**Price and Open Interest in Greek stock index futures market**

# CHRISTOS FLOROS[1]

Department of Economics, University of Portsmouth,
Portsmouth Business School, Portsmouth, PO1 3DE, UK.
E-Mail: Christos.Floros@port.ac.uk, Tel: +44 (0) 2392 844244.

Abstract

This paper examines the relation between price and open interest in Greek stock index futures market. The focus is on the GARCH effects and the long-run information role of open interest. The results show that current open interest helps in explaining the GARCH effects, while it provides a negative impact on returns. Furthermore, the evidence from cointegration tests shows that there is a long-run relation between open interest and futures price. This suggests that one can use the information of open interest to predict futures prices in the long run. These findings are strongly recommended to financial managers dealing with Greek stock index futures.

---

[1] Christos Floros is a Lecturer in Banking and Finance in the Department of Economics at the University of Portsmouth, UK.

## I.    INTRODUCTION

In this paper we investigate the price-open interest relation for stock index futures. Open interest is the total number of futures contracts that have not been 'closed out'[2]. It is often used to confirm trends and trend reversals for futures contracts. The open interest position is reported each day and represents the increase or decrease in the number of contracts for that day. By monitoring the changes in the open interest figures at the end of each trading day, some conclusions about the day's activity can be drawn. Increasing open interest means that new money is flowing into the marketplace, while declining open interest means that the market is liquidating and implies that the prevailing price trend is coming to an end. So, knowledge of open interest can prove useful toward the end of major market moves.

The price (or volatility)-open interest relation on financial futures markets continues to be of empirical interest[3]. Open interest is an important indicator for hedging (Kamara, 1993; Chen *et al*., 1995) and market depth (Bessembinder and Seguin, 1993). Previous empirical studies show evidence of strong correlations between price volatility and open interest. Bessembinder and Seguin (1993) study this relationship for eight futures markets and report a negative impact of expected open interest to volatility. They suggest that variations in open interest reflect changes in market depth, while greater market depth leads to lower volatility. Ragunathan and Peker (1997) show that positive open interests shocks have an impact on volatility than negative shocks. This also leads to the conclusion that market depth does have an effect on volatility. Watanabe (2001) shows that there is a significant negative relation between volatility and expected open interest for the Nikkei 225 stock index futures. However, their results provide evidence that the relation may vary with the regulation. Furthermore, Girma and Mougoue (2002) use a GARCH (1,1) model to explore the effect of volume and open interest on futures spreads return volatility. They show that lagged volume and open interest provide significant explanation for futures spreads volatility when entered separately. On the other hand, Ferris *et al*. (2002) find that open interest is not directly affected by the increase in volatility. Accordingly, "*open interest in the S&P 500 index futures is a useful proxy for examining the flow of capital into or out of the market, given pricing error information shocks*" (Ferris *et al*., p. 371). Recently, Yang *et al*. (2004) examine the long-run information role of open interest in futures markets. Their results show that there is a long-run relation between open interest and futures prices. This suggests that futures price is a primary source of open interest, while open interest does not cause futures prices in the long run.

This study contributes to the debate in two ways. First, it provides a further case study of a particularly interesting country, Greece. To the best of our knowledge, no previous study has tested the relationship between daily prices and open interest for both available stock index futures contracts, FTSE/ASE-20 and FTSE/ASE Mid 40, of the Athens Derivatives Exchange (ADEX). Second, it goes beyond the GARCH, Johansen and Granger causality econometric techniques. We specifically examine

---

[2] It is equal to the sum of either the outstanding long positions or the sum of the outstanding short positions.

[3] The majority of the empirical evidence is summarised in the paper by Karpoff (1987) and Sutcliffe (1993).

GARCH effects in our data and test how well the GARCH effects are explained by open interest. In addition, we investigate Granger causality on the basis of the existence of a cointegration (long-run) relationship among futures price and open interest.

The paper is organised as follows: Section II outlines the methodology and describes the data. Section III presents empirical results, and Section IV concludes the paper and summarises our findings.

## II. METHODOLOGY AND DATA

Financial research shows much evidence that returns characterized by leptokurtosis, skewness and volatility clustering. A usual way to capture the above stylised facts is to model the conditional variance as an ARCH process. Engle (1982) proposes an ARCH model to capture the changing in variance. He introduces the ARCH(p) time series models for explaining the time-varying volatility clustering phenomenon. Bollerslev (1986) extends ARCH model including past variances as well as past forecast errors. This model is referred to as GARCH (p,q) model. The GARCH (p,q) model captures the tendency in financial data for volatility clustering and incorporates heteroskedasticity into the estimation procedure. In GARCH (p,q), positive and negative past values have a symmetric effect on the conditional variance.

A quantitative approach that has been used to explain the price-open interest relationship is based on GARCH models. A significant number of research papers argue that GARCH (1,1) model accounts for temporal dependence in variance and excess kurtosis (Ciner, 2002). GARCH (1,1) model is found to be parsimonious and easier to identify and estimate the parameters, see Bollerslev (1986) and Enders (1995). Brailsford (1996) uses the GARCH (1,1) model and concludes that there is a strong support for the above model. Sharma *et al*. (1996) show that the market indicator returns are best described by the GARCH (1,1) model. Girma and Mougoue (2002) suggest that current trading volume and open interest do not remove the GARCH effect in three out of the four spreads.

This paper seeks to extend the work of Sharma *et al*. (1996) by investigating if open interest explains the GARCH effects for market returns. We test whether open interest is a good proxy for information arrival in explaining conditional heteroscedasticity. Open interest can therefore be used as explanatory variable in the conditional variance function of GARCH (1,1). Standard GARCH (1,1) specification is given by:

$$
\begin{aligned}
R_t &= \mu + \varepsilon_t \qquad\qquad\qquad \text{(Mean Equation)} \\
\sigma_t^2 &= \omega + a\varepsilon_{t-1}^2 + \beta\sigma_{t-1}^2 + \gamma OI_t \quad \text{(Variance Equation)}
\end{aligned}
\tag{1}
$$

The return parameter is given by $R_t = \ln(P_t) - \ln(P_{t-1})$ where $P_t$ is the daily closing futures price. $OI_t$ stands for the daily open interest at time *t*. It is also used as a proxy for market depth, see Bessembinder and Seguin (1993). If open interest is positive (negative) and significant, then positive (negative) effect on returns is expected. The variance equation includes lagged conditional variance terms and errors. Since $R_t$ are returns, we expect their mean value (which will be given by $\mu$) to be positive and small. We also expect the value of $\omega$ again to be small. All parameters in variance equation must be positive, and the sum of $\alpha$ and $\beta$ is expected to be less than, but

close to, unity, with $\beta > \alpha$. News about volatility from the previous period can be measured as the lag of the squared residual from the mean equation (ARCH term).

In addition, we follow the recent work of Yang *et al.* (2004) and test the evidence of long-run informational role of open interest in futures markets. The econometric methodology employs VAR, Johansen's method and Granger causality test. The Vector Autoregression (VAR) is commonly used for analysing the dynamic impact of random disturbances on the system of variables. The mathematical representation of a VAR is given by

$$y_t = A_1 y_{t-1} + ... + A_p y_{t-p} + Bx_t + \varepsilon_t \tag{2}$$

where $y_t$ is $k$ a vector of endogenous variables, $x_t$ is a vector of exogenous variables, $A_1,...,A_p$ and $B$ are matrices of coefficients to be estimated, and $\varepsilon_t$ is a vector of innovations. In our study, the log-futures price ($FUT_t$) and log-Open interest ($OP_t$) are jointly determined by a VAR with a constant. The AIC value suggests a VAR model with one lagged value of the endogenous variables. The VAR(1) model is given by

$$\begin{aligned} FUT_t &= a_{11}FUT_{t-1} + a_{12}OP_{t-1} + c_1 + \varepsilon_{1t} \\ OP_t &= a_{21}FUT_{t-1} + a_{22}OP_{t-1} + c_2 + \varepsilon_{2t} \end{aligned} \tag{3}$$

where $a_{ij}$, $c_i$ are the parameters to be estimated.

Furthermore, we implement VAR-based cointegration test using the methodology developed in Johansen (1991, 1995). Two or more integrated time series are said to cointegrate if a particular linear combination is integrated of an order lower than the order of integration of individual series. The purpose of cointegration is to determine whether a group of non-stationary series may be interpreted as a long-run equilibrium relationship. To test for cointegration, we rewrite Equation (2) as

$$\Delta y_t = \Pi y_{t-1} + \sum_{i=1}^{p-1} \Gamma_i \Delta y_{t-i} + Bx_t + \varepsilon_t \tag{4}$$

$$\text{where } \Pi = \sum_{i=1}^{p} A_i - I, \Gamma_i = -\sum_{j=i+1}^{p} A_j$$

If the coefficient matrix $\Pi$ has reduced rank $r<k$, then there exist $k$ x $r$ matrices $\alpha$ and $\beta$ each with rank $r$ such that $\Pi = \alpha\beta'$ and $\beta' y_t$ is stationary, *I(0)*. $r$ is the number of cointegrating relations (rank), while $\beta$ is the cointegrating vector. Johansen's method is to estimate the $\Pi$ matrix from VAR and to test whether we can reject the restrictions implied by the reduced rank of $\Pi$. The trace statistic[4] tests the null hypothesis of $r$ cointegrating relations against the alternative of $k$ cointegrating relations, where $k$ is the number of endogenous variables, for *r=0,1,..,k-1*. To examine the cointegration hypothesis for nearby futures prices and open interest we use

$y_t = \begin{pmatrix} FUT_t \\ OP_t \end{pmatrix}$. The long-run hypotheses are equivalent to *r=0* and *r=1* for

cointegration between futures price and open interest in the ADEX. The optimal lags in trace tests are selected by minimizing the AIC.

---

[4] The trace statistic for the null hypothesis of $r$ cointegrating relations is given by

$$LR(r \mid k) = -T \sum_{i=r+1}^{h} \log(1-\lambda_i).$$

If a set of integrated time series does cointegrate, short-run Granger causality effects can be examined. The Granger (1969) approach to the question of whether $x$ Granger causes $y$ or $y$ Granger causes $x$ for $(x,y)$ series. In our case, the Granger causality test can be translated in bivariate regressions for ($FUT_t, OP_t$) series of the form

$$OP_t = a_0 + a_1 OP_{t-1} + \beta_1 FUT_{t-1} + \varepsilon_t$$
$$FUT_t = a_0 + a_1 FUT_{t-1} + \beta_1 OP_{t-1} + u_t \qquad (5)$$

The null hypothesis is that $FUT_t$ does not Granger cause $OP_t$ in the first regression and $OP_t$ does not Granger cause $FUT_t$ in the second regression. The null hypotheses can be tested with Wald statistics and is given by $\beta_1 = 0$ for both regressions. If there is causality between open interest and futures price, we can then infer that there is evidence on the long-run information role of open interest in futures markets (futures price will drive open interest).

- *Data*

The data employed in this study comprise 525 daily (nearby) observations on the FTSE/ASE-20 stock index futures contract (August 1999- August 2001) and 415 daily (nearby) observations on the FTSE/ASE Mid 40 stock index futures contract (January 2000- August 2001). Closing prices for closing futures prices and open interests were obtained from the official web page of the Athens Derivatives Exchange (www.adex.ase.gr). The FTSE/ASE-20 comprises 20 Greek companies, quoted on the Athens Stock Exchange (ASE), with the largest market capitalisation (blue chips), while the FTSE/ASE Mid 40 comprises 40 mid-capitalisation Greek companies. Futures contracts are quoted on the Athens Derivatives Exchange (ADEX). The price of a futures contract is measured in index points multiplied by the contract multiplier, which is 5 Euros for the FTSE/ASE-20 contract and 10 Euros for the FTSE/ASE Mid 40 contract. There are four delivery months: March, June, September and December. Trading takes place in the 3 nearest delivery months, although volume in the far contract is very small. Both futures contracts are cash-settled and marked to market on the last trading day, which is the third Friday in the delivery (expiration) month at 14:30 Athens time.

### III. EMPIRICAL RESULTS

We begin the empirical analysis by first investigating the descriptive statistics of returns and open interest. We also provide the unit root tests. Table 1 shows the sample summary statistics and ADF values for FTSE/ASE-20 and FTSE/ASE Mid 40. It is observed that returns and open interest series for both FTSE/ASE-20 and FTSE/ASE Mid 40 have positive skewness, positive kurtosis and high value of J-B statistic test. This means that distributions are skewed to the right with leptokurtic pdf. Also, J-B statistic test suggests that the null hypothesis of normality is rejected.

Furthermore, it is well known that futures prices and open interest in futures market are non-stationary, see also Floros and Vougas (2004). Table 1 shows that the null hypothesis that futures return series and open interest series are stationary is rejected for both FTSE/ASE-20 and FTSE/ASE Mid 40. ADF tests suggest that both returns and open interest series are non-stationary and integrated of order one, *I(1)*. Graphical plots of returns and open interest for both FTSE/ASE-20 and FTSE/ASE Mid 40

indices are presented in Appendix 1. The nearby contract usually has the largest open interest, while as the contract nears maturity the open interest falls off drastically.

<<Table 1- about here>>

- *Price-Open Interest Relationship*

   We now investigate the relationship between daily price and open interest for Greek futures market. Table 2 shows the estimates of GARCH (1,1) model for FTSE/ASE-20, while Table 3 shows the estimates of the GARCH (1,1) model for FTSE/ASE Mid 40. The dependent variable is return (mean equation), while open interest is used as explanatory variable in the conditional variance function (Equation 1). The results show that $\alpha$ (the coefficient on the lagged squared residual term) and $\beta$ (the coefficient on the lagged conditional variance) remain significant for both indices. Also, the coefficients of open interest, $\gamma$, are negative and statistically significant at 5% level. Taken together, these results indicate that open interest as a proxy in the conditional variance helps in explaining the GARCH effects in futures market returns. There is, of course, evidence that current open interest has a negative impact on returns. Therefore, market depth has an effect on volatility of Greek stock index futures. According to Watanabe (2001, p. 656), a significant negative coefficient of open interest indicates that an increase in open interest mitigates volatility. These findings are in line with Bessembinder and Seguin (1993) and Watanabe (2001). Graphical plots of GARCH (1,1) variance series for FTSE/ASE-20 and FTSE/ASE Mid 40 are presented in Appendix 1.

<<Table 2- about here>>

<<Table 3- about here>>

   Because both (the logarithm of) futures price and open interest are integrated of order one, *I(1)*, it is of great interest to know whether there is a long-run (cointegration) relationship among these variables. We test for cointegration between $FUT_t$ and $OP_t$ by using the Johansen's (1988) cointegration method. Because $FUT_t$ and $OP_t$ are very different in nature (see figures in the Appendix 1), we allow for linear deterministic trend in our level data and intercepts in the cointegrating equations (CE). Table 4 (FTSE/ASE-20) and Table 5 (FTSE/ASE Mid 40) present various trace LR tests for the rank of the corresponding long-run impact matrix in a VAR(1) model for $FUT_t$ and $OP_t$ with an intercept. The trace test statistics is used. For this test, the number of cointegration relations under the null hypothesis, the ordered eigenvalues of the $\Pi$ matrix together with critical values are reported. The evidence for Greece, using trace LR tests, is that there is one cointegrating vector (indicating long-run relationship) between $FUT_t$ and $OP_t$. This is because the null hypothesis, *r=0*, is rejected in favor of *r=1*, whereas the null hypothesis *r=1* is not rejected. Statistical evidence, not reported in this study, based on the maximum eigenvalue LR tests, arrives at the same conclusion that one cointegrating vector exists.

<<Table 4- about here>>

<<Table 5- about here>>

Furthermore, Table 6 and Table 7 present the results from Granger Causality tests for FTSE/ASE-20 and FTSE/ASE Mid 40, respectively. For FTSE/ASE-20, we do reject the hypotheses that $FUT_t$ does not Granger cause $OP_t$, and $OP_t$ does not Granger cause $FUT_t$. So, we find that there is a bi-directional effect from $FUT_t$ to $OP_t$ and $OP_t$ to $FUT_t$ (feedback). For FTSE/ASE Mid 40, we cannot reject the hypothesis that $OP_t$ does not Granger cause $FUT_t$ but we do reject the hypothesis that $FUT_t$ does not Granger cause $OP_t$. Therefore, it appears that Granger causality runs one-way from $FUT_t$ to $OP_t$.

<<Table 6- about here>>

<<Table 7- about here>>

## IV.    SUMMARY

There are many reasons that traders pay attention to price and open interest. Open interest, or the total number of open contracts, applies primarily to the futures markets. It is often used to confirm trends for futures contracts. An increase in open interest along with an increase in price is said to confirm an upward trend, while an increase in open interest along with a decrease in price confirms a downward trend. This study investigates the relationship between price and open interest using data from the Greek futures market. We examine the nature of this relationship for two contracts traded on the Athens Derivatives Exchange, FTSE/ASE-20 and FTSE/ASE Mid 40.

First, we study the GARCH effects in our data and test how well the GARCH effects are explained by open interest. This paper uses a GARCH (1,1) model, since this model has been shown to be adequate for examining the relationship between returns and open interest. The results show that current open interest helps in explaining the GARCH effects, while it provides a negative impact on returns. In other words there is strong evidence that market depth does have an effect on price changes of Greek stock index futures. These findings are in line with Bessembinder and Seguin (1993) and Watanabe (2001).

Furthermore, we investigate the long-run relationship between futures price and open interest using the Johansen (1988) cointegration test. The hypothesis of one cointegrating equation cannot be rejected for any futures contracts, and hence, we find cointegration between futures price and open interest. These results provide strong evidence for long-run information role of open interest in stock index futures. In addition, the long-run causality results support the hypotheses that futures prices (open interest) drive open interest (futures prices) in the long run for FTSE/ASE-20, that is a bi-directional causality exists. Regarding the FTSE/ASE Mid 40 index, the results show that futures prices unidirectionally Granger cause open interest.
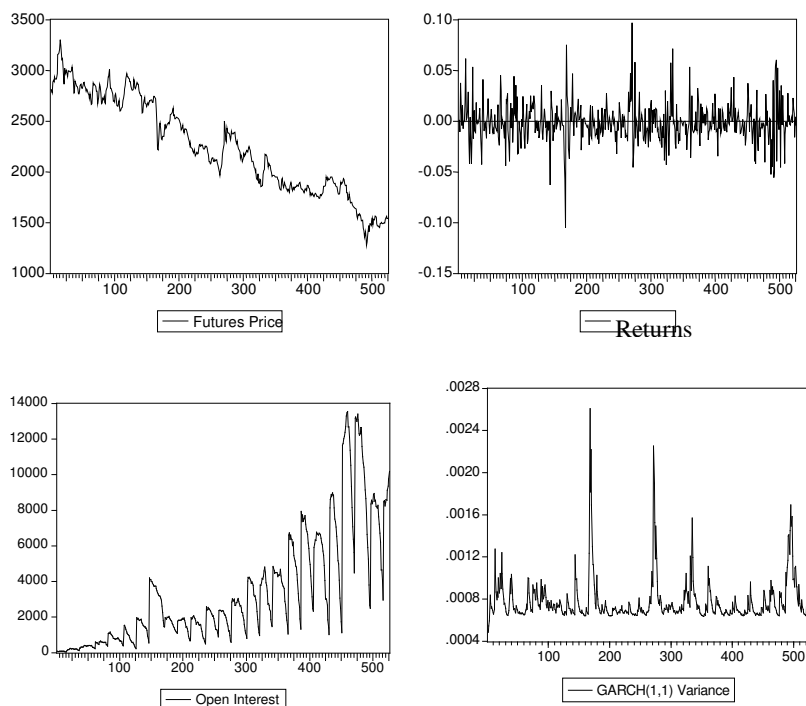
These results are consistent with the finding by Yang *et al.* (2004) in the form that futures price is the primary source of open interest while open interest does not cause futures prices in the long run. Specifically, our findings strongly suggest that one can use the information of open interest to predict futures prices in the long run for

FTSE/ASE-20 and FTSE/ASE Mid 40. Open interest depends on the futures price movements that have captured all relevant information about hedgers and speculators.
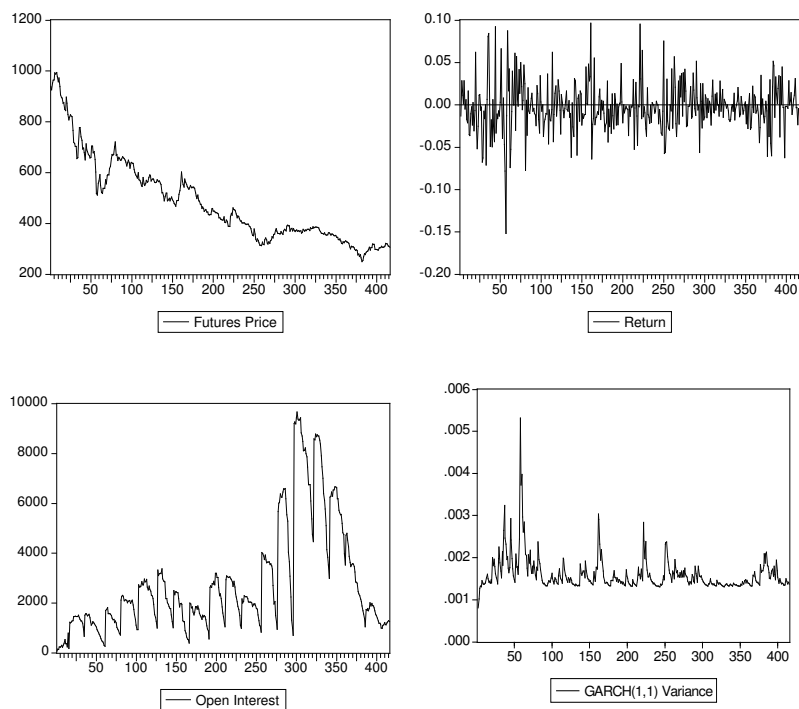
The findings of this study have important implications for Greek futures market efficiency. Also, the long-run information role of open interest is a good indicator for the usefulness of technical analysis in the futures markets. Future research should examine the relationship between volatility and trading volume, as well as trading volume and open interest using data from ADEX and other European Derivatives Exchanges.

# Appendix 1. Graphical plots: Price (P), Returns (R), Open Interest (OI) and Variance ($\sigma^2$)

➢ **FTSE/ASE-20 stock index**



➢ **FTSE/ASE Mid 40 stock index**

**REFERENCES**

Anderson, R. W. (1985), Some Determinants of the Volatility of Futures Prices, *Journal of Futures Markets*, 5, 331-348.

Bessembinder, H. and Seguin, P. J. (1992), Futures trading activity and stock price volatility, *Journal of Finance*, 47, 2015-2034.

Bessembinder, H. and Seguin, P. J. (1993), Price volatility, trading volume, and market depth: evidence from futures markets, *Journal of Financial and Quantitative Analysis*, 28, 21-39.

Bollerslev, T. (1986), Generalised Autoregressive Conditional Heteroskedasticity, *Journal of Econometrics*, 30, 307-328.

Brailsford, T. J. (1994), The Empirical Relationship Between Trading Volume, Returns and Volatility, *Research Paper* 94-01, Department of Accounting and Finance, University of Melbourne.

Brailsford, T. J. (1996), The Empirical Relationship Between Trading Volume, Returns and Volatility, *Accounting and Finance*, 36, 89-111.

Chen, N., Cuny, C. J. and Haugen, R. A. (1995), Stock volatility and the levels of the basis and open interest in futures contracts, *Journal of Finance*, 50, 281-300.

Chen, Y-J, Duan, J-C, and Hung, M-W (1999), Volatility and Maturity Effects in the Nikkei Index Futures, *Journal of Futures Markets*, 19, 895-909.

Ciner, C. (2002), Information content of volume: An investigation of Tokyo commodity futures markets, Pacific-Basin Finance Journal, 10, 201-215.

Enders, W. (1995), *Applied Econometric Time Series*, John Wiley & Sons, New York.

Engle, R. (1982), Autoregressive conditional heteroskedasticity with estimates of the variance of United Kingdom inflation, *Econometrica*, 50, 987-1007.

Faff, R. W. and McKenzie, M. D. (2002), The Impact of Stock Index Futures Trading on Daily Returns Seasonality: A Multicountry Study, *Journal of Business*, 75, 95-125.

Ferris, S. P., Park, H. Y. and Park, K. (2002), Volatility, open interest, volume, and arbitrage: evidence from the S&P 500 futures market, *Applied Economics Letters*, 9, 369-372.

Floros, C. and Vougas, D. V. (2004), Hedge ratios in Greek stock index futures market, *Applied Financial Economics*, 14(15), 1126-1132.

Girma, P. B. and Mougoue, M. (2002), An empirical examination of the relation between futures spreads volatility, volume, and open interest, *Journal of Futures Markets*, 22, 1083-1102.

Granger, C. (1969), Investigating causal relations by econometric models and cross-spectral methods, *Econometrica*, 37, 424-438.

Johansen, S. (1988), Statistical analysis of cointegrated vectors, *Journal of Economic Dynamics and Control*, 12, 231-254.

Johansen, S. (1991), Estimation and hypothesis testing of cointegration vectors in Gaussian vector autoregressive models, *Econometrica*, 59, 1551-1580.

Johansen, S. (1995), Identifying restrictions of linear equations with applications to simultaneous equations and cointegration, *Journal of Econometrics*, 69, 111-132.

Kamara, A. (1993), Production flexibility, stochastic separation, hedging, and futures prices, *Review of Financial Studies*, 4, 935-957.

Karpoff, J. M. (1987), The relation between price changes and trading volume: a survey, *Journal of Financial and Quantitative Analysis*, 22, 109-126.

Najand, M. and Yung, K. (1991), A GARCH examination of the relationship between volume and price variability in futures markets, *Journal of Futures Markets*, 11, 613-621.

Ragunathan, V. and Peker, A. (1997), Price variability, trading volume and market depth: evidence from the Australian futures market, *Applied Financial Economics*, 7, 447-454.

Sharma, J. L., Mougoue, M. and Kamath, R. (1996), Heteroscedasticity in stock market indicator return data: volume versus GARCH effects, *Applied Financial Economics*, 6, 337-342.

Sutcliffe, C. M. S. (1993), *Stock Index Futures: Theories and International Evidence*, Chapman & Hall.

Watanabe, T. (2001), Price volatility, trading volume, and market depth: evidence from the Japanese stock index futures market, *Applied Financial Economics*, 11, 651-658.

Yang, J., Bessler, D. A. and Fung, H.-G. (2004), The informational role of open interest in futures markets, *Applied Economics Letters*, 11, 569-573.

TABLE 1. Summary statistics for returns (R) and open interest (OI)

| | RETURNS: FTSE/ASE-20 | OPEN INTEREST: FTSE/ASE- 20 | RETURNS: FTSE/ASE MID 40 | OPEN INTEREST: FTSE/ASE MID 40 |
|---|---|---|---|---|
| MEAN | -0.001145 | 3420.662 | -0.002699 | 2813.284 |
| MEDIAN | -0.001726 | 2221.000 | -0.003161 | 2040.000 |
| MAXIMUM | 0.097055 | 13556.00 | 0.096205 | 9674.000 |
| MINIMUM | -0.104776 | 40.00000 | -0.151776 | 65.00000 |
| STD. DEV | 0.019777 | 3267.643 | 0.028337 | 2221.638 |
| SKEWNESS | 0.325381 | 1.314898 | 0.102337 | 1.456530 |
| KURTOSIS | 6.690511 | 4.035948 | 5.840684 | 4.313418 |
| JARQUE-BERA | 307.1985 | 175.0925 | 140.2592 | 176.9904 |
| PROB. | 0.000000 | 0.000000 | 0.000000 | 0.000000 |
| ADF- level | -0.777813 | -3.259862 | -1.954468 | -3.200247 |
| ADF-1$^{st}$ diff. | -11.55063 | -16.53414 | -12.81365 | -14.37406 |

- *Notes*: Critical values for ADF tests are (1%) -3.4452, (5%) 2.8674, (10%) 2.5699 (FTSE/ASE-20); (1%) -3.4483, (5%) 2.8688, (10%) 2.5706 (FTSE/ASE Mid 40).

TABLE 2. GARCH (1,1) Model for FTSE/ASE-20

Dependent Variable: $R_t$

| Mean Equation | Coefficient | Std. Error | z-Statistic | Prob. |
|---|---|---|---|---|
| Constant | -0.001145 | 0.000862 | -1.327817 | 0.1842 |
| **Variance Equation** | | | | |
| ω | 0.000254 | 9.93E-05 | 2.553231* | 0.0107 |
| a | 0.150000 | 0.076668 | 1.956489* | 0.0504 |
| β | 0.600000 | 0.156130 | 3.842963* | 0.0001 |
| γ | -1.61E-08 | 7.75E-09 | -2.081829* | 0.0374 |

* Significant at the 5% level.

TABLE 3. GARCH (1,1) Model for FTSE/ASE Mid 40

Dependent Variable: $R_t$

| Mean Equation | Coefficient | Std. Error | z-Statistic | Prob. |
|---|---|---|---|---|
| Constant | -0.002699 | 0.001123 | -2.403818* | 0.0162 |
| **Variance Equation** | | | | |
| ω | 0.000520 | 0.000113 | 4.591651* | 0.0000 |
| a | 0.150000 | 0.071321 | 2.103181* | 0.0354 |
| β | 0.600000 | 0.091762 | 6.538687* | 0.0000 |
| γ | -5.32E-08 | 1.07E-08 | -4.972124* | 0.0000 |

* Significant at the 5% level.

TABLE 4. Johansen cointegration test for FTSE/ASE-20

| Series: $FUT_t$ $OP_t$ | | | | |
|---|---|---|---|---|
| Hypothesized No. of CE | Eigenvalue | Trace Statistic | 5 Percent Critical Value | 1 Percent Critical Value |
| None ** | 0.064528 | 36.07231 | 15.41 | 20.04 |
| At most 1 | 0.002134 | 1.119279 | 3.76 | 6.65 |
| *(**) denotes rejection of the hypothesis at the 5%(1%) level | | | | |
| Trace test indicates 1 cointegrating equation(s) at both 5% and 1% levels | | | | |

TABLE 5. Johansen cointegration test for FTSE/ASE Mid 40

| Series: $FUT_t$ $OP_t$ | | | | |
|---|---|---|---|---|
| Hypothesized No. of CE | Eigenvalue | Trace Statistic | 5 Percent Critical Value | 1 Percent Critical Value |
| None ** | 0.050754 | 25.10774 | 15.41 | 20.04 |
| At most 1 | 0.008523 | 3.543692 | 3.76 | 6.65 |
| *(**) denotes rejection of the hypothesis at the 5%(1%) level | | | | |
| Trace test indicates 1 cointegrating equation(s) at both 5% and 1% levels | | | | |

TABLE 6. Granger Causality test for FTSE/ASE-20

| Pairwise Granger Causality Tests | | | |
|---|---|---|---|
| Lags: 1 | | | |
| Null Hypothesis: | Obs | F-Statistic | Probability |
| $OP_t$ does not Granger Cause $FUT_t$ | 525 | 10.5307 | 0.00125* |
| $FUT_t$ does not Granger Cause $OP_t$ | | 14.5179 | 0.00016* |

* Reject the Null hypothesis


TABLE 7. Granger Causality test for FTSE/ASE Mid 40

| Pairwise Granger Causality Tests | | | |
|---|---|---|---|
| Lags: 1 | | | |
| Null Hypothesis: | Obs | F-Statistic | Probability |
| $FUT_t$ does not Granger Cause $OP_t$ | 415 | 3.76640 | 0.05297* |
| $OP_t$ does not Granger Cause $FUT_t$ | | 0.61528 | 0.43326 |

* Reject the Null hypothesis