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SAMUELSON'S HYPOTHESIS IN GREEK STOCK INDEX FUTURES MARKET

Christos Floros, Dimitrios V. Vougas

Abstract

Samuelson (1965) argues that futures prices become increasingly volatile as futures contracts approach maturity. However, available evidence does not provide clear support for Samuelson's hypothesis (or maturity effect) for index futures. This paper applies linear regressions and GARCH (volatility) models to examine the maturity effect of index futures contracts using daily data from the Athens Derivatives Exchange (ADEX). To the best of our knowledge, this is the first empirical investigation of the Greek futures markets. Our results suggest that volatility series depend on time to maturity. When data for the nearby month contracts are considered, employed GARCH models show a stronger support to the hypothesis than traditional linear regressions. In general, it is concluded that Samuelson's hypothesis is valid, and therefore, volatility of the series increases as expiry approaches. These findings are helpful to risk managers dealing with Greek stock index futures.

Key words: Futures, ADEX, Samuelson, GARCH.
JEL Classification: G13, G15.

1. Introduction

It is apparent that early in a futures contract's life, little is known about the future spot price, but as the contract approaches maturity the rate of information acquisition increases (Kolb, 1994). This is the basic theory behind the maturity effect. In other words, when there is a long time to delivery, new information may affect the delivery price. Nevertheless, when delivery is about to take place, there is not enough time for further information acquisition, and the 'new' information has a definite effect on the delivery price. In view of this, several theories attempt to explain the relationship between contract maturity and volatility. First, there is strong evidence that volatility is higher when information about the harvest of some good (commodities) is reaching the market. Hence, volatility depends primarily on the time of the year. Secondly, volatility may depend on the day of the week or other 'seasonal' effects and not so much on the contract's expiration.

More specifically, in empirical studies, 'Samuelson's hypothesis' is stated as explaining the relationship between futures prices and maturity. The negative relationship between volatility and days to maturity is often referred to as the 'maturity effect'. The alternative hypothesis states that volatility is related to information flows.

Samuelson (1965) states that volatility of futures prices should increase as the contract approaches expiration (at maturity date). He uses the assumption that futures price equals expected future spot price. That is, Samuelson's model implies that the futures price should be more volatile near expiration. Hence, the variance[1] of futures prices increases as the futures contract approaches maturity. Therefore, futures prices react more strongly to information as they approach expiration than otherwise[2]. Then, it could be possible to have an increase in margins[3], as the margin size is a positive function of the volatility of futures prices. Therefore, the cash balances will also rise, and then, the correlation between spot and futures prices will decline.

Theoretically, Samuelson (1965, p. 786) explains the role of harvest patterns as follows:

> *"The present theory can contribute an elegant explanation of why we should expect far-distant futures to move more sluggishly than near ones. Its explanation does not lean at all on the undoubted fact that, during certain*

[1] Rutledge (1976) suggests that the variance of the futures price is an empirical problem.
[2] It should be noted that contract maturity has no effect on the flow of valuable information for stocks.
[3] Margin is defined as the cash balanced (or security deposit) required from a futures trader.

pre-harvest periods when stocks are normally low, changes in spot prices can themselves be expected to experience great volatility".

More recently, Johnson (1998, p. 3) explains the behaviour of futures traders and fund managers in relation to Samuelson hypothesis as follows:

"If this is the case then a fund manager wishing to keep futures price volatility to a minimum would need to trade in the longest dated contract. If, however, price volatility is unrelated to the length of time to maturity, fund managers can initiate a futures position in the most convenient contract, than in any other contract currently trading. This may enable a futures trader to remain within a single contract and not have to make a decision regarding the appropriate time to roll over into the next to mature contract".

Samuelson (1965) uses two assumptions, namely that: (i) each futures price equals the trading date expectation of the delivery date spot price[1], and (ii) the spot price is stationary following an AR(1). In general, the theory of Samuelson's hypothesis requires two conditions: systematic increase in spot return volatility near each futures expiration date or negative covariation between spot returns, and the slope of the futures term structure.

In addition, according to Sutcliffe (1993), the expected value of the spot price at delivery exceeds the current index futures price, and therefore, there is a risk premium. So, Samuelson's arguments do not apply to index futures. Also, Bessembinder *et al*. (1996) argue that the first condition is implausible, while for the second condition they state that the hypothesis is not correct in markets where spot prices follow a random walk. This case depends upon the behaviour of the spot prices. Furthermore, according to Bessembinder *et al*. (1996, p. 3), '*it is certainly possible that a systematic clustering of information flows near futures delivery dates could cause commensurate increases in price change variances at those times, consistent with the Samuelson hypothesis*'. However, Bessembinder *et al*. (1996) conclude that the information flows condition is not necessary as the hypothesis holds where information flows do not cluster near delivery dates. In general, they show that the Samuelson hypothesis is successful without the two conditions: the clustering of information flows near delivery dates, and that futures price is an unbiased forecast of the delivery date spot price. They conclude that the hypothesis is correct in markets where equilibrium spot prices are *mean reverting*.

Barnhill *et al*. (1987) argue that Samuelson's hypothesis is a 'monotonic' maturity hypothesis. This results from the assumption of stationary, autoregressive process for spot prices. In addition to that, Anderson and Danthine (1983) point out that Samuelson's hypothesis is a hypothesis about the uncertainty resolution[2]. They suggest that futures price volatility is high when we have large amounts of supply and demand. However, Milonas (1986) points out that, far from maturity, futures contracts contain much more uncertainty. As a result, prices will respond less strongly to new information. Recently, Hong (2000) argues that Samuelson's effect is a 'price elasticity effect'. This is due to the fact that the price elasticity of the futures contract increases and so its return volatility rises, as it approaches the expiration date. Also, Hong (2000) states that Samuelson's effect does not hold when the information asymmetry is large, while in markets where the information asymmetry is small, there is a definite effect.

This paper examines the relationship between daily volatility and time to expiration (maturity) in the Greek futures markets. For this, a range of volatility regressions is employed. Our findings are important since no previous work has examined Samuelson's hypothesis in the Greek futures markets. The paper is organised as follows. Section 2 provides a detailed literature review, while Section 3 outlines the methodology. Section 4 describes the data, and Section 5 presents empirical results from various econometric models. Finally, Section 6 concludes the paper and summarizes the findings.

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[1] Kolb (1994) states that futures prices follow *martingales*. This implies that futures prices equal the expected future spot prices.

[2] According to Anderson and Danthine (1983), Samuelson's hypothesis is a case of the 'state variable hypothesis', where uncertainty resolution is greatest before expiration, see also Allen and Cruickshank (2000).

2. Literature Review

A wide area of research examines futures price volatility in a number of markets. It is a common belief that factors such as trading volume and maturity may cause price volatility. First, Segall[1] (1956) suggests that changes in interest rates could have a greater effect on the price of contracts further from maturity and that various factors (e.g. the 'uncertainty factor' or the 'speculative effect'[2]) and events may affect the value of the contract during its life. Anderson (1985) and Kenyon *et al*. (1987) find that seasonality is an important factor that influences futures price volatility. Further, Sutcliffe (1993) argues that the approach of delivery has a predictable effect on the absolute size of the basis[3]. In addition, Khoury and Yourougou (1993) argue that time to expiration is one of the factors that cause futures price volatility. However, according to Moosa and Bollen (2001) the empirical evidence on the maturity effect in futures prices is mixed. Usually, futures prices are more volatile when they are close to expiry because high price volatility indicates more information. As the contract approaches maturity, the rate of information increases, and therefore, there is an increase in volatility. In general, Moosa and Bollen (2001, p. 693) suggest that there are two conclusions about the hypothesis of maturity effect in futures prices: *(i) the seasonal effect is more important than the maturity effect for agricultural commodities, and (ii) the maturity effect plays a significant role in determining the volatility of futures prices for commodities (but not for these which the cost-of-carry model of futures prices works well)*.

Previous empirical studies find some support for Samuelson's hypothesis. First, Rutledge (1976) discusses that both silver and cocoa contracts futures prices support the hypothesis, but for wheat and soybean oil there is no support of the hypothesis. Also, Dusak-Miller (1979) and Castelino and Francis (1982) find strong evidence for commodity contracts. Anderson (1985) supports Samuelson's hypothesis for nine commodities and argues that the seasonal effect is the most important factor affecting volatility. He argues that the hypothesis is not valid where spot prices are non-stationary. Milonas (1986) also finds support for Samuelson's hypothesis in 10 of 11 commodities (i.e. agricultural, financial and metal contracts). Furthermore, Grammatikos and Saunders (1986) argue that the variance of the price in futures decreases with the time to maturity of the contract. In addition, Karpoff (1987) reports that the time to delivery of futures contracts affects the price variability. Bessembinder et al. (1996) show that markets for real assets support Samuelson's hypothesis. They argue that the hypothesis is strongly supported in agricultural markets, where there is a large mean reverting component in spot prices. Also, in studying commodity futures from Chicago Board of Trade (CBOT), Hennessy and Wahl (1996) explain the seasonality and maturity effect and find support to the Samuelson hypothesis.

From previous studies, it is known that the maturity effect in financial futures markets is not very strong. First, Barnhill *et al*. (1987) apply Samuelson's hypothesis to the U.S. Treasury-bond futures market and find that a significant effect does exist. For UK market, Chamberlain (1989) uses daily data of the FTSE-100 index futures contracts to examine Samuelson's hypothesis. His results are mixed. The March 1985 contract indicates no relationship between volatility and maturity, while the June 1985 contract shows a definite support for Samuelson's hypothesis. However, Board and Sutcliffe (1990) show little support to Samuelson's hypothesis for the period from May 1984 to August 1989. In a recent study, Bessembinder *et al*. (1996) argue that in financial futures there is no relationship between volatility and time to expiry, since there is no significant relation between prices and the futures term slope. Also, Johnson (1998) examines the relationship between price volatility and length of time to maturity for SPI futures using several volatility regressions. He finds no evidence of the hypothesis in Australian share price index futures. In addition, Johnson (1998) finds that volatilities of near and far contracts are highly correlated.

For NYSE Composite and S&P 500 indices, Park and Sears (1985) show a significant positive effect of maturity on volatility. Consistently, Han and Misra (1990) find no support for Samuelson's hypothesis, also using the S&P 500 index. The results after the stock market crash in

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[1] Segall (1956) uses wheat futures to examine the relationship between maturity and price volatility. He does not find evidence to support the uncertainty effect.
[2] See Hong (2000).
[3] See Sutcliffe (1993, p. 135) for the behaviour of the basis factor during the life of a contract.

October 1987 show a positive relationship between volatility and futures. Recently, Moosa and Bollen (2001) examine the maturity effect using the S&P 500 futures contracts. To test for the maturity effect, they use a simple OLS model (including a dummy variable for the maturity effect), which measures the volatility. Moosa and Bollen (2001) find that volatility is independent of the time to maturity. Also, Galloway and Kolb (1996) find that the prices of financial futures contract do not exhibit a maturity effect. This finding is in line with the results obtained by Moosa and Bollen (2001), Leistikow (1989), and Han *et al*. (1999). Leistikow (1989) finds no support for Samuelson's hypothesis in commodity futures, and also, Han *et al*. (1999) find no maturity effect for currency futures, since the relationship between volatility and days to maturity is found to be positive.

Serletis (1991) finds a statistically significant maturity effect for a number of oil futures contracts. In another paper, Serletis (1992) finds that the introduction of volume trading as an explanatory variable significantly reduces the power of time until maturity for energy futures. His results show that energy futures prices are more volatile and trading volume increases as futures contracts approach maturity. Also, Bessembinder *et al*. (1996) suggest strong negative relations between crude oil prices and futures term slopes, indicating that Samuelson's hypothesis is likely to hold. Recently, Walls (1999) investigates the electricity futures markets (NYMEX, COB and PV) by looking at the volatility and maturity effect. In general, the results proposed by Walls (1999) differ substantially from the results obtained by Serletis (1992), as Walls (1999) suggests that price volatility increases for 86% as the futures contracts approach maturity (Serletis' (1992) results show 70%), and that the maturity effects seem to be stronger than for the other energy futures. Notice that, Herbert (1995) finds that the volume rather than maturity explains better variance price volatility in natural gas futures.

A paper that studies Samuelson's hypothesis, using ARCH/GARCH models, is by Yang and Brorsen (1993). They find that only 6 of the 15 contracts support the hypothesis, while 9 of the 15 contracts show that seasonality is important. In addition, Chen *et al*. (1999) use a bivariate GARCH model to examine the maturity effects for the Nikkei-225 stock index and index futures. Chen *et al*. (1999) argue that the maturity and GARCH effects are simultaneously present. They find that the conditional variance of futures price decreases if its maturity is shortened (as the contracts approach expiration). Recently, Allen and Cruickshank (2000) apply Samuelson's hypothesis to commodity futures contracts on three international exchanges: the Sydney Futures Exchange (SFEX), the London International Futures and Options Exchange (LIFFE), and the Singapore International Monetary Exchange (SIMEX). They conclude that Samuelson's hypothesis holds in most of the futures contracts. Adrangi and Chatrath (2003) examine the non-linear dependence in futures returns of coffee, cocoa and sugar using ARCH-type models. More specific, to examine the impact of any time-to-maturity (TTM) effects on the tests for non-linearity they consider GARCH specifications with and without a dummy variable in the variance equation. The results show a negative TTM coefficient, indicating a strong support to the Samuelson hypothesis. Also, according to Adrangi and Chatrath (2003, p. 254) '*TTM plays a role as a "control variable" in the tests of chaos*'. Recently, Akin (2003) examines the volatility dynamics of 11 financial futures returns by looking at the Samuelson hypothesis. The results show a strong time-to-maturity effect for currency futures, and mixed evidence in equity index and interest rate futures.

3. Methodology

As discussed earlier, Samuelson (1965) assumes the following assumptions: (i) Spot prices (S) must follow a stationary first order autoregressive process and, (ii) Futures prices (F) are unbiased predictors of the expiration price. Recall that the hypothesis requires either a negative covariation between spot returns and the slope of the futures term structure, or systematic increases in spot return volatility near futures expiration date. That is,

$$S_t = aS_{t-1} + u_t \text{ or } S_t - S_{t-1} = a(S_{t-1} - S_{t-2}), \quad (1)$$

where, $E(u_t) = 0$ and $E(u_t^2) = \sigma^2$. If $\alpha < 1$, the variance of the change in futures prices will rise as a contract approaches expiry.

Rutledge (1976) proposes a model where the spot price is generated through a fist order autoregression of the change in spot prices. That is,

$$S_t - S_{t-1} = \beta(S_{t-1} - S_{t-2}) + u_t \,. \tag{2}$$

If $\beta \neq 0$, futures prices variation will actually decrease as expiry approaches.

The theoretical relationship between a stock index futures price and its underlying asset is given by the *cost-of-carry model*.

$$F_t = S_t \exp[(r-d)(T-t)], \tag{3}$$

where S_t is the stock index price at time *t*, F_t is the value of the futures price, *r* is the risk-free rate of return, *d* is the dividend yield, and *T-t* is the maturity date for the futures contract, see Brooks *et al*. (2001). It is apparent that the value of the index at any time depends on the price of the stock. The idea is to invest $F_t \exp[(r-d)(T-t)]$, now, and get S_t back at maturity of the futures contract.

In a seminal paper, Bessembinder *et al*. (1996) show that the variance of futures price changes (in relation to the cost-of-carry model) is given by

$$Var(\Delta f_t) = Var(u_t) + \tau^2 Var(\Delta s_t) + 2\tau Cov(u_t, \Delta s_t)\,, \tag{4}$$

where $\Delta f_t = \ln(F_{t+1,T}) - \ln(F_{t,T})$, $\Delta s_t = s_{t+1} - s_t$, and $u_t = \ln(\frac{P_{t+1}}{E_t(P_{t+1})})$. P_t is the spot price at date t, $E_t(.)$ denotes the expectation, and $F_{t,T}$ denotes the futures price at date *t*, for delivery at date T. Also, *Var* and *Cov* stand for variance and covariance, respectively. Under Equation 4, Samuelson's hypothesis shows an increase in $Var(\Delta f_t)$ as the number of periods until the time to expiration (delivery) decreases.

According to Bessembinder et al. (1996, p. 8), 'the Samuelson hypothesis holds if and only if the variance of unexpected spot returns (u_t) increases as the delivery date approaches'. In addition, they state that the hypothesis may rely on the negative covariation between spot returns and changes in the futures term slope. Therefore, they conclude that it is important to focus on the futures term slope variation rather than in spot return variances close to expiration dates. Another theory, explaining the futures price, is the general equilibrium model from Hemler and Longstaff (1991). They argue that, the model shows an increase or decrease to the variance of futures returns as the delivery date approaches. Samuelson's hypothesis does not hold when the covariances between changes in the spot index and changes in the volatility of stock returns are zero.

For empirical examination of Samuelson's hypothesis and volatility measurement in futures markets, several techniques may be applied. Johnson (1998) and Allen and Cruickshank (2000) use three ways to estimate futures price volatility. Also, Bessembinder *et al*. (1996) use the concept of 'nearby' to define volatility of the contract closest to expiry (i.e. Nearby 1). Therefore, nearby 2 is the second closest to expiry and so on. Following this method, Allen and Cruickshank (2000) calculate the average volatility by nearby analysis and find support for Samuelson's hypothesis (i.e. 10 of the 12 commodities show strong evidence in the hypothesis).

A second method of examining Samuelson's hypothesis is through a regression of daily futures volatility on days to expiry and spot volatility. Allen and Cruickshank (2000) estimate daily volatility on days to expiry using entire and reduced datasets (i.e. sets used for spot volatility regressions). Again, 10 of the 12 commodities show strong support for Samuelson's hypothesis, as the coefficient on the days to expiry is found to be negative and statistically significant from zero.

Following Bessembinder *et al*. (1996), a regression of daily spot prices can be employed with near futures prices used as proxies for spot prices. This is so, because from theory, close- to-expiry futures prices should approach spot prices. Using this regression, Allen and Cruickshank

(2000) show that the coefficients of the spot volatilities are positive and significant as expected. Our methodology is based on early works by Moosa and Bollen (2001), Walls (1999), Johnson (1998) and Allen and Cruickshank (2000).

According to Johnson (1998), Antoniou and Holmes (1995), Grammatikos and Saunders (1986) and Allen and Cruickshank (2000), there are several measures of volatility[1]. For example, Rutledge (1979) uses the absolute log change from one trading day to the next, while Tauchen and Pitts (1983) use the square of the first difference of the futures price of adjacent periods. In addition, Karpoff (1987) uses the absolute value of the first difference to measure volatility. In this paper, we investigate the effect of time until maturity on price volatility and estimate volatility as follows:

$$Vola_t = \left|\ln F_t - \ln F_{t-1}\right| \times 100. \tag{5}$$

Equation (5) measures the absolute value of the continuously compounded rate of return multiplied by 100.

First, we measure the maturity effect using the following linear regression equation:

$$Vola_t = a + \beta \ln M_t + \varepsilon_t, \tag{6}$$

where volatility is defined by Equation (5), M_t is the number of days to maturity and ε_t is an independently and identically distributed random disturbance with mean zero and finite variance, i.e. $\varepsilon \sim iid(0,\sigma^2)$. Notice that, it would also be possible to use the number of calendar days remaining until delivery of futures contract takes place, because information arrives during non-trading periods (e.g. weekends). However, here we use the number of trading days remaining, following the work of Moosa and Bollen (2001) and Walls (1999).

According to Walls (1999), the intercept of Equation (6) should be positive and statistically significant, since it reflects price volatility at contract maturity, when futures and spot prices are close. For Samuelson's hypothesis to be correct, $\beta < 0$ and statistically significant, so that price volatility increases as the number of days until contract maturity decreases, see Walls (1999) and Herbert (1995). In other words, as we move closer to the 'delivery' date of the contract, the maturity effect index becomes smaller in value.

We also apply stochastic volatility models to our data for modelling the variance of each series. Since Samuelson's hypothesis holds when models show evidence of greater variance, we use various GARCH specifications. With these specifications, we test whether there is a change in the volatility of the series by including a dummy variable in the mean equation, following Allen and Cruickshank (2000); see also McMillan and Speight (2004).

Specifically, we capture financial time series characteristics by employing a GARCH(1,1) model, and its EGARCH(1,1) and TGARCH(1,1) extensions. All models have a dummy variable (D_t) in the mean equation. That is,

$$Vola_t = a + \beta D_t + \varepsilon_t. \tag{7}$$

The dummy variable D_t takes the value 1 for the final 10 trading days from the contract expiry, and 0 for all other days. In this approach, when β is positive and statistically significant, then Samuelson's hypothesis holds, implying a greater change in volatility over this period.

Finally, we test Samuelson's hypothesis using two different linear regressions. Equation (8) estimates volatility of a near contract and a far contract. Following Johnson (1998), the volatility of near contract ($Vola_t$) could be expressed in terms of volatility of the far contract ($Vola_{t+1}$). That is,

$$Vola_t = a + \beta Vola_{t+1} + \varepsilon_t. \tag{8}$$

[1] Sutcliffe (1993, p. 176) presents some of the definitions of price volatility.

In this case, Samuelson shows a beta greater than one ($\beta > 1$) and statistically significant, implying a greater volatility in contracts closest to maturity (Johnson, 1998, p. 17).

Similarly, we apply the regression for the volatility of a far and a near contract. In other words, the volatility of far contract is now expressed in terms of the volatility of the near contract (i.e. reverse regression).

$$Vola_{t+1} = a + \beta Vola_t + \varepsilon_t . \qquad (9)$$

Equations (8) and (9) highlight the relationships between near and far contracts and depend on the volatility (see Johnson (1998) for details).

4. Data Description

Daily closing prices for the FTSE/ASE-20 stock index futures are used over the period of August 1999-August 2001. For the FTSE/ASE Mid 40 stock index futures, daily closing prices are used over the period of January 2000-August 2001.

The sample is examined both as a whole and split into smaller sub-periods (i.e. monthly contracts). According to Sutcliffe (1993), it is necessary to split up the data for analysing the maturity effect. We consider (i) data with one series for each index, and (ii) data for the nearby month contracts that leaves us with 20 or 25 observations per contract (monthly contracts). In the first case, futures series are constructed by splicing together contracts near maturity. More specific, the first closing price (from the current month) was picked up in order to make the futures series for both indices. Our series have 516 and 406 observations for FTSE/ASE-20 and FTSE/ASE Mid 40 respectively. In the second case, we have 24 contracts for FTSE/ASE-20 index and 19 contracts for the FTSE/ASE Mid 40 index. This technique has been used by Herbert (1995), Serletis (1991), and Najand and Yung (1991). All data are collected from the official web page of the Athens Derivatives Exchange (www.adex.ase.gr).

Table 1 has statistical information for volatility. The results for both indices show positive skewness and high kurtosis coefficient. This means that, the distribution is skewed to the right, and also that the pdf is leptokurtic. The Jarque-Bera statistics tests are very high, rejecting normality. This is in line with Kolb (1994) who suggests that the distribution of futures price is non-normal (leptokurtic). In addition, Pagan (1996) shows that returns of most financial assets have semi-fats tails. Also, our results support the study of Allen and Cruickshank (2000) who show evidence of non-normality and excess kurtosis for several commodity futures contracts.

Table 1

Statistics for Volatility

Series	FTSE/ASE-20	FTSE/ASE Mid 40
Number of Obs.	516	406
MEAN	1.376316	2.029543
MEDIAN	0.937917	1.375003
MAXIMUM	10.47763	15.17758
MINIMUM	0.000000	0.000000
STD. DEV	1.443069	2.030635
SKEWNESS	2.120449	1.857231
KURTOSIS	9.449835	8.293527
JARQUE-BERA	1278.607	705.6899
PROB.	0.000000	0.000000

5. Empirical Results

We begin the empirical analysis by examining the stationarity condition, which is required for the existence of the maturity effect in the price of the futures contracts, under the theory of unit root and integration (see Floros and Vougas, 2004).

Bessembinder *et al*. (1996) explain further the stationarity condition required for Samuelson's hypothesis and state that it is not strictly required. However, according to Allen and Cruickshank (2000), the main condition for Samuelson's hypothesis is price stationarity. Anderson (1985) suggests that Samuelson's hypothesis is not correct when spot prices are non-stationary. So, our initial concern is to test for non-stationarity in our data. We employ the Augmented Dickey Fuller (ADF) and Philips Perron (PP) tests to test stationarity. The results of stationarity test confirm that volatility series do not contain unit roots[1]. This is consistent with the findings of Allen and Cruickshank (2000). Further, the results suggest that Spot series for both FTSE/ASE-20 and FTSE/ASE Mid 40 contain a unit root. Also, the stationarity tests for maturity coefficient (M) show that time to maturity series do not contain a unit root. Hence, the condition of Samuelson's hypothesis holds, and we conclude that the hypothesis is correct for Greek futures markets. The results are in line with results from Walls (1999) for electricity futures contracts.

Since the volatility series do not contain unit roots, we proceed by using a range of volatility regressions to test for maturity effects in the data.

From Equation 1, when $a < 1$, the volatility of futures price will increase as maturity approaches. Table 2 reports the parameter estimate and results from the model specified by Equation 1. The results show a coefficient parameter alpha less than one (i.e. $a < 1$) and significantly different from zero. Hence, the variance of the change in futures prices for both FTSE/ASE-20 and FTSE/ASE Mid 40 will rise as maturity approaches. So, Samuelson's hypothesis is suspected to be correct.

Table 2

Regression results (Equation 1)

Index	α	t_α
Part A. $S_t = aS_{t-1} + u_t$		
FTSE/ASE-20	0.9998	8951.114*
FTSE/ASE Mid 40	0.9995	5266.758*
Part B. $S_t - S_{t-1} = a(S_{t-1} - S_{t-2}) + u_t$		
FTSE/ASE-20	0.0572	2.707992*
FTSE/ASE Mid 40	0.1894	3.148985*

* Significant at the 5% level.

Table 3 reports results for the regression model specified by Equation 6. Recall that in Equation 6, we expect the intercept α to be positive. This reflects the price volatility at contract maturity. Also, we expect the maturity coefficient β to be negative, so that Samuelson's hypothesis holds. Table 3 reports results for both futures indices. For FTSE/ASE-20 and FTSE/ASE Mid 40 indices, the two conditions hold. Hence, there is a maturity effect and Samuelson's hypothesis is valid for the Greek data, as price volatility increases. Also, the constant term is positive and significantly different from zero. This finding is consistent with Walls (1999) for electricity futures.

Table 3

Regression results: $Vola_t = a + \beta \ln M_t + \varepsilon_t$ (One Series)

Index	α	t_α	β	t_β
FTSE/ASE-20	1.7488	8.9827*	-0.1702	-2.2322*
FTSE/ASE Mid 40	2.6650	8.1557*	-0.2912	-2.2294*

* Significant at the 5% level.

[1] The results of stationarity tests are available upon request.

Tables 4 and 5 report results from Equation 6, when data for the nearby month contracts are considered. In this case, we report 24 contracts for FTSE/ASE-20 (Table 4) and 19 contracts for FTSE/ASE Mid 40 (Table 5). For FTSE/ASE-20, the constant term is positive and significantly different from zero in 17 out of 24 contracts. Hence, 70.83% of constant term coefficients reflect price volatility at contract maturity, when futures and spot prices are close. For similar equation, Walls (1999) finds 92.85% (i.e. 13 of the 14 contracts in electricity futures). The coefficient on maturity (β) is negative and significantly different from zero for 5 of the 24 contracts. This implies that 20.8% of beta coefficients support Samuelson's hypothesis. However, it must be noted that the coefficient on maturity is found to be negative only in 13 of the 24 contracts (i.e. 54.16%). Similarly, for FTSE/ASE Mid 40, results show a negative and significant slope coefficient for 4 of the 19 contracts. This indicates that 21% of slope coefficient parameters imply that price volatility increases as the number of days until contract maturity decreases. In total, β is negative in 13 out of 19 contracts (i.e. 68.42%). In addition, for 15 out of 19 contracts examined, a is positive and significantly different from zero.

Table 4

Regression results: $Vola_t = a + \beta \ln M_t + \varepsilon_t$ (FTSE/ASE-20)

CONTRACT	OBS.	a	t_a	β	t_β
Sept 99	16	2.1577	2.3274**	-0.4188	-1.0331
Oct 99	20	0.7777	0.6773	0.4351	0.7958
Nov 99	25	0.6276	1.9034**	0.1330	0.6502
Dec 99	20	1.9925	1.9235**	-0.1074	-0.2278
Jan 00	25	0.7983	1.4464	0.3054	1.1700
Feb 00	20	0.5745	0.9821	0.2772	1.0415
Mar 00	20	2.2613	2.0562**	-0.4571	-1.0671
Apr 00	25	4.8879	2.2846**	-1.3462	-1.7695*
May 00	20	0.6306	1.0094	0.2293	0.6469
June 00	21	0.8129	1.7635**	-0.0279	-0.1440
July 00	24	0.4121	1.3852	0.2623	2.2636**
Aug 00	20	0.7175	1.9281**	0.0643	0.3865
Sept 00	20	4.6381	2.6323**	-1.0055	-1.4537
Oct 00	25	2.0312	7.0591**	-0.3363	-2.1013*
Nov 00	20	2.3876	2.8838**	-0.5817	-1.7281*
Dec 00	20	1.3018	2.2244**	0.3283	1.0460
Jan 01	25	2.1646	2.8732**	-0.4214	-1.5297
Feb 01	20	0.1203	0.4926	0.4444	2.7341**
Mar 01	20	1.4897	2.2140**	-0.2182	-0.8104
Apr 01	25	1.5326	1.8880**	-0.2583	-0.9087
May 01	20	2.2008	2.5360**	-0.6404	-1.7867*
June 01	20	1.2270	2.2527**	0.0867	0.3668
July 01	25	6.3348	5.8351**	-1.6708	-3.8907*
Aug 01	20	0.0932	0.1757	0.6712	2.2296**

** Indicates that constants are positive and significantly different from zero.

* Indicates that slope coefficients are negative and significantly different from zero (i.e. Samuelson's hypothesis is correct). Asterisk(s) denote(s) significance at the 5% or 10% level.

Table 5

Regression results: $Vola_t = a + \beta \ln M_t + \varepsilon_t$ (FTSE/ASE Mid 40)

CONTRACT	OBS.	a	t_a	β	t_β
Feb 00	20	2.0155	2.5858**	-0.1682	-0.4655
Mar 00	20	6.4450	3.5494**	-1.5039	-1.9917*
Apr 00	25	5.9555	2.5547**	-0.9339	-1.1153
May 00	20	4.5262	2.6241**	-0.8071	-1.0238
June 00	21	1.0931	1.4332	0.1554	0.4726
July 00	24	1.0651	1.6581**	0.4121	1.3882
Aug 00	20	2.7715	2.0799**	-0.4558	-0.8527
Sept 00	20	4.8993	3.1002**	-1.0039	-1.6438*
Oct 00	25	1.7803	2.8656**	-0.0654	-0.2762
Nov 00	20	0.5457	0.9762	0.2088	0.6962
Dec 00	20	1.6711	2.4080**	0.4779	1.1329
Jan 01	25	4.7049	3.8553**	-1.1805	-2.6877*
Feb 01	20	2.9723	2.7198**	-0.2832	-0.5448
Mar 01	20	2.1114	1.6433**	-0.1854	-0.3569
Apr 01	25	0.6161	1.1541	0.2326	1.1281
May 01	20	1.2263	2.3926**	-0.1785	-0.8001
June 01	20	1.7006	3.3862**	-0.2540	-1.2666
July 01	25	4.5190	3.2423**	-0.9018	-1.6537*
Aug 01	20	0.5016	0.7123	0.5480	1.5538

** Indicates that constants are positive and significantly different from zero.

* Indicates that slope coefficients are negative and significantly different from zero (i.e. Samuelson's hypothesis is correct). Asterisk(s) denote(s) significance at the 5% or 10% level.

GARCH Modelling

Following Allen and Cruickshank (2000), we apply (G)ARCH specifications to model futures volatility, and use diagnostic tests to find whether ARCH effects exist in the data. Calculated Ljung-Box statistics suggest ARCH processes, although the LM tests suggest that ARCH effects are not present in the volatility series. Further, Allen and Cruickshank (2000) fit ARCH (1) and GARCH (1,1) models to their series.

Ljung-Box Q-statistics for up to 20 lagged values show evidence that the null hypothesis of no autocorrelation in volatility series is rejected at 5% level (i.e. $p<0.05$), but the actual level of autocorrelation is very small. Our findings are consistent with Allen and Cruickshank (2000) for futures volatilities from three international commodity futures markets.

Then, we fit various GARCH models to the data. As before, we use two different techniques. We fit volatility models for each index and examine monthly contracts. The best GARCH representation is selected by AIC. The model with lowest AIC is taken to fit data best.

For examining Samuelson's hypothesis, we employ GARCH(p,q), EGARCH(1,1), and TGARCH(1,1) models with a dummy variable (D_t) in the mean equation (Equation 7). Firstly, results from variance equations suggest that conditional variance exhibits reasonably long persistence of volatility. Also, in some cases, the leverage effect is statistically significant, indicating existence of leverage over the period. Hence, a negative shock increases the conditional variance. These results are not presented in this paper, as we focus on the results obtained from the mean equations. Recall that the maturity coefficient, β, in the mean equation should be positive and statistically significant to have a positive change in volatility.

Table 6 reports results from the mean equation of several GARCH models for the FTSE/ASE-20 index. The EGARCH model shows a lower AIC value, and thus our data can be better modelled by an Exponential-GARCH. However we highlight that the coefficient of the dummy variable (β) is always positive but not significantly different from zero. Therefore, there is no maturity effect to the FTSE/ASE-20 over this period. However, three models show a significant increase in volatility. The null hypothesis of no autocorrelation is rejected, and Engle's ARCH-LM test statistics suggests no ARCH processes in the residuals.

Table 6

GARCH Results: $Vola_t = a + \beta D_t + \varepsilon_t$ (One Series- FTSE/ASE- 20)

MODEL	AIC	DUMMY	T-RATIO
EGARCH	3.355235	0.151233	1.406589
GARCH(1,1)	3.372845	0.199313	1.619083
TGARCH	3.369526	0.168776	1.490780
GARCH(0,1)	3.502231	0.236723	1.779514*
GARCH(0,2)	3.458925	0.158079	1.191193
GARCH(2,1)	3.369546	0.191749	1.704481*
GARCH(1,2)	3.372953	0.215492	1.714755*
GARCH(2,2)	3.369914	0.202666	1.615789

* Significant at the 10% level.

Using monthly series, we obtain various results for the maturity effect in the price of FTSE/ASE-20 futures contracts. In total we examine 24 contracts for FTSE/ASE-20 index. The results of mean equations from the selected models are presented in Table 7. The coefficient of dummy variable, which presents the maturity effect, is positive and statistically significant for 11 out of 24 contracts. Therefore, we find that 45.8% of maturity effect coefficients are positive and statistically significant in Equation 6 for monthly contracts. Only in five cases beta coefficients are not significantly different from zero.

Table 7

GARCH Results: $Vola_t = a + \beta D_t + \varepsilon_t$ (Monthly Series- FTSE/ASE- 20)

CONTRACT	OBS.	MODEL	DUMMY	T-RATIO
Sept 99	16	EGARCH	-0.2082	-1.7349
Oct 99	20	GARCH(1,1)	-0.7474	-3.4942
Nov 99	25	EGARCH	0.0460	0.4867
Dec 99	20	GARCH(1,1)	0.5908	1.8414*
Jan 00	25	GARCH(1,1)	-0.3947	-0.8382
Feb 00	20	GARCH(1,1)	0.1494	1.4002
Mar 00	20	EGARCH	-0.4996	-8.3300
Apr 00	25	TGARCH	1.4746	3.7350*
May 00	20	EGARCH	0.1627	1.4948
June 00	21	GARCH(1,1)	0.9388	4.3628*
July 00	24	EGARCH	-0.6457	-15.245
Aug 00	20	EGARCH	-0.2815	-787.73

Table 7 (continuous)

CONTRACT	OBS.	MODEL	DUMMY	T-RATIO
Sept 00	20	GARCH(1,1)	1.9839	3.5319*
Oct 00	25	EGARCH	0.2264	3.3777*
Nov 00	20	GARCH(1,1)	0.5470	2.4261*
Dec 00	20	EGARCH	0.1836	2.6592*
Jan 01	25	EGARCH	0.3659	4.4091*
Feb 01	20	EGARCH	-0.2454	-713.44
Mar 01	20	EGARCH	0.3540	2.5978*
Apr 01	25	EGARCH	-0.0022	-0.0152
May 01	20	EGARCH	0.2193	5.6832*
June 01	20	TGARCH	-0.2831	-3.5097
July 01	25	GARCH(1,1)	3.0425	14.912*
Aug 01	20	GARCH(1,1)	-0.9432	-2.5041

* Indicates that slope coefficients are positive and significantly different from zero
(i.e. Samuelson's hypothesis is correct). Asterisk(s) denote(s) significance at the 5% or 10% level.

On the other hand, results obtained for FTSE/ASE Mid 40 volatility data are quite different. In this case, the selected model shows a positive and statistically significant beta coefficient. In other words, the EGARCH model indicates that volatility depends on the time to maturity. Therefore, since the dummy variable in the mean equation is always positive, we conclude that Samuelson's hypothesis holds for FTSE/ASE Mid 40. Table 8 shows results from mean equations. Q-statistics probabilities indicate rejection of the null hypothesis of no autocorrelation, while LM tests suggest no ARCH in the residuals. These findings are consistent with Allen and Cruickshank (2000).

Table 8

GARCH Results: $Vola_t = a + \beta D_t + \varepsilon_t$ (One Series- FTSE/ASE Mid 40)

MODEL	AIC	DUMMY	T-RATIO
EGARCH	4.095283	0.373240	2.512987*
GARCH(1,1)	4.104449	0.383582	2.527534*
TGARCH	4.109345	0.396665	2.595279*
GARCH(0,1)	4.167464	0.478489	2.359882*
GARCH(0,2)	4.138991	0.341718	1.806806*
GARCH(2,1)	4.104808	0.427754	2.719855*
GARCH(1,2)	4.105451	0.395951	2.460432*
GARCH(2,2)	4.106632	0.473560	2.969257*

* Significant at the 10% or 5% level.

Furthermore, we use monthly series to measure volatility of FTSE/ASE Mid 40 index and find that 6 contracts out of 19 contracts support Samuelson's hypothesis. In other words, 31.58% of contracts show that the dummy coefficient (i.e. beta) is positive and significantly different from zero. Therefore, we conclude that the variance of FTSE/ASE Mid 40 changes positively indicating a rise in volatility at maturity. Hence, Samuelson's hypothesis is valid. Notice that 9 contracts show an insignificant beta coefficient. Table 9 reports results from mean equations for FTSE/ASE Mid 40. Variances in June 2000, August 2000, September 2000, March 2001 and July 2001 tend to be greater shortly before expiration.

Table 9

GARCH Results: $Vola_t = a + \beta D_t + \varepsilon_t$ (Monthly Series- FTSE/ASE-40)

CONTRACT	OBS.	MODEL	DUMMY	T-RATIO
Feb 00	20	EGARCH	0.1398	0.4300
Mar 00	20	EGARCH	0.0307	0.3187
Apr 00	25	GARCH(1,1)	0.5802	0.6852
May 00	20	GARCH(1,1)	0.3971	0.8261
June 00	21	GARCH(1,1)	1.2174	4.8854*
July 00	24	EGARCH	-0.3586	-3.4002
Aug 00	20	GARCH(1,1)	1.8951	4.5046*
Sept 00	20	EGARCH	0.8236	2.7353*
Oct 00	25	GARCH(1,1)	0.5495	1.0835
Nov 00	20	EGARCH	0.0974	0.4029
Dec 00	20	TGARCH	-1.3583	-1.8909
Jan 01	25	EGARCH	2.4203	12.944*
Feb 01	20	GARCH(1,1)	0.1012	0.2738
Mar 01	20	EGARCH	0.5236	2.6474*
Apr 01	25	EGARCH	-0.4014	-3.0514
May 01	20	GARCH(1,1)	0.0725	0.6986
June 01	20	EGARCH	0.0483	0.2490
July 01	25	GARCH(1,1)	2.7964	7.8960*
Aug 01	20	TGARCH	-1.5357	-2.6242

* Indicates that slope coefficients are positive and significantly different from zero (i.e. Samuelson's hypothesis is correct). Asterisk(s) denote(s) significance at the 5% or 10% level.

Finally, we follow Johnson (1998) about the relationship between volatility of near and far contracts. He uses daily settlement prices to calculate volatility on futures prices. In other words, to test Samuelson's hypothesis further, Equations 8 and 9 are estimated. In Equation 8 (9), volatility of near (far) contract is expressed in terms of volatility of far (near) contract. Johnson (1998) states that β must be greater than one, to have greater volatility in contracts closest to maturity. Table 10 summarises results from Equation 8. In all cases, although variables are positive and significant, volatility of near contract is less than that of the far contract. In other words, β is always less than one. This result is consistent with the findings of Johnson (1998) for SPI futures contract. Therefore, the results show less volatility in contracts closest to maturity.

Table 10

Regression results: $Vola_t = a + \beta Vola_{t+1} + \varepsilon_t$ (One Series)

Index	α	t_α	β	t_β
FTSE/ASE-20	1.1778	12.989*	0.1454	2.5187*
FTSE/ASE Mid 40	1.7663	12.091*	0.1302	2.1005*

* Significant at the 5% level.

Running the reverse regression (i.e. Equation 9), we conclude that volatility of far contract is also less than that of near contract. The results are presented in Table 11. As β is still less than one, there is no evidence supporting Samuelson's (1965) hypothesis. However, in all cases, the relationship between near and far contracts depends on volatility. Our findings are in line with results obtained by Johnson (1998).

According to Johnson (1998, p. 3), “This being the case index futures traders are free to trade whatever contract is the most convenient and decisions based on price volatility can be put aside, as they have no impact on contract choice”.

Table 11

Regression results: $Vola_{t+1} = a + \beta Vola_t + \varepsilon_t$ (One Series)

Index	α	t_α	β	t_β
FTSE/ASE-20	1.1784	12.875*	0.1454	2.3644*
FTSE/ASE Mid 40	1.7666	11.639*	0.1302	1.8730*

* Significant at the significance levels. Asterisk(s) denote(s) significance at the 5% or 10% level.

6. Summary and Conclusions

This paper examines the relationship between volatility and time to expiration. We empirically investigate Samuelson’s (1965) hypothesis. Critics of Samuelson’s hypothesis suggest a greater volatility in futures contracts closer to maturity. In general, this is a behavioural hypothesis, where futures price reflects current information about the spot price at maturity (expiry date). Hence, as maturity approaches, the amount of information increases, indicating large changes in price volatility.

Others suggest that Samuelson’s hypothesis holds when information about the harvest of commodities is reaching the market, and therefore, volatility depends on the time of the year. In addition, a number of papers show that the hypothesis is correct when information flows do not cluster near delivery dates, and also, in markets where equilibrium spot prices are mean reverting. Overall, empirical results of the volatility-maturity relationship for futures show little support to Samuelson’s hypothesis. In most cases, the maturity effect in index futures markets is not strong. For futures contracts, other than index futures (and commodities) results suggest that Samuelson’s hypothesis is strongly supported (in particular for agricultural commodities and energy futures).

Previous empirical studies for UK and U.S. financial markets do not indicate clearly whether there is a maturity effect in the stock index futures markets. Here, we analyse the maturity effect in the Athens Derivatives Exchange (ADEX). We examine the maturity effect in the price of FTSE/ASE-20 and FTSE/ASE Mid 40 futures contracts of the ADEX. Using daily data, the period is examined as a whole and split into monthly periods. A range of volatility models is employed. These include simple linear regressions and GARCH models.

For both indices, the model proposed by Samuelson (1965) shows that the variance of the change in futures prices will rise as maturity approaches. Secondly, simple linear regressions suggest that there is a maturity effect, and therefore, Samuelson’s hypothesis seems to be correct for both FTSE/ASE-20 and FTSE/ASE Mid 40 index.

In the case of monthly contracts, we find that 70.83% (17 out of 24 contracts) of constant term coefficients are significant for FTSE/ASE-20, reflecting price volatility at contract maturity. In addition, 20.8% (5 out of 24 contracts) beta coefficients support Samuelson’s hypothesis. Similarly, for FTSE/ASE Mid 40, results suggest that 21% (4 out of 19 contracts) of slope coefficient parameters show price volatility increases as the number of days until contract maturity decreases.

On the other hand, using GARCH models, we arrive at different conclusions. First, for FTSE/ASE-20, there is no evidence to support Samuelson’s hypothesis over the whole period. However, using monthly series, results from the mean equations suggest that 45.8% (11 out of 24 contracts) of maturity effect coefficients support Samuelson’s hypothesis.

For FTSE/ASE Mid 40, results (over the whole sample) show a positive and significant coefficient, indicating that volatility depends on time to maturity. Also, using monthly series to measure volatility, we find that 31.58% (6 out of 19) of the contracts indicate a rise in volatility at maturity.

Finally, following Johnson (1998) about the relationship between volatility of near and far contracts, we conclude that the relationship depends on the volatility parameter. In other words, volatilities of near and far contracts are highly correlated, implying that the volatility factor depends on the time period under examination.

In summary, this paper finds that the volatility series depends on the time to maturity. This result is not consistent with the findings of Moosa and Bollen (2001) and Galloway and Kolb (1996) for the S&P 500 futures contract. In general, our empirical results show that Samuelson's hypothesis is correct when linear regressions are used. Also, when data for nearby month contracts are considered, GARCH models show a stronger support to Samuelson's hypothesis rather than linear regressions. Our findings are in line with results obtained by Allen and Cruickshank (2000), Walls (1999) and Johnson (1998).

Further empirical work should investigate pairwise relationships between volume-maturity, basis-maturity and volatility-volume to a wider range of futures contracts.

References

1. Allen, D.E. and Cruickshank, S.N. (2000), Empirical testing of the Samuelson hypothesis: An application to futures markets in Australia, Singapore and the UK, *Working Paper, School of Finance and Business Economics, Edith Cowan University*.
2. Anderson, R. W. (1985), Some determinants of the volatility of futures prices, *Journal of Futures Markets*, **5**, 331-348.
3. Anderson, R.W. and Danthine, J.P. (1983), The time pattern of hedging and the volatility of futures prices, *Review of Economic Studies*, **50**, 249-266.
4. Antoniou, A. and Holmes, P. (1995), Futures trading, information and spot price volatility: evidence for the FTSE-100 stock index futures contract using GARCH, *Journal of Banking and Finance*, **19**, 117-129.
5. Barnhill, T.M., Jordan, J.V. and Seale, W.E. (1987), Maturity and refunding effects on treasury-bond futures price variance, *Journal of Financial Research*, Vol. **X**, No. 2, 121-131.
6. Bessembinder, H., Coughenour, J.F., Seguin, P.J. and Smeller, M.M. (1996), Is there a term structure of futures volatilities? Reevaluating the Samuelson hypothesis, *Journal of Derivatives*, **4**, 45-58.
7. Board, J.L. G. and Sutcliffe, C.M.S. (1990), Information, volatility, volume and maturity: an investigation of stock index futures, *Review of Futures Markets*, **9**.
8. Bollerslev, T. (1986), Generalised Autoregressive Conditional Heteroskedasticity, *Journal of Econometrics*, **30**, 307-328.
9. Bollerslev, T. (1987), A conditional heteroscedasticity time series model for speculative prices and rates of return, *Review of Economics and Statistics*, **69**, 542-547.
10. Bollerslev, T. and Wooldridge, J.M. (1992), Quasi-maximum likelihood estimation and inference in dynamic models with time varying covariances, *Econometric Reviews*, **11**, 143-172.
11. Brooks, C., Rew, A.G., and Ritson, S. (2001), A trading strategy based on the lead-lag relationship between the spot index and futures contract for the FTSE 100, *International Journal of Forecasting*, **17**, 31-44.
12. Castelino, M.G. and Francis, J.C. (1982), Basis speculation in commodity futures: the maturity effect, *Journal of Futures Markets*, **2**, 195-206.
13. Chamberlain, T.W. (1989), Maturity effects in futures markets: some evidence from the City of London, *Scottish Journal of Political Economy*, **36**, 90-95.
14. 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.
15. Dickey, D.A. and Fuller, W.A. (1979), Distribution of the estimators of autoregressive time series with a unit root, *Journal of the American Statistical Association*, **74**, 427-431.

16. Dusak-Miller, K. (1979), The relation between volatility and maturity in futures contracts, in *Commodity Markets and Futures Prices* (Ed.) R.M. Leuthold, Chicago Mercantile Exchange, Chicago, 25-36.
17. Engle, R.F. (1982), Autoregressive conditional heteroskedasticity with estimates of the variance of U.K. inflation, *Econometrica*, **50**, 987-1007.
18. Engle, R.F. and Ng, V. (1993), Measuring and testing the impact of news on volatility, *Journal of Finance*, **48**, 1749-1779.
19. Floros, C. and Vougas, D.V. (2004), Hedge Ratios in Greek Stock Index Futures Market, *Applied Financial Economics*, 14(15), 1125-1136.
20. Galloway, T. and Kolb, R.W. (1996), Futures prices and the maturity effect, *Journal of Futures Markets,* **16**, 809-828.
21. Glosten, L.R., Jagannathan, R., and Runkle, D.E. (1993), On the Relation Between the Expected Value and the Volatility of the Nominal Excess Return on Stocks, *Journal of Finance*, **48**, 1779-1801.
22. Grammatikos, T. and Saunders, A. (1986), Futures price variability: A test of maturity and volume effects, *Journal of Business*, **59**, 319-330.
23. Han, L.M. and Misra, L. (1990), The relationship between the volatilities of the S&P 500 index and futures contracts implicit in their call option prices, *Journal of Futures Markets*, **10**, 273-285.
24. Han, L-M, Kling, J. M. and Sell, C.W. (1999), Foreign exchange futures volatility: Day-of-the-week, intraday, and maturity patterns in the presence of macroeconomic announcements, *Journal of Futures Markets*, **19**, 665-693.
25. Hemler, M.L. and Longstaff, F.A. (1991), General equilibrium stock index futures prices: theory and empirical evidence, *Journal of Financial and Quantitative Analysis*, **26**, 287-308.
26. Hennessy, D.A. and Wahl, T.I. (1996), The effects of decision making on futures price volatility, *American Journal of Agricultural Economics*, **78**, 591-603.
27. Herbert, J.H. (1995), Trading volume, maturity and natural gas futures price volatility, *Energy Economics*, **17**, 293-299.
28. Hong, H. (2000), A model of returns and trading in futures markets, *Journal of Finance*, Vol. **LV**, 959-988.
29. Johnson, J. (1998), Does the Samuelson effect hold for SPI futures?, Working Paper, *Department of Accounting and Finance, The University of Western Australia*.
30. Karpoff, J.M. (1987), The relation between price changes and trading volume: a survey, *Journal of Financial and Quantitative Analysis*, **22**, 109-126.
31. Kenyon, D., Kenneth, K., Jordan, J., Seale, W. and McCabe, N. (1987), Factors affecting agricultural futures price variance, *Journal of Futures Markets,* **7**, 73-91.
32. Khoury, N. and Yourougou, P. (1993), Determinants of agricultural futures price volatilities: evidence from Winnipeg commodity exchange, *Journal of Futures Markets*, **13**, 345-356.
33. Kolb, R.W. (1994), '*Understanding Futures Markets*', Kolb Publishing Company, 4th Edition.
34. Leistikow, D. (1989), Announcements and futures price variability, *Journal of Futures Markets*, **9**, 477-486.
35. Milonas, N.T. (1986), Price variability and the maturity effect in futures markets, *Journal of Futures Markets*, **6**, 443-460.
36. Moosa, I.A. and Bollen, B. (2001), Is there a maturity effect in the price of the S&P 500 futures contract?, *Applied Economics Letters*, **8**, 693-695.
37. 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.
38. Nelson, D. (1991), Conditional Heteroscedasticity in Asset Returns: A New Approach, *Econometrica*, **59**, 347-370.
39. Pagan, A. (1996), The econometrics of financial markets, *Journal of Empirical Finance*, **3**, 15-102.
40. Pagan, A.R. and Schwert, G.W. (1990), Alternative models for conditional stock volatility, *Journal of Econometrics*, **45**, 267-290.

41. Park, H.Y. and Sears, R.S. (1985), Estimating stock index futures volatility through the prices of their options, *Journal of Futures Markets*, **5**, 223-237.
42. Rutledge, D.J.S. (1976), A note on the variability of futures prices, *Review of Economics and Statistics*, **58**, 118-120.
43. Rutledge, D.J.S. (1979), Trading volume and price variability: new evidence on the price effects of speculation, in *Futures Markets: Their Establishment and Performance* (ed. B.A. Goss), Croom Helm, London, 1986, 137-156.
44. Samuelson, P.A. (1965), Proof that properly anticipated prices fluctuate randomly, *Industrial Management Review*, **6**, 41-49.
45. Segall, J. (1956), The effect of maturity on price fluctuations, *Journal of Business*, **29**, 202-206.
46. Serletis, A. (1991), Rational expectations, risk and efficiency in energy futures markets, *Energy Economics*, **12**, 111-115.
47. Serletis, A. (1992), Maturity effects in energy futures, *Energy Economics*, **14**, 150-157.
48. Sutcliffe, C.M.S. (1993), *Stock Index Futures: Theories and International Evidence*, Chapman & Hall.
49. Tauchen, G.E. and Pitts, M. (1983), The price variability volume relationship on speculative markets, *Econometrica*, 51, 485-505.
50. Walls, W.D. (1999), Volatility, volume and maturity in electricity futures, *Applied Financial Economics*, **9**, 283-287.
51. Yang, S.R. and Brorsen, B.W. (1993), Nonlinear dynamics of daily futures prices: Conditional heteroskedasticity or chaos?, *Journal of Futures Markets*, **13**, 175-191.
52. Zakoian, J.M. (1990), Threshold heteroskedastic models, *Manuscript, CREST, INSEE*, Paris.