Evaluating the Efficiency of Emerging Options Markets: Evidence from Greece

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Abstract

This paper examines the efficiency of the emerging Greek options market of the Athens Derivatives Exchange by focusing on the returns of options written on the large capitalization FTSE/ASE-20 index. We find that, although individual calls and puts earn substantially higher (absolute) returns than those of options in developed markets, these returns are not inconsistent even with the simple Black and Scholes theoretical framework. Risk-adjusted returns of naked puts are, in general, significant and, thus, consistent with previous empirical findings. Furthermore, option portfolios that are immune to various sources of risk are found to earn the risk-free rate, indicating the absence of real profit opportunities. We conclude that, although mispricing is potentially an issue in the Greek options market, its magnitude is not necessarily higher than that documented in traditional, developed markets. Overall, we cannot reject the efficiency of the Athens Derivatives Exchange, since our results do not support the alternative hypothesis that emerging markets are likely to be associated with more severe options mispricing, which is not arbitraged away due to higher transaction costs and thinner trading.

Keywords: Market efficiency; Emerging markets; Options

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1. Introduction

Market efficiency constitutes a fundamental issue in finance research and has been long studied by financial economists. Market efficiency is typically associated with asset returns, in the sense that an efficient market is characterized by the absence of mispricing with asset returns being commensurate with specific underlying risk factors. Although the majority of empirical papers that have examined market efficiency have traditionally focused on equity markets, the research interest in the efficiency of options markets has been increasing in the finance literature during the past decade.

This paper examines option returns in an emerging market, namely the Athens Derivatives Exchange (ADEX) in Greece, with particular emphasis on the extent of mispricing present in the market. Previous papers have mainly focused on developed options markets such as the US and the UK, with the issue of market efficiency in developing markets having been largely ignored. Although the examination of developed options markets is partly justified by the fact that they are characterized by high-volume trading so that option prices are likely to be more informative, we propose that emerging markets can provide an interesting new field of research.

Since options are risky assets, standard capital asset pricing theory predicts that they should earn a risk-premium related to their systematic risk. Coval and Shumway (2001) further demonstrate that, under a set of realistic assumptions, option returns must be increasing in strike price space, while calls should earn a return in excess of that of the underlying asset and puts should have an expected return below the risk-free rate. Focusing on calls and puts written on the S&P 500 index between 1990 and 1995, they find that option returns in their sample indeed exhibit these characteristics. However, returns do not appear to vary linearly with their respective market betas, indicating that additional factors are potentially priced.

In contrast, Ni (2006) finds that the Coval and Shumway (2001) theoretical predictions do not apply for call options written on individual stocks. Examining a sample of US calls for the period 1996-2005, she reports average call option returns that are decreasing in strike price, with out-of-the-money (OTM) calls earning negative returns. This puzzling finding is potentially explained through investors' seeking of idiosyncratic skewness, leading to higher than expected OTM call prices and, hence, lower returns. Jones (2001) analyzes a set of S&P 500 index options and concludes that idiosyncratic variance alone is insufficient in explaining short-term OTM put returns. He argues, therefore, that a multi-factor model is necessary to understand the risk-premia associated with options. Moreover, Broadie, Chernov and Johannes (2009) examine a larger sample of S&P 500 index options, namely from 1987 to 2005, with particular emphasis on puts. Contrary to Coval and Shumway, they report that the Black and Scholes (1973) option pricing model cannot be rejected based on deep OTM put returns. Also, at-the-money (ATM) put and straddle returns are found to be consistent with jump models.

Liu (2007) focuses on arguably the two most common sources of risk in the options market, namely changes in the value of the underlying and changes in the underlying's volatility. By forming delta and vega neutral straddles with options written on the FTSE 100, she explores the hypothesis that option portfolios that are immune to delta and vega risk should earn the risk-free rate, and finds that this prediction is supported for ATM and in-the-money (ITM) portfolios. However, OTM straddles appear to earn significantly negative returns, with one potential explanation for this result being the fact that delta and vega neutrality, measured as Black and Scholes local sensitivities, do not necessarily hold for the entire holding period of the straddles. The paper also examines risk-reversals, which are option positions that profit from negative skewness, and finds that, even after controlling for the bid-ask spread, trading these portfolios has been significantly profitable during the sample period from 1996 to 2000.

O'Brien and Shackleton (2005) examine the effect of systematic moments of order higher than two in explaining the cross-section of option returns. They focus on FTSE 100 index options and conclude that while systematic variance is significant in explaining option returns, the effect of historical coskewness and cokurtosis is less evident. Finally, one of the papers that have significantly motivated the present study is the Santa-Clara and Saretto (2009) examination of S&P 500 options returns. In particular, they analyze the performance of various trading strategies and find that these strategies are associated with very high returns, an effect that is especially pronounced for those that involve short positions in options, and that these returns are not justified by their exposure to market risk according to traditional asset pricing models. However, after accounting for transaction costs and margin requirements, the above mentioned returns become less significant, or even negative. Consequently, even though a certain level of mispricing is documented in the US options market, a typical investor cannot exploit real profit opportunities due to the high costs involved and, instead of being arbitraged away, options mispricing is allowed to persist.

The objective of this paper is to shift the focus from developed options markets to their emerging counterparts. To this extent, we examine the returns of options written on the Greek large capitalization index FTSE/ASE-20 for the time-period January 2004 to January 2007. The main hypothesis of interest is that the Athens Derivatives Exchange exhibits a level of efficiency comparable to that of developed markets. Given the global nature of today's marketplace and the fact that large, international investors with significant experience in more established options markets account for most of the trading volume in Greece, it is not unreasonable to assume that the ADEX should be a relatively efficient market, with option prices reflecting 'true' asset values that do not offer returns that deviate from those justified by their risk-exposure.

The alternative hypothesis is partly motivated by the Santa-Clara and Saretto (2009) study, and states that higher transaction costs, combined with thinner trading, are likely to be associated with a higher level of options mispricing, measured by the returns of options and options strategies in excess of their exposure to risk. Intuitively, higher trading costs will result in a widened no-arbitrage band, and market prices of options will be allowed to deviate further from their theoretical price without arbitrageurs being able to profit from the discrepancy and, in the process, forcing prices to their 'fair' level.

Given the higher transaction costs that characterize the Athens Derivatives Exchange, the above mentioned alternative hypothesis predicts that positions in individual options in Greece earn different risk-adjusted returns than those typically earned by options in the US or the UK developed markets. In addition, trading strategies that are risk-neutral would be more likely to earn returns that are statistically different from the risk-free rate in an emerging market compared to its developed counterparts.

Overall, the results appear to support the efficiency of the Athens Derivatives Exchange. Although naked option positions in Greece earn substantially higher returns than their US counterparts, the discrepancy between realized returns and those justified by the *Capital Asset Pricing Model* (CAPM) or the Black and Scholes (1973) option pricing model is not necessarily larger than that traditionally documented in the US market. More importantly, portfolios that are formed to be delta and/or vega neutral are found to earn the risk-free rate, providing further support for the efficiency of the Greek options market. In summary, the developing market of the Athens Derivatives Exchange does not appear to offer real profit opportunities, after controlling for risk, and the extent to which options might be considered as mispriced is not found to be higher than that characterizing the US and the UK markets.

The remaining of the paper is organized as follows. Section 2 presents the data used in the empirical analysis and gives an overview of the Greek large-capitalization index and its returns throughout the sample period. Section 3 discusses observed returns of naked positions in individual, European-style calls and puts written on the FTSE/ASE-20. Section 4 examines the efficiency of the ADEX using the three most commonly used criteria, namely deviations of realized returns from theoretical ones, CAPM alphas, and the returns of zero-risk trading strategies, such as delta and vega neutral straddles. Finally, Section 5 provides a comparison between the results and previous empirical findings from developed markets, while Section 6 concludes.

2. Data

The options data used in this paper refers to European-style options written on the FTSE/ASE-20 index which includes the 20 most liquid and largest capitalization Greek stocks. All relevant options data is publicly available through the exchange's website (www.adex.ase.gr). For every trading day, option prices are obtained for the two nearest expiration dates which are typically more liquid than longer-term contracts. The options expire on the third Friday of the month and settlement is in cash.

The original dataset consisted of 15,198 calls and 18,217 puts traded on the Derivatives Market of the Athens Stock Exchange. The sample runs from January 2004 to January 2007 for a total of 770 trading days. Similarly to previous studies, several filters are employed. First, all options with prices that lay outside the well-known theoretical bounds or are near zero are excluded from the dataset. Moreover, calls and puts with less than one week (five trading days) to maturity are dropped. Finally, options with less than five traded contracts on a given day are excluded to avoid illiquidity concerns. The above filters resulted in a reduced dataset of 9,761 calls and 9,212 puts.

Table 1 reports some descriptive statistics with respect to the number of daily observations. Although the sample consists of 12.34 calls and 11.90 puts on average per trading day, it can be seen from Figure 1 that the number of observations in a day exhibits significant variability throughout the period of January 2004 to January 2007. The number of calls (puts) per day exhibits a standard deviation of 3.26 (2.99) and ranges from a minimum of 5 to a maximum of 23 (24).

The risk-free interest rate is proxied by Euribor which, along with the underlying FTSE/ASE-20 index, was obtained through DataStream. The Athens Composite Share Price Index was obtained from Reuters. The continuous dividend yield of the underlying asset was calculated by using futures contracts on the FTSE/ASE-20 index (futures data is also available through the exchange's website) and solving equation (1) for the dividend yield q:

$$F_0^T = S_0 e^{(r-q)T} \tag{1}$$

where F_0^T is the value at time 0 of a futures contract on the index expiring at T, S_0 is the spot price of the index, and r is the risk-free rate.

The sample period could be characterized as one of a significantly high increase in the level of the underlying large-capitalization FTSE/ASE-20 index. From a level of 1,194.2 on the first trading day of 2004, the index has experienced a rapid growth to reach 2,566 at the end of January 2007. This translates into an overall appreciation of 114.87% over the entire 37 months period or, equivalently, 28.15% annually. The evolution of the FTSE/ASE-20 throughout the sample period is presented in Figure 2. The mean daily return is 0.1% with a standard deviation of 105 basis points, and the Jarque-Bera test rejects the null hypothesis of normality in the returns' distribution at the 5% confidence level. In addition, spot returns appear to be an I(0) process, since the Dickey-Fuller test for the order of integration produces a t-statistic equal to 1.64 and therefore cannot reject the null hypothesis of stationarity in the time-series of arithmetic returns at the 5% significance level.

Not surprisingly, returns of the FTSE/ASE-20 index exhibit an extremely high correlation with returns of the Athens Composite Share Price Index (ACSPI) which is constructed to capture the overall performance of the Athens Stock Exchange (ASE) and includes the 60 most liquid and largest capitalization stocks. In addition to a correlation coefficient of 0.98, when rolling regressions of FTSE/ASE-20 excess returns on ACSPI excess returns are estimated, the resulting betas are very close to unity throughout the sample period, reflecting the fact that the 20 largest capitalization stocks that are included in the FTSE/ASE-20 heavily influence the overall performance of the ASE.

3. Option Returns

As has been already mentioned in the previous Section, the call options dataset (post filtering) consists of 9,761 call observations across 770 trading days. Daily arithmetic returns for each individual call are computed using closing prices for each calendar day.[1] Obviously, the fact that not all strike prices have traded options on every day reduces the number of calls for which daily returns can be computed. Whenever a specific call is not traded on two consecutive trading days, or the call price remains the same over this window, the call return is treated as a missing observation. The above limitations reduce the number of computable daily returns to 6,884 observations.

Let c_t be the price of a call option with strike price K and time-to-maturity T. The daily arithmetic return R_c for this call is estimated as the difference between c_{t+1} and c_t, divided by c_t.

$$R_c = \frac{c_{t+1} - c_t}{c_t} \qquad (2)$$

Options with different strike prices are likely to earn returns that differ significantly. For instance, Coval and Shumway (2001) show that option returns should be increasing across strike price space. In order to examine the behaviour of call returns across different strikes, individual calls are sorted into four groups according to their

[1] In addition to being a commonly used methodology in the literature, closing option prices are used in computing daily returns since the Athens Derivatives Exchange states that they are quoted to reflect a representative estimate of the 'true' value of an option contract at the end of the trading day. Option returns have also been examined using last trade prices obtaining similar results.

moneyness, with moneyness proxied by the option's Black and Scholes (BS) delta.[2] These moneyness groups are created such that strike prices for calls are increasing across the strike group number, with group 1 including calls with the lowest strikes and group 4 including calls with the highest strikes. The call's Black and Scholes delta simultaneously accounts for differences in underlying index level, index volatility and time-to-maturity across individual options. Panel A of Table 2 contains the criteria for assigning call option returns to the four strike groups.

After classifying calls according to their moneyness, summary statistics for call returns of each of the strike groups are computed. Panel B of Table 2 presents the mean, standard error and skewness of call returns across the four groups. T-statistics for the null hypothesis that the average call return is statistically indistinguishable from zero are in brackets. Finally, the average call BS beta and average volume of traded contracts for each option category are reported. The BS beta β_{BS} for each call is of particular interest since standard asset pricing theory predicts that average call returns should increase as β_{BS} increases, and it is estimated using equation (3), where K is the option's exercise price and σ is the underlying's volatility. Following Coval and Shumway (2001), this also implies that β_{BS} will be higher for calls with higher strikes than for their lower strikes counterparts. The intuition behind this theoretical prediction is that calls with higher strike prices represent more levered positions in the underlying asset and are, therefore, riskier investments.

$$\beta_c = \frac{S_0}{c} N[\frac{\ln(\frac{S_0}{K}) + (r - q + \frac{\sigma^2}{2})T}{\sigma\sqrt{T}}] \qquad (3)$$

As can be seen from Panel B of Table 2, average daily arithmetic returns for call options in the Greek market are positive and particularly high, compared, for instance, to call returns in the US. Call returns are found to be statistically significant for near-the-money contracts in groups 2 and 3, and marginally insignificant for ITM and OTM contracts in groups 1 and 4, ranging from a minimum of 1.41% daily for the low-strike,

[2] Option moneyness is frequently proxied by the ratio K/S of the strike price K to the price of the underlying S, and by the logarithm of the above ratio divided by the underlying's volatility σ (see Ni (2006) for a more detailed discussion). The subsequent analysis of option returns has also been performed under these additional moneyness proxies with the results being similar to the ones obtained under the delta moneyness classification and, therefore, are not reported for brevity.

most in-the-money calls to a maximum of 3.34% for the high-strike, most out-of-the-money ones. These figures correspond to annual returns of roughly between 352% and 835%, depending on the options' moneyness, and are much higher than returns of calls written on the S&P 500, which have been around 100% per annum (see Coval and Shumway (2001)).

Furthermore, average call returns appear to support theoretical predictions, in the sense that they are strictly increasing across strike price space. The average BS betas for the four groups are also increasing as the strike increases, indicating that options which exhibit a higher correlation with the market tend to earn higher returns on average than options which are more weakly correlated with the market. For instance, β_{BS} ranges from 15.87 for the low-strike group to 44.42 for the high-strike one.

Another interesting finding is the monotonic relationship between the variability and the skewness of call returns, and the strike group. Call returns are found to be generally positively skewed, with the exception of the negative skewness in the low-strike group 1. In addition to being mostly positive, skewness across the strike groups is found to be increasing across the group number, such that deep ITM calls exhibit the lowest skewness while deep OTM ones exhibit the highest skewness. With respect to the volatility of option returns, calls in the lowest-strike category tend to earn returns that exhibit less variability, based on the standard error of the distribution, while returns of higher-strike calls are more volatile. Finally, the average number of traded contracts per group appears to be increasing in the group number for groups 1 to 3, since the most ITM calls have the fewest traded contracts and group 3 has the highest number of contracts per option. This monotonic relationship, though, does not hold for the most OTM calls, which appear to have less traded contracts than the options in group 3. Overall, call returns in the Greek options market are substantially higher than the returns of calls in developed markets. Conforming to theoretical predictions, uncovered positions in calls have earned returns in excess of the underlying asset and increasing in the strike price.

With respect to put options, the initial dataset consisted of 9,212 put observations for the time-period running from January 2004 to January 2007. With p_t denoting the closing price at day t of a put option with strike K and time-to-maturity T, the daily arithmetic return R_p of the option is calculated as:

$$R_p = \frac{p_{t+1} - p_t}{p_t} \quad (4)$$

Whenever a specific put does not have trade prices for two consecutive days or the put price remains the same over this window, the corresponding put return is treated as a missing observation. This results in a reduced dataset of 6,482 put returns. Similarly to the methodology used for call options, puts are assigned into four strike groups, using the BS delta to proxy for the option's moneyness. Panel A of Table 2 presents the cutoff points, with strike price increasing as the group number increases. This means that group 1 includes put options with the lowest strikes while group 4 includes puts with the highest strikes. However, contrary to calls, moneyness for put options moves in the opposite direction, with group 1 representing deep OTM puts and group 4 representing deep ITM ones.

Panel C of Table 2 reports the mean, standard error and skewness of put returns across the four strike groups. T-statistics of the average return being different from zero (in brackets) are also reported, as well as the average put beta and average number of traded contracts, while the BS beta of a put option is estimated using the following equation:

$$\beta_p = -\frac{S_0}{c} N[-\frac{\ln(\frac{S_0}{K}) + (r - q + \frac{\sigma^2}{2})T}{\sigma\sqrt{T}}] \quad (5)$$

As can be seen from the Table, daily arithmetic put returns in the Greek market have been highly negative and statistically significant for all strike groups, ranging from a minimum of -5.37% for low-strike, deep OTM puts, to a maximum of -3.61% for high-strike, deep ITM ones. Not surprisingly, puts with higher betas (in absolute terms) tend to earn more negative returns than their lower beta counterparts. This makes intuitive sense since puts with high (absolute) betas have relatively low strike prices, representing more levered positions in the underlying asset, and are, thus, perceived as more risky investments.

Panel C of Table 2 appears to confirm the theoretical prediction of put returns increasing in strike price space. As options move from the low-strike puts in group 1 to the high-strike ones in group 4, average returns increase by becoming less negative. Moreover, the volatility and skewness of returns is monotonically decreasing in strike price, with skewness remaining positive in all categories. For instance, deep OTM puts in the lowest strike group 1 exhibit the highest standard error (0.47) and skewness (1.70), while high-strike, deep ITM puts in group 4 have returns that are much less volatile (st. error 0.20) and skewed (0.64). Finally, unlike calls which are more liquid the closest they get to being ATM, put options appear to be more heavily traded when they are OTM. Puts in group 2 are the most liquid, in terms of average traded contracts, with group 1 being the second most liquid category. Deep ITM puts are much less liquid, with average trading volume being 3 or 4 times lower than that of the first two strike groups of OTM puts.

Overall, put options in the Greek market earn negative returns which are decreasing (in absolute terms) as strike price increases, in line with theoretical predictions as well as with empirical findings from other options markets. The returns, however, of short positions in Greek puts are significantly larger than those documented in developed markets, ranging from 903% to 1,343% per year, depending on the strike price. This implies an asymmetric relationship between returns of calls and puts of similar moneyness, since average put losses significantly outweigh average gains from their corresponding calls.

4. Evaluating Market Efficiency

Trading options in the ADEX appears to offer very high returns, especially in the case of shorting OTM puts. Although returns in the Greek options market are significantly higher than those traditionally documented in developed markets, this difference in magnitude cannot provide a direct measure of the market's efficiency before the underlying risks are taken into consideration. In order to evaluate the efficiency of the ADEX and to compare it with the developed US and UK markets, three commonly used methodologies are employed. More specifically, the relative efficiency of the Greek market is measured based on the difference between actual option returns and those predicted by the theoretical Black and Scholes (1973) pricing model, the magnitude and significance of CAPM alphas, and the significance of returns of delta and delta/vega neutral straddles.

4.1. Deviations of Actual Returns from Theoretical Returns

This subsection examines whether observed returns of calls and puts are consistent with option pricing models such as the Black and Scholes (1973) option pricing formula. In order to analyze this relationship, actual market prices are substituted with theoretical prices, derived from the above model, and option returns are re-estimated.

The Black and Scholes option pricing formula has been one of the most commonly used methods for pricing options in the literature. Within this framework, the theoretical BS price of a European-style option is given as a function of the spot price S_0 of the underlying index, the option's strike price K, the risk-free rate r, the time-to-maturity T, the standard deviation σ of the underlying, and the dividend yield q. Within the BS framework, the theoretical prices C_{BS} and P_{BS} of a European call and a put, respectively, are given by:

$$C_{BS} = S_0 e^{-qT} N(d_1) - K e^{-rT} N(d_2) \tag{6}$$

$$P_{BS} = K e^{-rT} N(-d_2) - S_0 e^{-qT} N(-d_1) \tag{7}$$

with

$$d_1 = \frac{\ln(\frac{S_0}{K}) + (r - q + \frac{\sigma^2}{2})T}{\sigma\sqrt{T}}$$

$$d_2 = d_1 - \sigma\sqrt{T}$$

For each option in the dataset, its theoretical BS price is calculated by plugging in the vector of six parameters in the equations above. Although most of them are readily observable, estimating the standard deviation σ of the underlying for the period until the option expires is a less straightforward task. For instance, a potential proxy for σ can be obtained through a model based on historical levels of realized volatility (an example of this would be the volatility forecast of a GARCH specification). However, an estimate of implied volatility is used as a proxy for the future standard deviation of the underlying's returns instead, since it is generally considered to be a more appropriate proxy in the context of theoretical option prices. More specifically, despite the fact that historically fitted models have been shown to predict future volatility accurately compared to option implied volatilities in certain cases, the former fail to account for the observed volatility premium (i.e. the widely documented difference between volatility inferred from option prices and its subsequent realization). Consequently, in this study, the parameter σ in the BS formula is treated as a proxy for investors' risk-neutral expectations of future volatility levels when pricing options, rather than an accurate prediction of its real-world future realization.

The implied volatility for a set of options trading on a given day is obtained by minimizing the sum of squared errors between market prices and theoretical BS prices with respect to σ. Let $Q_{i,M}$ denote the market price of a given call or put option and $Q_{i,BS}$ the theoretical BS price of that option. The following minimization across the available strikes K is performed for the nearest as well as for the second nearest expiration, and it provides an estimate of the implied volatility $\hat{\sigma}$ that is used in computing theoretical returns.

$$SSE = \min_{\hat{\sigma}} \sum_{i=1}^{K} [(Q_{i,M}(S, K_i) - Q_{i,BS}(S, K_i, \hat{\sigma}))^2] \tag{8}$$

Table 3 reports summary statistics for the returns of calls and puts, respectively, under theoretical BS prices. It can be easily seen from Panel A of Table 3 that theoretical BS call returns are comparable to observed returns, implying that the Black and Scholes formula produces option prices that are systematically close to actual market prices. Average betas, as well as the other statistics remain at similar levels, while the monotonic positive relationship between strike and returns still holds, with low-strike calls earning the lowest returns and high-strike calls earning the highest.

With respect to put options, results in Panel B of Table 3 indicate that, under the BS framework, mispricing is even less of an issue for puts relative to calls, in contrast to previous empirical papers which argue that mispricing in developed markets is mostly evident for put contracts. More specifically, theoretical BS put returns are slightly higher (more negative) than realized returns across all moneyness groups, indicating that, although writing puts offers very high returns in absolute terms, this is not necessarily inconsistent even with the simple BS model. For instance, writing deep OTM puts is typically referred to as an example of a trading strategy that offers abnormally high returns relative to its risk characteristics. However, the results suggest that although writing deep OTM puts in group 1 earns the admittedly high average return of 5.05% per day, the relatively simple BS assumptions predict even higher daily returns (6.68% daily).

4.2. Risk-Adjusted Returns

Since options are risky financial assets, standard asset pricing theory predicts that they should earn returns that are commensurate with their systematic risk. The *Capital Asset Pricing Model*, in particular, expresses the expected excess return of an option as a linear function of the option's beta and the expected market risk-premium:

$$E[R_i - R_f] = \beta_i E[R_m - R_f] \quad (9)$$

where R_i is the return of the ith option, β_i is the option's beta, R_m is the return of the FTSE/ASE-20, R_f is the risk-free rate, and $E[\cdot]$ is an expectation operator. Within the CAPM framework, calls that exhibit a higher covariance with the index, as measured by the call's BS beta, are expected to earn on average higher returns than their lower covariance counterparts. Put options, on the other hand, were shown to have negative betas, which are decreasing in absolute terms as strike price increases. Therefore, puts with more negative betas are expected to earn more negative returns than their lower (in absolute magnitude) beta counterparts.

In order to test the above theoretical predictions, equation (10) is regressed separately for calls and for puts across different strike groups

$$R_i - R_f = \eta_0 + \eta_1 \beta_i (R_m - R_f) + \varepsilon \quad (10)$$

where η_0 is the intercept term, η_1 is the risk-premium earned by the ith option, and ε is a random error term. Under the CAPM's null hypothesis for this test, the intercept should be statistically indistinguishable from zero (η_0=0) and the risk-premium should be equal to unity (η_1=1), for both calls and puts.

Table 4 reports the regression results for all strike groups of calls and puts. As can be seen from Panel A, the risk-premium of calls, measured as the slope coefficient η_1 of (10), is significantly positive in all cases, ranging from 0.86 to 1.03. More importantly, risk-premia are found to be statistically indistinguishable from one for ITM calls in groups 1 and 2, and very close to (albeit statistically different from) the theoretical value of unity for OTM calls in groups 3 and 4. In addition to estimated risk-premia lying close to unity, mostly insignificant intercepts provide further evidence of the CAPM's ability to explain observed call returns. For instance, η_0 is found to be statistically insignificant for ITM as well as for deep OTM calls (groups 1, 2 and 4), with only OTM contracts in group 3 having a significant η_0. Finally, it should be noted that the explanatory power of the model, measured by the Adjusted R^2, is relatively high, ranging from a minimum of 65% (deep OTM) to a maximum of 90% (deep ITM), indicating that the combination of call betas and the market risk-premium can explain a relatively high proportion of the variance of call returns.

Panel B of Table 4 reports regressions results across all put sub-samples. Risk-premia are statistically indistinguishable from unity for ITM puts (groups 3 and 4) and only marginally different from one in the case of OTM puts in group 2. The η_1 coefficient for deep OTM puts in group 1 is the only exception, since it is found to be significantly lower than its theoretical value of one. Regarding the intercept terms, η_0 is significantly negative in all cases. Proxied by the regression's intercept, put risk-adjusted returns are monotonically increasing (decreasing in absolute terms) across strikes, with deep OTM puts losing 2.85% and deep ITM ones losing 1.18% on a daily basis. Finally, the Adjusted R^2 is again relatively high, exceeding 89% for deep ITM contracts, indicating that the CAPM's beta has significant explanatory power over put returns.

Overall, options in the Greek market appear to be positively related with BS betas, when controlling for the market risk-premium. In the majority of cases, the slope coefficients of the CAPM regressions are statistically indistinguishable from the theoretical value of unity for both call and put options, while intercepts are equal to zero for calls. The above results seem to imply that the linear risk-return relationship of the standard, single-factor CAPM goes some way explaining observed option returns in the Greek market. However, significantly negative intercepts in put regressions somewhat complicate the analysis, implying that other risk-factors are potentially being priced in addition to the options' systematic variance.

In the mean-variance world of the CAPM, investors are compensated only for bearing the systematic risk stemming from asset returns' covariance with market returns. Recent options literature, though, documents an additional risk-factor being priced in the options market, namely changes in the underlying's volatility. Since options are more valuable when volatility is high, volatility changes should be directly related to option prices and, therefore, option returns. In order to account for this additional risk-factor, the extended version of the CAPM, described in (11) is tested:

$$R_i - R_f = \eta_0 + \eta_1 \beta_i (R_m - R_f) + \eta_2 vega_i \Delta\sigma_{imp} \frac{1}{Q_i} + \varepsilon \tag{11}$$

where $vega_i$ is the i[th] option's BS vega, $\Delta\sigma_{imp}$ is the daily change in the FTSE/ASE-20 implied volatility, Q_i is the market price of option i, and η_2 is the corresponding volatility risk-premium. The option's vega is defined as the first derivative of the option's price Q with respect to the underlying's volatility σ ($\partial Q/\partial\sigma$), and it measures the sensitivity of the option's price to changes in σ. It should also be noted that, in the context of the above regression specification, σ is defined as the ATM implied volatility. Due to the use of market prices of ATM calls in extracting an estimate of one of the explanatory variables in (11), daily returns of ATM calls are excluded from the dependent variable vector $[R_i - R_f]$ since they would provide a near-perfect fit in the regression and would, therefore, introduce some bias into the estimated coefficients.[3]

Similarly to the standard CAPM's regression in (10), the null hypothesis for the extended model in (11) is that both risk-premia are equal to unity, i.e. $\eta_1 = \eta_2 = 1$. Panels A and B of Table 5 report regression results of the extended CAPM for calls and puts, respectively. With respect to call options, it appears that introducing $\Delta\sigma_{imp}$ in the regression does not significantly alter the estimated intercepts η_0 or the slope coefficients η_1. Consistent with theoretical predictions, calls are found to earn a significant volatility risk-premium, with η_2 being significantly positive for all strike groups. Moreover, the volatility risk-premium is statistically indistinguishable from unity in groups 2 and 4, and relatively high, albeit lower than 1, in group 3. The only problematic result in the calls sub-sample is the estimated η_2 for deep ITM calls in group 2, which is found to be significantly higher than its theoretical value.

Results for put options are not as straightforward at those for calls. Although the slope coefficients η_1 are still very close to unity, intercept terms remain significantly negative, indicating put overpricing. Furthermore, the risk-premium for volatility changes

[3] The ATM implied volatility is estimated by substituting Q_{BS} with the actual market price of the nearest-to-the-money call in the Black and Scholes formula, and then solving for the volatility parameter σ.

deviates from its predicted value of unity across all strike groups. However, η_2 remains positive for all groups, confirming the theoretical prediction of changes in volatility being positively related to changes in the value of the option. Finally, it should be noted that the correlation between the two main regressors in (11), namely between $[R_m - R_f]$ and $\Delta\sigma_{imp}$, is -0.10 over the sample period. Although a negative correlation between the market risk-premium and changes in index volatility is to be expected since it is a well-documented empirical finding that index volatility rises following a negative index return compared to a positive return of similar magnitude, it could be argued that the low level of dependence between the two explanatory variables suggests that the regression results are relatively free of collinearity concerns.

4.3. Straddles

Delta-neutral portfolios are formed by combining long positions in calls and puts of the same moneyness, with moneyness defined as $(1 - K_c/e^{rT}S_0)$ and $(K_p/e^{rT}S_0 - 1)$ for calls and for puts, respectively. In order to estimate the weights w_c and w_p of the portfolio's value that correspond to investing in calls and puts, respectively, the following two equations are simultaneously solved. The first equation stems from the straddle's delta ($delta_s$), which is a linear combination of individual options' deltas ($delta_c$ and $delta_p$), being equal to zero, while the second one reflects the fact that the possible combinations are restricted to only long positions in same-moneyness options. Obviously, since BS deltas are by definition positive for call options and negative for put options, there is only one possible combination of weights that satisfies both of these conditions.

$$\begin{gathered} delta_s = w_c delta_c + w_p delta_p = 0 \\ w_c + w_p = 1 \end{gathered} \tag{12}$$

Since both beta and delta are measures of an option's sensitivity to changes in the value of the market index, they are effectively proxies for the same type of market risk. In other words, delta-neutral portfolios of index options can also be considered as beta-neutral positions. In the CAPM world, systematic variance, proxied by a security's beta, is the only source of risk that is priced in the market. Therefore, a delta-neutral index straddle has zero exposure to systematic risk, and should earn the risk-free rate of return.

Panel A of Table 6 presents descriptive statistics for the daily returns of delta-neutral straddles across the four moneyness groups. These groups are formed such that moneyness increases as options move from the first group to the fourth one, with group 1 including long positions in deep OTM options and group 4 including deep ITM ones. As can be seen from the Table, delta-neutral portfolios are found to earn relatively low returns which are increasing across moneyness. More specifically, deep OTM straddles lose around 3 basis points, while deep ITM portfolios earn 38 basis points on a daily basis, with average returns increasing as we move from group 1 to group 4. More importantly, though, straddle returns are statistically indistinguishable from the risk-free rate for all moneyness groups, confirming theoretical predictions that option combinations that are immune to changes in the value of the underlying should be considered as risk-free and, therefore, have returns equal to the daily risk-free rate. In addition, straddle returns exhibit low volatility (roughly 1% across all groups), slightly negative skewness and negative excess kurtosis.

Overall, results from examining delta-neutral straddles provide some support for the validity of the Black-Scholes model as well as the CAPM in the Greek options market. However, although the theoretical prediction that portfolios with zero delta-risk should offer returns that are equal to the risk-free rate is empirically confirmed, it should be noted that delta-neutral straddles are potentially exposed to other sources of risk. An additional, widely recognised source of risk in the options market refers to changes in the level of the underlying's volatility until the option's expiration, and it is measured by the option's vega ($\partial Q/\partial \sigma$). Intuitively, since the value of an option is positively related to the future volatility σ of the underlying, changes in volatility will affect the option's price and, consequently its expected return.

The methodology of Liu (2007) is followed to create delta and vega neutral portfolios by combining long positions in the underlying and in puts with short positions in calls of similar moneyness. More specifically, on each calendar day, delta and vega neutral straddles are formed by buying one unit of the index and w_c units of the call, while selling w_p units of the put, the moneyness of which is the closest to the call's moneyness. In order for the straddle's exposure to delta and vega risk to be zero, the following conditions must be met:

$$delta_s = 1 + w_c delta_c + w_p delta_p = 0$$
$$vega_s = w_c vega_c + w_p vega_p = 0 \tag{13}$$

Obviously, the delta of the underlying is equal to one and its vega is zero. Also, calls have positive deltas and puts have negative ones, but both options have positive vegas. Therefore, w_p must be positive and w_c negative to ensure that $delta_s = vega_s = 0$. In total, 6,562 delta and vega neutral straddles are formed following the previously described methodology. The average difference in moneyness between calls and puts is 0.0126, with 69% of straddles including options with moneyness levels that differ by a maximum of 0.01. Straddles are then assigned to four groups based on their moneyness, with group 1 including combinations of options that are deep OTM and group 4 including deep ITM options. Panel B of Table 6 presents summary statistics for the daily returns of delta and vega neutral straddles, across the four moneyness groups.

The null hypothesis is that straddles with zero risk-exposure to market movements and to volatility changes must earn the risk-free rate. Indeed, it is found that daily straddle returns for all moneyness groups are statistically indistinguishable from zero, as well from the daily risk-free rate. Average returns are increasing across moneyness, with deep OTM straddles earning negative returns (0.09%) and deep ITM straddles earning the highest positive returns (0.35%).

Although these results are in line with theoretical predictions, it should be noted that this methodology suffers from a relatively well known limitation. More specifically, BS delta and vega are measures of local sensitivity, referring to expected changes in the option's price for a marginal change in the index's level and volatility, respectively. Therefore, straddles created in the above way will be delta and vega neutral only instantaneously and with respect to very small changes in the FTSE/ASE-20 and its volatility. In order to ensure near-zero risk-exposure, straddles have to be rebalanced regularly, at the obvious expense of higher transaction costs. For instance, Liu (2007) argues that such portfolios '… start off delta and vega neutral, but the neutrality is unlikely to hold in one week's time'. In this study, straddle returns are examined at a daily frequency in an attempt to minimise the impact of changing delta/vega across our holding period and it is found that, even without considering the substantially higher transaction costs, the null hypothesis of straddles earning the risk-free rate cannot be rejected.

In order to determine whether straddles are indeed delta and vega neutral, portfolio returns are regressed against the future changes in the underlying FTSE/ASE-20 and the future changes in implied volatility that corresponds to the period until the options' expiration, using equation (14).

$$E[R_s] = \eta_0 + \eta_1 E[R_m] + \eta_2 \Delta\sigma_{imp} + \varepsilon \tag{14}$$

where R_s is the daily straddle return, and $\Delta\sigma_{imp}$ is the daily change in BS implied volatility. Under the assumption of delta and vega neutrality, the null hypothesis is that $\eta_0 = \eta_1 = \eta_2 = 0$, and Panel C of Table 6 reports the regression results across the four moneyness groups.

The first thing to notice is that η_1 is insignificant for groups 2 to 4 and borderline insignificant for deep OTM options in group 1. In effect, straddles across all moneyness categories remain approximately delta-neutral during the trading day of interest and are, thus, not affected by changes in the level of the underlying index. However, although delta neutrality seems to hold, not all straddle types are vega neutral. The vega-neutrality coefficients η_2 for OTM groups 1 and 2 are marginally insignificant with t-stats equal to 1.62 and 1.63, respectively, while ITM straddles in groups 3 and 4 have significant values of η_2 (t-stats are 2.07 and 3.23, respectively).

In summary, delta and vega neutral straddles appear to earn returns that are statistically indistinguishable from the daily risk-free rate, irrespective of their moneyness. This finding supports the theoretical prediction that positions that are immune to the two most common sources of risk in the options market (namely changes in the level of the underlying and changes in the underlying's volatility) should earn the risk-free rate. In addition, although straddle returns have been calculated using closing option prices, it should be mentioned that the results remain unchanged even when last trade prices are used instead. However, when interpreting these results, one should have in mind that, despite the fact that all straddles appear to be delta-neutral in the one-day period, ITM positions are subject to some vega risk.

5. Comparison with Findings from Developed Markets

In order to put the above findings into context, option returns in the Greek market are compared to those observed in developed markets. Although the high magnitude of returns to individual calls and puts written on the FTSE/ASE-20 seems puzzling at a first glance, compared to option returns written on the S&P 500 or the FTSE100, it is concluded that they are not necessarily inconsistent with traditional option pricing models. Furthermore, returns of various trading strategies, such as delta and vega neutral straddles, indicate that risk-return theoretical predictions are strongly supported in the Greek market, similarly to its UK and US counterparts.

First, call options in developed markets have been found to earn relatively high average returns. For instance, Coval and Shumway (2001) focus on options written on the S&P 500 index from January 1986 to October 1995, and report weekly call returns ranging from 1.48% for deep ITM calls to 5.13% for deep OTM ones. Supporting theoretical predictions, these returns are in excess of the underlying's rate of appreciation for the same time period and monotonically increasing as strike price increases. On the other hand, Driessen and Maenhout (2006) examine returns of options written on the FTSE100 from April 1992 to June 2001, and find that, in contrast to S&P options, returns of UK calls have been significantly lower. Average weekly returns of short-term FTSE100 calls range from 0.28% for ATM options to 0.04% for deep OTM ones, while the theoretical monotonic relationship between returns and moneyness is not supported. As was discussed in Section 3, returns of calls written on the FTSE/ASE-20 have been significantly higher than those previously documented in the US and the UK markets. More specifically, deep ITM calls earn 7.05% per week, while deep OTM ones earn around 16.70% per week, with call returns strictly increasing across strikes. As has already been noted, though, the fact that average returns of Greek call options are four times higher compared to the US, and more than fifty times the magnitude of UK call returns of similar moneyness, might be at least partially explained by the rapid growth of the underlying FTSE/ASE-20 during the 2004-2007 sample period.

A well documented finding in the related literature refers to the fact that put options tend to earn on average higher returns (in absolute terms) than calls of similar moneyness. This asymmetry is highlighted by Coval and Shumway (2001) for the US market, with puts written on the S& 500 losing between -14.56% for deep OTM puts to -6.16% for deep ITM ones. Confirming theoretical predictions, these put returns are below the risk-free rate, as well as increasing (becoming less negative) as strike price increases (see also Bondarenko (2003) and Broadie, Chernov and Johannes (2009) for returns of S&P 500 puts within different sample periods). With respect to the UK, Driessen and Maenhout (2006) find that puts written on the FTSE100 have highly negative returns, ranging from -6.86% for short-term, deep OTM options to -4.58% per week for deep ITM ones. In contrast to FTSE100 calls, puts support the theoretical prediction of strictly increasing returns (decreasing in magnitude) across moneyness, while the difference between put returns in the US and in the UK is significantly smaller than the one documented for calls. Section 3 reports that puts written on the FTSE/ASE-20 lose between -26.85% (deep OTM) and -18.05% (deep ITM) on a weekly basis, while, similarly to results for developed markets, put returns in Greece become less negative as strike price increases. Overall, writing put options on the FTSE/ASE-20 results in higher average returns compared to same-moneyness S&P 500 or FTSE100 puts, with put returns in the Greek market being closer to results from the US rather than the UK options market.

The fact that options are found to consistently earn very high returns, with the most extreme case typically being returns to writing deep OTM puts, has led some authors to describe options returns as 'puzzling'. However, Broadie, Chernov and Johannes (2009) argue that, unless they are compared to a reasonable benchmark, it is difficult to conclude whether high option returns constitute in fact a paradox. Instead of examining the absolute magnitude of option returns, they propose comparing them with returns calculated by theoretical option pricing models in order to determine whether realized returns differ significantly from what standard options theory predicts. Following this line of thought, Coval and Shumway (2001) estimate theoretical US call returns under the Black and Scholes/CAPM framework and find that they are even higher than those observed in the market, concluding that, if anything, actual US call returns are in fact lower than what would be expected based on their market risk. For instance, theoretical weekly returns for ATM calls written on the S&P 500 are around 4%, compared to realized returns of only 2% per week. This study shows that theoretical call returns in the Greek market are only slightly lower than observed returns, and that this difference is likely to be economically insignificant. Although this methodology does not imply that the Black and Scholes is an exact option pricing model or that the CAPM assumptions necessarily hold in the Greek market, comparing observed returns with a theoretically reasonable benchmark goes some way rejecting a 'naïve' conclusion that high Greek call returns are particularly puzzling. In addition, it should be noted that alternative theoretical models that account for stochastic volatility and jump-risk, such as Heston (1993) and Merton's (1976) models, might go a step further in explaining observed call returns.

In contrast to previous empirical findings, it is found that put returns in the Greek market are more easily explainable by simple theoretical models compared to calls. Broadie, Chernov and Johannes (2009) show that the significantly negative returns of S&P 500 puts are not inconsistent even with the basic Black and Scholes option pricing model, since theoretical put returns are even more negative than actual returns. Applying this methodology to puts written on the FTSE/ASE-20 yields similar results, with BS put returns consistently found to be somewhat higher (more negative) than observed returns.

In addition to comparing realized returns with model-based ones, the significance of observed returns can also be examined by focusing on risk-adjusted estimates, proxied by the intercepts of CAPM regressions on option returns. Under standard CAPM theory, alphas are expected to be statistically indistinguishable from zero, since expected returns are only compensating investors for bearing systematic risk. Focusing on the Greek market, this theoretical prediction is supported in the case of calls which have insignificant alphas. Put returns appear to be relatively puzzling, since after controlling for their systematic risk, intercepts remain statistically significant across all moneyness categories. These results are similar to Broadie, Chernov and Johannes' (2009) examination of risk-adjusted returns of puts written on the S&P500, who report statistically significant CAPM alphas, ranging from -51.72% for OTM puts to -24.60 for deep ITM ones (on a monthly basis). Also note that, these results remain unchanged, even after incorporating changes in the underlying's volatility as an additional explanatory factor in the extended CAPM, indicating that additional factors are potentially priced in the Greek market, a conclusion that is consistent with the explanation proposed by Broadie, Chernov and Johannes (2009) for the US market.

After examining individual option returns, the focus moves to returns of option portfolios. First, a trading strategy that has received a fair amount of attention in the related literature explores returns of delta-neutral combinations of options which, under the CAPM's assumptions, should be equal to the risk-free rate. The intuition behind this methodology is that, since these straddles are formed such that they are essentially zero-delta (or, equivalently, zero-beta), they have no exposure to risk from market movements and, consequently, should earn the risk-free rate. However, Coval and Shumway (2001) as well as Broadie, Chernov and Johannes (2009) report that delta-neutral straddles which are formed by combining calls and puts written on the S&P 500 have, in fact, statistically significant returns in their respective sample periods. For instance, Coval and Shumway (2001) find that ATM straddles lose around 3% on a weekly basis, with straddle returns generally increasing (becoming less negative) as strike price increases. In contrast, zero-delta straddles in Greece are found to have insignificant returns, irrespective of their moneyness, indicating that the CAPM's market-risk alone goes some way into explaining the return characteristics of options combinations.

It has been suggested that the significant returns of delta-neutral straddles in developed markets are due to the fact that, although these straddles are theoretically immune to changes in the value of the underlying, they might still be exposed to other sources of risk. The attention that volatility risk has received in recent studies prompts Liu (2007) to focus on delta and vega neutral straddles, combining long positions in the underlying and a put with a short position in a call of similar moneyness. Since these straddles have zero exposure to the two most commonly accepted sources of risk in the options market, namely changes in the value of the underlying as well as changes in the underlying's volatility, they are expected to earn the risk-free rate. However, Liu (2007) examines a sample of options written on the FTSE100 from January 1996 to April 2000, and finds that, while weekly returns of delta and vega neutral straddles are insignificant for ATM and ITM combinations, OTM and deep OTM straddles have significantly negative returns. Moreover, she argues that one potential explanation for the above mentioned results might be that, since delta and vega are estimated as local sensitivities, the straddles' neutrality is unlikely to hold across her return-estimation period of one week. As was discussed in Section 4.3, delta and vega neutral straddles on the FTSE/ASE-20 have returns that are slightly negative and increasing across strikes. More importantly, though, straddle returns across all moneyness levels are statistically indistinguishable from the risk-free rate, supporting theoretical predictions.

6. Conclusion

This paper has examined the efficiency of the emerging market of the Athens Derivatives Exchange compared to developed options markets, from the perspective of returns that are commensurate with underlying risks. It is shown that returns of individual options in Greece are not inconsistent with empirical findings from developed options markets, such as the US and the UK. In addition, returns of delta and delta/vega neutral straddles are found to be statistically indistinguishable from the risk-free rate, implying that returns of these trading strategies are in line with theoretical predictions, with p-values even higher than those documented in traditional, developed markets.

These results appear to reject the hypothesis of ADEX exhibiting a lower level of efficiency, attributed to the relatively high transaction costs and illiquid trading in the Greek options market, compared to the US. Santa-Clara and Saretto (2009) document a potential mispricing in S&P options that results in various option strategies earning abnormally high returns relative to their risk. However, these profit opportunities are allowed to persist instead of being arbitraged away due to the relatively high bid-ask spread, as well as the strict margin requirements in the US market. Following this line of thought, one might expect that the Greek market would offer a greater scope for options mispricing, since exploiting these profit opportunities would be even more costly for a typical investor due to the significantly higher bid-ask spreads as well as to thinner trading.

In order to put the significant difference in trading costs between developed and emerging markets into context, one should consider that trading volume in Greece is dramatically lower than, for instance, the US. During 2006, slightly less than 600,000 FTSE/ASE-20 option contracts were traded in ADEX, while the respective volume for

S&P500 options traded in CBOE exceeded 104 million. In addition, the fees charged by the exchange for each transaction are higher in the Greek market, with ADEX charging market-makers around €0.20 per trade (depending on the option's moneyness) while CBOE charging around $0.20 per trade (depending on total contracts traded). [4]

However, the relative efficiency of ADEX cannot be rejected, since trading strategies do not appear to offer significant profit opportunities in this emerging options market, even without accounting for transaction costs. This seems to indicate that the Greek market exhibits a degree of efficiency comparable to that of developed markets, at least with respect to the absence of opportunities for abnormal profits in excess of the underlying risks.

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Table 1: Option Observations per Trading Day

	Calls	Puts
Mean	12.34	11.90
Median	12	12
Standard deviation	3.26	2.99
Minimum	5	5
Maximum	23	24

This Table presents descriptive statistics of the options dataset used. Calls and puts are tabulated separately.

Figure 1: Option Observations per Trading Day

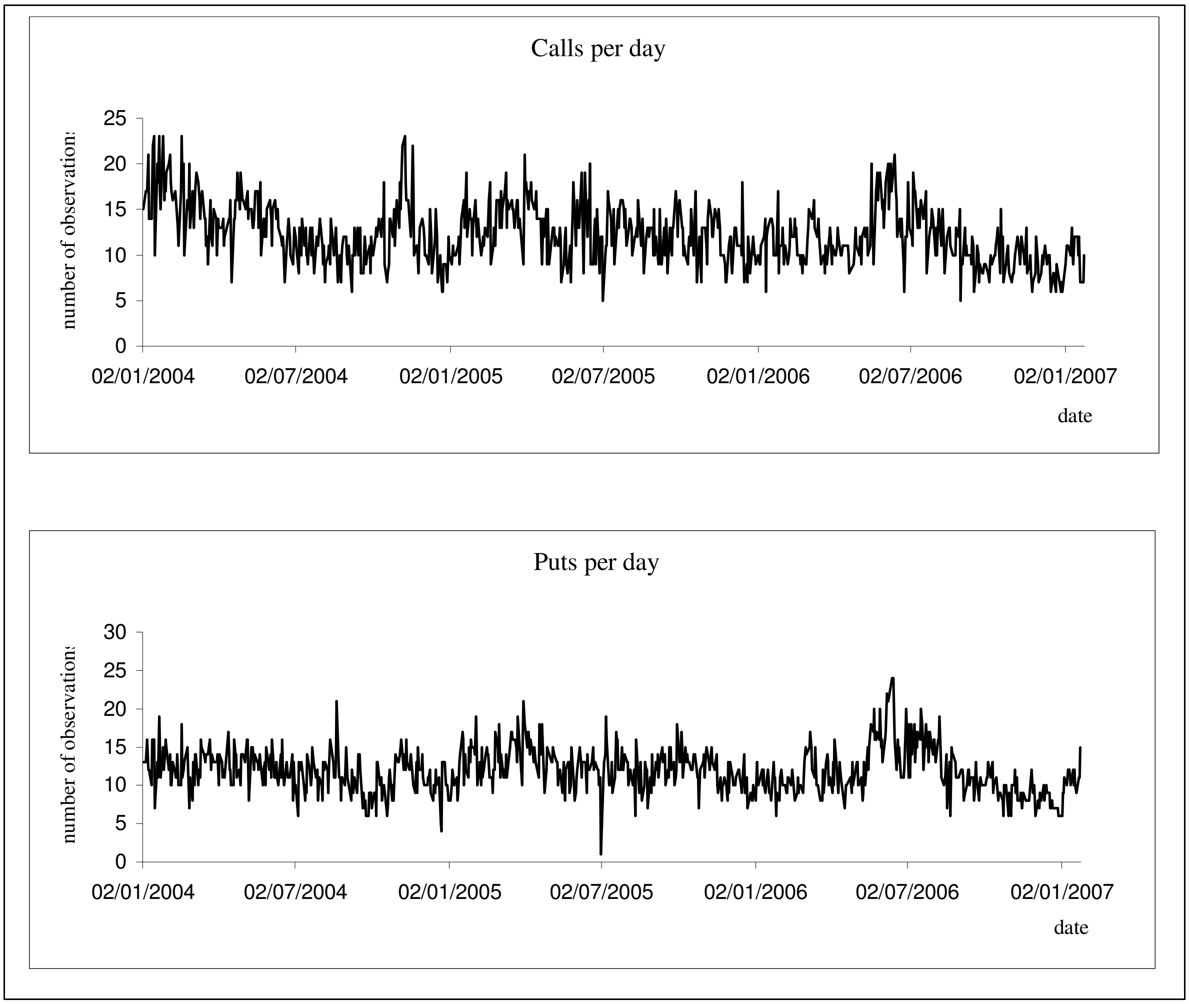

Figure 2: FTSE/ASE-20 Index

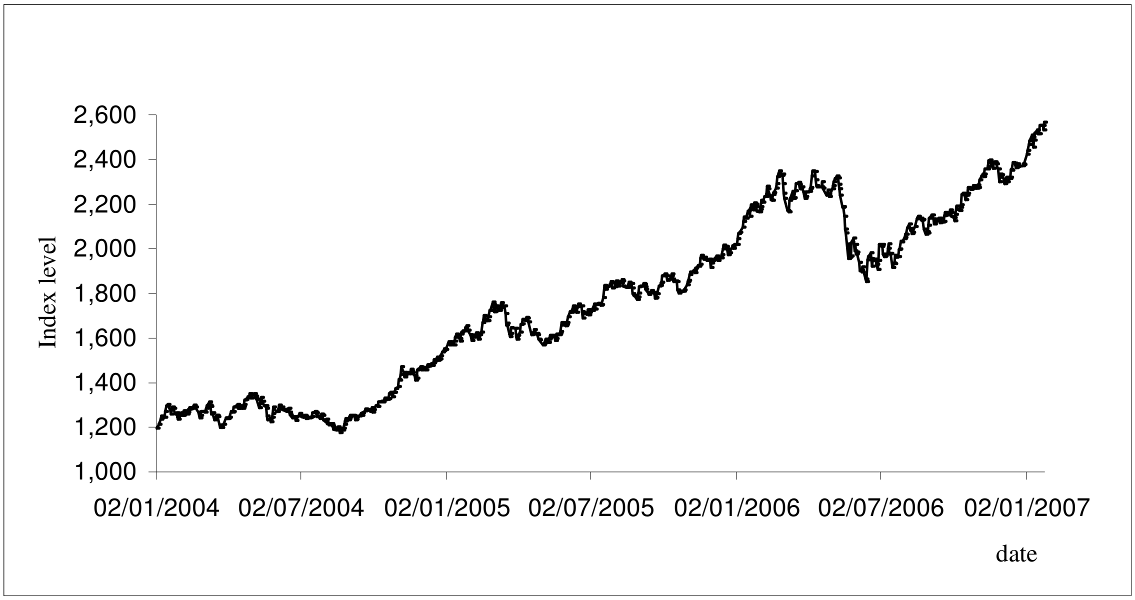

Table 2: Option Returns

Panel A: Strike Groups				
Strike Group	1	2	3	4
Calls	0.75 ≤ delta ≤ 1	0.5 ≤ delta < 0.75	0.25 ≤ delta < 0.5	0 ≤ delta < 0.25
Puts	-0.25 ≤ delta ≤ 0	-0.5 ≤ delta < -0.25	-0.75 ≤ delta <-0.5	-1 ≤ delta < -0.75
Panel B: Call Returns				
Beta	15.87	21.73	30.90	44.42
Volume	41.31	99.81	195.30	135.59
Average Return	0.0141	0.0159	0.0299	0.0334
t-stat	(1.90)	(3.07)	(4.95)	(1.50)
St. Dev	0.1721	0.2438	0.3540	0.5866
Skewness	-0.1030	0.2828	0.8311	1.1761
No. of Obs	538	2,195	3,453	697
Panel C: Put Returns				
Beta	-43.79	-27.67	-21.20	-16.74
Volume	113.78	132.66	74.19	29.97
Average Return	-0.0537	-0.0430	-0.0374	-0.0361
t-stat	(-4.90)	(-6.39)	(-6.18)	(-4.56)
St. Dev	0.4749	0.3248	0.2445	0.2003
Skewness	1.7023	1.6737	0.8470	0.6410
No. of Obs	1,875	2,331	1,635	640

Panel A tabulates the cutoff points for assigning calls and puts into moneyness bins based on the options' Black and Scholes deltas. Panels B and C present descriptive statistics of call and put returns, respectively.

Table 3: Option Returns under Theoretical Black and Scholes Prices

Strike Group	1	2	3	4
		Panel A: Calls		
Average Return	0.0126	0.0175	0.0236	0.0378
t-stat	(1.73)	(3.58)	(4.06)	(1.71)
St. Dev	0.1691	0.2292	0.3409	0.5846
Skewness	-0.10	0.36	0.65	1.16
No. of Obs	538	2,195	3,453	697
		Panel B: Puts		
Average Return	-0.0668	-0.0443	-0.0390	-0.0379
t-stat	(-6.63)	(-6.87)	(-6.68)	(-4.95)
St. Dev	0.4363	0.3113	0.2362	0.1940
Skewness	1.27	1.86	0.86	0.62
No. of Obs	1,875	2,331	1,635	640

This Table presents descriptive statistics of theoretical option returns under Black and Scholes prices. Panel A refers to calls while B refers to puts.

Table 4: Estimated Regression Coefficients of the CAPM

$$R_i - R_f = \eta_0 + \eta_1 \beta_i (R_m - R_f) + \varepsilon$$

Strike Group	1	2	3	4	All
			Panel A: Calls		
η_0	-0.0038	-0.0022	-0.0068	0.0112	-0.0026
t-stat (η_0=0)	(-1.65)	(-1.08)	(-2.39)	(0.86)	(-1.28)
η_1	1.0254	0.9858	0.9476	0.8595	0.9291
t-stat (η_1=0)	(70.22)	(112.55)	(110.20)	(35.91)	(144.91)
t-stat (η_1=1)	(1.74)	(-1.62)	(-6.09)	(-5.87)	(-11.06)
Adj. R^2	0.90	0.85	0.78	0.65	0.75
			Panel B: Puts		
η_0	-0.0285	-0.0143	-0.0115	-0.0118	-0.0184
t-stat (η_0=0)	(-4.90)	(-4.81)	(-4.89)	(-4.54)	(-8.70)
η_1	0.8627	0.9806	0.9931	0.9919	0.9158
t-stat (η_1=0)	(69.37)	(98.48)	(96.04)	(73.43)	(145.16)
t-stat (η_1=1)	(-11.04)	(-1.95)	(-0.67)	(-0.60)	(-13.35)
Adj. R^2	0.72	0.81	0.85	0.89	0.76

This Table tabulates the results from estimating the standard CAPM regression on the daily returns of options written on the FTSE/ASE-20 index. The sample period runs from January 2004 to January 2007. Results for calls and for puts are presented in Panels A and B, respectively.

Table 5: Estimated Regression Coefficients of the extended CAPM

$$R_t - R_f = \eta_0 + \eta_1 \beta_t [R_m - R_f] + \eta_2 vega_i \Delta\sigma_{imp} \frac{1}{Q_i} + \varepsilon$$

Strike Group	1	2	3	4	All
			Panel A: Calls		
η_0	-0.0039	-0.0023	-0.0075	0.0038	-0.0038
t-stat (η_0=0)	(-1.77)	(-1.24)	(-2.86)	(0.31)	(-2.00)
η_1	1.0152	0.9979	0.9623	0.9023	0.9496
t-stat (η_1=0)	(72.97)	(121.56)	(120.68)	(40.81)	(159.71)
t-stat (η_1=1)	(1.09)	(-0.26)	(-4.72)	(-4.42)	(-8.48)
η_2	6.6113	0.9552	0.6889	1.0664	0.8197
t-stat (η_2=0)	(7.76)	(17.92)	(24.20)	(12.02)	(34.71)
t-stat (η_2=1)	(6.59)	(-0.84)	(-10.93)	(0.75)	(-7.64)
Adj. R^2	0.91	0.87	0.81	0.71	0.79
corr(R_m-R_f, $\Delta\sigma_{imp}$)	-0.01	-0.10	-0.09	-0.23	-0.11
			Panel B: Puts		
η_0	-0.0298	-0.0160	-0.0120	-0.0112	-0.0194
t-stat (η_0=0)	(-5.20)	(-5.42)	(-5.14)	(-4.34)	(-9.28)
η_1	0.8661	0.9798	0.9920	0.9907	0.9175
t-stat (η_1=0)	(70.57)	(99.53)	(97.17)	(73.71)	(147.32)
t-stat (η_1=1)	(-10.91)	(-2.05)	(-0.78)	(-0.69)	(-13.24)
η_2	0.0865	0.0990	0.2007	0.3056	0.0924
t-stat (η_2=0)	(7.34)	(7.44)	(6.62)	(2.88)	(13.15)
t-stat (η_2=1)	(-77.56)	(-67.72)	(-26.36)	(-6.54)	(-129.09)
Adj. R^2	0.73	0.81	0.85	0.90	0.77
corr(R_m-R_f, $\Delta\sigma_{imp}$)	0.03	-0.04	-0.01	-0.01	-0.08

This Table tabulates the results from estimating the extended CAPM on the daily returns of options written on the FTSE/ASE-20 index. The estimated coefficients for calls and for puts are presented in Panels A and B, respectively. The last row of each Panel tabulates the correlation between the two dependant variables, namely between the excess return of the market and the daily change in implied volatility.

Table 6: Straddles

Moneyness Group	m < -0.03	-0.03 < m < 0	0 < m < 0.03	0.03 < m
Panel A: Summary Statistics for Delta Neutral Straddles				
Average	-0.0003	0.0013	0.0017	0.0038
St. Error	0.01	0.01	0.01	0.01
t-stat	(-0.03)	(0.13)	(0.18)	(0.44)
Median	0.0002	0.0014	0.0019	0.0040
Skewness	-0.17	-0.22	-0.18	-0.12
Kurtosis	1.22	1.11	1.09	0.14
No of Obs.	2,347	1,852	1,341	1,022
Panel B: Summary Statistics for Delta and Vega Neutral Straddles				
Average	-0.0009	0.0006	0.0009	0.0035
St. Error	0.02	0.01	0.01	0.02
t-stat	(-0.06)	(0.04)	(0.06)	(0.22)
Median	-0.0003	0.0010	0.0010	0.0038
Skewness	0.19	0.07	0.40	0.04
Kurtosis	2.85	1.70	2.00	0.60
No of Obs.	2,347	1,852	1,341	1,022
Panel C: Estimated Regression Coefficients $E[R_s] = \eta_0 + \eta_1 E[R_m] + \eta_2 \Delta\sigma_{imp} + \varepsilon$				
η_0	-0.003	-0.002	-0.004	-0.006
t-stat	(-2.17)	(-1.22)	(-1.64)	(-2.03)
η_1	0.050	-0.053	-0.005	-0.021
t-stat	(1.71)	(-1.58)	(-0.11)	(-0.39)
η_2	0.012	0.014	0.023	0.047
t-stat	(1.62)	(1.63)	(2.07)	(3.23)

Panels A and B present summary statistics of the daily returns of delta and delta/vega neutral straddles, respectively. Risk-neutral portfolios are constructed by combining same-moneyness calls and puts, and they are assigned into separate moneyness bins. Panel C tabulates the results of local sensitivity regressions that examine whether delta/vega neutral straddles retain risk-neutrality with respect to changes in the underlying's spot level and to changes in the underlying's implied volatility.