | -8.2315 | -8.2277 |
| SIC _{tv} | -1.9033 | -1.9009 | -1.9012 | -1.9013 |

Notes: For the specification of the bivariate GARCH-M(1,1) model refer to equations (5) to (10) in text. The coefficient, s_{1biv} , is the ‘lagged’ conditional variance of stock index returns included in the conditional mean of trading volume. The subscript *biv* refers to bivariate. The subscripts *sr* and *tv* refer to the stock index returns and trading volume equations respectively. For the rest see Notes to Table 5.

Appendix: Table A
Univariate EGARCH-M(p,q) Estimation of Stock Index Returns
FTSE/ASE 20 Index Nearby Futures Contract (27/08/1999-31/12/2005)

| Coefficients | Model 1 | Model 2 | Model 3 | Model 4 |
|-------------------------------|----------------------|---------------------|----------------------|----------------------|
| Panel A. Conditional mean | | | | |
| a_{0uni} | -0.007 (-1.333) | -0.006 (-1.157) | -0.008 (-0.983) | -0.007 (-1.336) |
| b_{1uni} | 0.065* (2.960) | 0.068* (3.147) | -0.037 (-0.119) | 0.065* (2.982) |
| b_{2uni} | | -0.008 (-0.315) | | |
| c_{1uni} | | | 0.103 (0.339) | |
| d_{1uni} | -0.001 (-1.327) | -0.001 (-1.162) | -0.001 (-0.995) | -0.001 (-1.324) |
| Panel B. Conditional variance | | | | |
| α_{0uni} | -0.353* (-17.109) | -0.356* (-2.470) | -0.354** (-1.677) | -0.343** (-1.772) |
| β_{1uni} | 0.966* (138.890) | 0.967* (56.030) | 0.966* (38.307) | 1.102* (7.503) |
| β_{2uni} | | | | -0.136 (-0.878) |
| γ_{1uni} | 0.209* (6.132) | 0.210* (3.868) | 0.210* (2.931) | 0.193* (2.953) |
| δ_{1uni} | -0.011 (-1.526) | -0.011 (-1.428) | -0.011 (-1.335) | -0.011 (-0.976) |
| ζ_{1uni} | -0.053* (-2.238) | -0.053* (-2.523) | -0.053* (-2.344) | -0.048* (-2.086) |
| Panel C. Model diagnostics | | | | |
| m_3 | 0.019 | 0.015 | 0.017 | 0.012 |
| m_4 | 1.635* | 1.639* | 1.640* | 1.640* |
| $X^2(2)$ | 176.35* | 177.24* | 177.57* | 177.33* |
| Q(20) | 21.698 | 22.067 | 22.077 | 21.759 |
| Q ² (20) | 28.937** | 29.236** | 28.956** | 27.028 |
| AIC | -8.2565 | -8.2549 | -8.2555 | -8.2551 |
| SIC | -8.2294 | -8.2244 | -8.2250 | -8.2246 |

Notes: For the specification of the univariate EGARCH-M(p,q) model refer to equations (A) and (B) below. The subscript *uni* refers to univariate. The figures in parentheses are *t*-statistics. m_3 and m_4 are coefficients of skewness and kurtosis of the standardised residuals respectively. $X^2(2)$ is the Jarque-Bera-normality test. Q(20) and Q²(20) are 20th order Ljung-Box statistics of the standardised and squared standardised residuals respectively. AIC and SIC are the Akaike and Schwarz information criteria respectively. * and ** denotes significance at the 5% and 10% level respectively.

Model: The conditional mean and variance equations of the univariate EGARCH-M(p,q) specification are:

$$\Delta f_t = a_{0uni} + \sum_{i=1}^p b_{iuni} \Delta f_{t-i} + \sum_{j=1}^q c_{juni} u_{t-j}^f + d_{1uni} h_t^f + u_t^f \quad (\text{A})$$

$$\ln(h_t^f) = \alpha_{0uni} + \sum_{i=1}^p \beta_{iuni} \ln(h_{t-i}^f) + \sum_{j=1}^q \gamma_{juni} |u_{t-j}^f / \sqrt{h_{t-j}^f}| + \sum_{j=1}^q \zeta_{juni} (u_{t-j}^f / \sqrt{h_{t-j}^f}) + \delta_{1uni} v_{t-1} \quad (\text{B})$$

where $f_t = \ln(F_t)$ is the natural logarithm of the contract's settlement futures price, F_t ; $\Delta f_t = f_t - f_{t-1}$ is the price log-relative, Δf_{t-i} are past returns, u_{t-j}^i are MA terms, h_t^i is the conditional variance of Δf_t , and u_t^i are random disturbance terms. Unlike the linear GARCH-M(p, q) model there are no restrictions on the parameters α_{0uni} , β_{1uni} , γ_{juni} , and ξ_{juni} to ensure non-negativity of the conditional variance. Persistence of volatility is measured by β_{1uni} . The asymmetric effect of negative and positive shocks is captured by ξ_{juni} and γ_{juni} respectively; ξ_{juni} measures the sign effect and γ_{juni} measures the size effect. If $\xi_{juni} < 0$ a negative shock (bad news) tends to reinforce the size effect. The converse takes place when $\xi_{juni} > 0$. Bad news will mitigate the size effect. Finally, the lagged volume variable, v_{t-1} , is intended to capture the effect of trading volume on the conditional variance of returns.

¹ For an investigation in the initial margin requirements in the U.S. stock market see Hardouvelis and Theodossiou, 2002.

² See e.g. Telser (1981) and Fische and Goldberg (1986).

³ See e.g. Fenn and Kupiec (1993), and Chatrath, Adrangi and Allender (2001).

⁴ See e.g. Telser (1981), Hartzmark (1986) and Fische, Goldberg, Gosnell and Sinha (1990).

⁵ See Bauwens, Laurent and Rombouts (2006) for a recent survey on multivariate GARCH (MGARCH) models. They assert that these models are important for the study of the relations between the volatilities and co-volatilities of several assets and markets, since it is now widely accepted that financial volatilities move together over time across assets and markets.

⁶ These important developments and changes include, among others, the official entry of Greece into the European Economic and Monetary Union (EMU) on January 1, 2001, and the official upgrade of Greek financial markets by Morgan Stanley Capital International (MSCI) from an emerging to developed status on June 1, 2001.

⁷ See Fische and Goldberg (1986) for an early review.

⁸ Henry and McKenzie (2006) consider the relationship between traded volume and volatility allowing for the impact of short sales. The evidence supports a non-linear,

bidirectional relationship between volume and volatility. Their analysis covers the 21 most actively traded and liquid stocks on the HKSE.

⁹ The Athens Stock Exchange (ASE S.A.) and the ADEX S.A. were merged in July 17, 2002 to form a new company, the Athens Exchange S.A. (ATHEX). ADECH continued to operate as a separate company.

¹⁰ It is worth noting that we did not perform the tests on the FTSE/ASE Mid-40 Index futures contracts, due to the low trading volume compared to FTSE/ASE 20 Index futures contracts.

¹¹ For more information on the establishment and development of the Greek derivatives market see *ASE Fact Book 2006*. The historical information on margin requirements was provided by the Risk Management Department of ADECH.

¹² EONIA is the effective overnight reference rate for the euro. It is computed as a weighted average of all overnight unsecured lending transactions undertaken in the interbank market, initiated within the euro area by the contributing banks. EONIA is computed with the help of the European Central Bank (ECB). The historical data of EONIA was provided by Reuters Support Services.

¹³ The diagonal VECH formulation, of Bollerslev, Engle and Wooldridge (1988), is employed for the construction of the bivariate GARCH-M(p,q) model, to allow for greater flexibility and the inclusion of the various exogenous variables in the conditional mean, variance and covariance equations. The diagonal VECH formulation was preferred to the BEKK formulation of Engle and Kroner (1995), since the BEKK model is more complex and consequently more difficult to construct (see Brooks, 2002). Jacobs and Onochie (1998) also use a diagonal VECH formulation for the estimation of a bivariate

EGARCH-M(p,q) model, to examine the relationship between return variability and trading volume in international futures markets.

¹⁴ It is worth noting that the coefficient, δ_{biv} , although it remains negative, it is statistically insignificant in the bivariate GARCH-M(p,q) model.

¹⁵ The GARCH-M(1,1)-ARMA(1,0) model, is considered superior to model 4, the GARCH-M(2,1)-ARMA(1,0) model, as depicted by the smaller AIC and SIC information criteria and the statistically insignificant $\beta_{2\text{uni}}$ coefficient.

¹⁶ The results are also similar for both models 1 and 2, when using contemporaneous trading volume, instead of lagged trading volume, in the conditional variance of stock index returns.

¹⁷ See Federation of European Securities Exchanges, 2007.