Information Asymmetry, Bid-Ask Spreads and Option Returns

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Abstract

This study analyses two different types of information in the stock market. The first type represents changes in information where informed investors know if the stock price will increase or decrease. The second type is less specific – the direction is unknown, but informed investors know that the stock price either will increase or decrease. The different flows of information are estimated within a GARCH framework, using shocks in Swedish OMX index returns and options strangle returns respectively. The results show significant conditional stock index and options strangle variance, although with notable differences. The stock index returns exhibit a high level of variance persistence and an asymmetric initial impact of shocks to variance. Options strangle returns have a relatively low variance persistence, but a higher (and more symmetric) initial impact of shocks. A time series regression of call and put option bid-ask spreads is performed, relating spreads to these two types of information, as well as other explanatory variables. The results show that option spreads are related to shocks in index and options strangle returns, as well as the conditional variance of the stock returns. Market makers appear to alter option bid-ask spreads primarily in response to unexpected shocks in stock index and options strangle returns – and to changes in the expected variance level of stock returns.

Keywords: Information asymmetry; option bid-ask spreads; time series; stock and options strangle shocks.

JEL classification: G10; G13; G14

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1. Introduction

In the market microstructure literature, there is extensive evidence of time varying bid-ask spreads in the stock market. Inventory models (see Stoll, 1978; Amihud and Mendelson, 1980, 1982; Ho and Stoll, 1981) motivate spreads as compensation to market makers for bearing the risk of an undesired inventory. Hence, if the inventory risk is time varying and varies across securities, spreads should fluctuate accordingly. In asymmetric information models (see Copeland and Galai, 1983; Glosten and Milgrom, 1985; Kyle, 1983; Easley and O'Hara, 1987; Back, 1993; Foster and Viswanathan, 1994), market makers have an informational disadvantage relative to informed investors. Therefore they have to quote spreads wide enough to compensate for losses arising from trading with informed investors. When informed investors are active spreads increase.

Most models are developed to explain the bid-ask spreads of stocks, but are relevant for derivatives as well. In addition to inventory and information asymmetry models, Cho and Engle (1999) propose a derivative hedge theory, where bid-ask spreads of options are related to the bid-ask spreads of the underlying securities, e.g. stocks or futures. If market makers can hedge options perfectly in the underlying security, they are not exposed to inventory or information asymmetry risk in the options market. Hence, option spreads should reflect inventory and information asymmetry costs in the underlying security.

According to inventory and asymmetric information models, the volatility of the underlying security determines options bid-ask spreads. First, higher volatility of the underlying security increases the risk of unhedged inventory options, and is therefore expected to result in wider option spreads. Second, following Copeland and Galai (1983), higher volatility in the underlying security may be the result of informed trading. If this is the case, informed investors might also be present in the options market, widening options spreads. The second argument is consistent with the derivative hedge theory. If informed trading causes higher volatility in the stock, it will produce wider stock spreads. Consequently, as the underlying stock market becomes less liquid, so does the options market, since it thereby is more costly to hedge the option positions.

Here information is divided into two categories. First, an informed investor may know whether the underlying security will increase or decrease tomorrow. The second category is less specific; the direction is unknown, but an informed investor knows that the underlying security either will increase or decrease. According to Cox and Rubinstein (1985), these two types of information can exist independently at the same time, causing information asymmetry. As recognised by Cherian and Jarrow (1998) and Nandi (1999), one type of investor may know whether the stock price will increase or decrease (often called a directional investor) and another type of investor might have information about the future volatility of the stock (volatility or un-directional investor). Supposedly, the first type of investor would trade stocks and the second options.[1]

This study decomposes the information into two types empirically. The first type represents unexpected directional information and is measured as stock index shocks, whereas the second type is measured as options strangle shocks. An options strangle position utilises un-directional information, i.e. information about the volatility of the underlying security until expiration. The two types of information shocks are estimated within an asymmetric GARCH(1,1) framework, allowing a dynamic formulation of the conditional stock index and options strangle variance. Following Engle and Ng (1993), news impact curves are presented for measuring the response of the conditional variance to new information, i.e. lagged shocks. Notably, the conditional options strangle variance can be viewed as a measure of volatility of volatility, as formulated by Nandi (1999).

The main purpose of this study is to perform a time series regression of option bid-ask spreads and to study the dynamic relationship between the spreads and the information shocks. In doing so, it is possible to investigate the relative importance of the two types of information, measured as shocks in index and strangle returns respectively, for determining the size of option spreads. Furthermore, it is also convenient to analyse whether option spreads are related to conditional variance in the GARCH framework or unexpected shocks.

[1] More specifically, when an investor is in possession of directional information, he/she can use the stock market, where the stock position has a positive or negative delta, depending on the information content. If the trader has un-directional information, he/she wishes to have a delta neutral position, but with a non-zero gamma or vega, which is exactly what an options strangle position constitutes.

This study contributes to previous research in several ways. First, the empirical decomposition of information into two different types, using GARCH specifications of stock and strangle returns, constitutes a new idea. Second, a time series regression analysis relating option spreads to these two types of information has never been conducted before.[2] Third, previous studies have concluded, theoretically and empirically, that the conditional stock index variance is important for options spreads. This study, however, is the first to investigate whether option spreads are more sensitive to the conditional stock index variance or corresponding shocks. Furthermore, the empirical analysis is conducted with data from the Swedish OMX stock index options market, presently one of the ten largest stock index options markets in the world. This data has never been used in a similar study before.

The results show significant conditional variance, according to the GARCH estimations, in OMX stock index returns and options strangle returns, although with notable differences. The index returns exhibit a high level of variance persistence, as observed in previous studies.[3] Also, there is significant evidence of asymmetry; negative stock index shocks have a larger impact on conditional stock index variance than positive shocks. The strangle returns appear to have relatively lower persistence in conditional variance, but a considerably higher initial impact of shocks to variance. Furthermore, there is no significant asymmetry; positive and negative options strangle shocks have a similar impact on conditional variance.

The time series regressions with call and put bid-ask spreads as dependent variables indicate significant relationships between the spreads and the index and options strangle shocks. For both calls and puts, the bid-ask spread is positively related to option strangle shocks. This is consistent with the idea that option spreads become wider (narrower) on days when there is a large unexpected increase (decrease) in volatility – when un-directional information is revealed through trading. Also, option bid-ask spreads are not significantly influenced by the conditional options strangle variance. Evidently, option spreads are related to unexpected strangle shocks, and not to the expected, conditional, variance. Using the alternative

[2] George and Longstaff (1993) as well as Cho and Engle (1999) examine the cross-sectional distribution of bid-ask spreads in the S&P 100 index options market. Chan et al. (1995), compare the intraday behaviour of spreads of CBOE equity options and NYSE stocks. Fahlenbrach and Sandås (2003) use panel data methods to analyse whether inventory risk can rationalise the bid-ask spreads for FTSE 100 stock index options.

[3] See e.g. Bollerslev (1987) for some early US evidence, and Hansson and Hördahl (1997) for evidence from the Swedish stock market.

definition of conditional options strangle variance, the volatility of the volatility of stock index returns does not appear to be an important determinant of the option bid-ask spreads.

Call and put spreads are differently related to stock index shocks. In the regression model for the call spread, stock index shocks have a significantly positive result on the spread, whereas in the put spread model, the relationship is significantly negative. This is quite obvious, since the value of a call (put) increases (decreases) as the stock index increases. Also, positive stock index shocks may cause market makers to increase the call ask quote relatively more than the bid, and decrease the put ask quote more than the corresponding bid. As positive information is revealed through trading, the market maker is more exposed to increases in the stock index. Hence, there could be a tendency towards increasing (decreasing) call (put) spreads. However, the most direct interpretation of these empirical results is that option spreads are related to the size of the option premium. Finally, option bid-ask spreads are positively related to the conditional stock index variance. Evidently, market makers appear to alter option spreads in response to changes in the variance of stock returns as well as to stock index shocks.

The remainder of the study is organised as follows. Section 2 describes the Swedish market for OMX stock index options, section 3 presents the data and methodology and section 4 the empirical results. Section 5 ends the study with some concluding remarks.

2. The Swedish market for OMX-stock index options and futures

In September 1986 the Swedish exchange for options and other derivatives, OM, introduced the OMX stock index. OMX is a value-weighted stock index based on the 30 most actively traded stocks at the Stockholm Stock Exchange (StSE), since 1998 acquired by OM. The purpose of the introduction was to use the index as an underlying asset for trading in standardised European index options and futures.

At OM, all derivatives are traded within a computerised system. The trading system consists of an electronic limit order book, managed by OM. If possible, incoming orders are automatically matched against orders already in the limit order book. If no matching orders can be found, the orders are added to the book. Only members of the exchange can trade directly at OM.[4] Members are either ordinary dealers or market makers. The trading environment thus constitutes a combination of an electronic matching system and a market making system.[5] Market makers supply liquidity to the market by posting bid-ask spreads on a continuous basis. Trading based only on a limit order book could exhibit problems with liquidity since the high degree of transparency may adversely affect the willingness of investors to place limit orders to the market. The trading system at StSE is also based on a limit order book. However, there are no market makers at the Swedish stock market.

The Swedish OMX index option market consists of European calls and puts, as well as futures contracts, with different time to expiration.[6] At any time throughout a calendar year, trading is possible in at least three option contracts series, with up to one, two and three months to expiration respectively. On the fourth Friday each month, if the exchange is open, one series expires and another with three months to expiration is initiated. For instance, towards the end of September, the September contracts expire and are replaced with the December contracts. At that time, the October contracts (with time to expiration of one month) and the November contracts (with time to expiration of two months) are also listed. In addition to this basic maturity cycle, options and futures with up to two years maturity exist. These long contracts always expire in January and are included in the basic maturity cycle when they have less than three months to expiration.

The same cycle applies for OMX stock index calls and puts. Furthermore, for every options series, a range of strikes is available. Before November 28, 1997, strikes are set at 20 index point intervals. Thereafter, starting with the contracts expiring in February 1998, new rules apply, where strikes are set at 40 index point intervals. Furthermore, on April 27, 1998, OM decided to split the OMX stock index with a factor 4:1.[7] After the split, strikes below 1,000

[4] The OM is the sole owner of the London Securities and Derivative Exchange (OMLX). The two exchanges are linked to each other in real time. This means that a trader at the OMLX has access to the same limit order book as a trader at the OM. In 1995, 35 members were registered at the OM and 50 at the OMLX.

[5] Compare e.g. the trading system at the CBOE, which is a continuous open-outcry auction among competitive traders; floor brokers and market makers.

[6] The options and futures are all settled in cash at expiration, where one option contract is worth an amount of 100 times the index. For valuation purposes, the index futures contracts are commonly considered as the underlying security for the index call and put options with the identical maturity. For instance, the OM uses option valuation formulas according to Black (1976) for assessing margin requirements.

[7] The split reduced the option contract size to a fourth of its previous value. The index multiplier is 100 before as well as after the split.

points are set at 10 point intervals, whereas strikes above 1,000 points are set at 20 point intervals. When new options series are introduced strike prices are centred round the value of the OMX index. Further, as the stock index value increases or decreases with a considerable amount during the time to expiration, new strikes are introduced. Thus, the prevailing strike price range depends on the development of the index during the time to expiration.

3. Methodology

3.1 Two different types of information shocks

Two daily time series are constructed; one for OMX stock index returns and another for returns from a rolling options strangle position. The stock index return at day *t* is calculated as the difference between the natural logarithm of the stock index value at day *t* (I_t) and the corresponding value at day $t-1$ (I_{t-1}):

(1) $$R_{s,t} = \ln I_t - \ln I_{t-1}$$

The options strangle position is initiated at day $t-1$ by buying one call option, with a strike just above the stock index value at day $t-1$, and one put option, with a strike just below the stock index value. The position is held until day *t*, when it is closed and the options strangle return is calculated as:

(2) $$R_{o,t} = \ln(C_t + P_t) - \ln(C_{t-1} + P_{t-1})$$

where C_t is the mid-quote of the call option at day *t*, i.e. the average of the bid-ask quotes, and P_t the corresponding mid-quote of the put. To obtain a time series for options strangle return, a new options strangle position is initiated each trading day, using the closest to out-of-the-money options available. The option series closest to expiration is always used, except during expiration weeks. Each Thursday before the expiration week, the option series is "rolled over" into the next contracts. For instance, on Thursday the week prior to the January expiration week, January options held from Wednesday to Thursday close are sold at the prevailing mid-quotes. Then, an options strangle position is initiated at the Thursday's mid-quotes of the February contracts. This position is held until Friday's close. Thereafter, February options are used until the next rollover. If the Friday before the expiration week is a holiday, the rollover is initiated at the close of the corresponding Wednesday.

To obtain the information shocks, unexpected changes in the returns, stock index and options strangle returns are modelled as AR(1) processes with GARCH(1,1) errors, allowing for asymmetry in the conditional variance. Hence, the conditional variance can respond differently to positive and negative shocks, in accordance with Glosten et al. (1993):

(3) $$R_{s,t} = \sum_{i=1}^{5} \mu_{s,i} D_{i,t} + \sum_{i=1}^{5} \rho_{s,i} D_{i,t} R_{s,t-1} + \varepsilon_{s,t}$$

$$h_{s,t} = \delta_s + \theta_s \varepsilon_{s,t-1}^2 + \alpha_s \varepsilon_{s,t-1}^2 Q_{s,t-1} + \gamma_s h_{s,t-1}$$

(4) $$R_{o,t} = \sum_{i=1}^{5} \mu_{o,i} D_{i,t} + \sum_{i=1}^{5} \rho_{o,i} D_{i,t} R_{o,t-1} + \varepsilon_{o,t}$$

$$h_{o,t} = \delta_o + \theta_o \varepsilon_{o,t-1}^2 + \alpha_o \varepsilon_{o,t-1}^2 Q_{o,t-1} + \gamma_o h_{o,t-1}$$

Here, the $D_{i,t}$'s are dummy variables for days of the week ($D_{1,t}$ equals one on Mondays and zero other vice, $D_{2,t}$ one on Tuesdays, and so forth), $\varepsilon_{s,t}$ ($\varepsilon_{o,t}$) is the stock index (options strangle) return residual, or shock, assumed to be IID with the conditional options strangle (stock index) variance $h_{s,t}$ ($h_{o,t}$). In the conditional variance equations $Q_{s,t}$ ($Q_{o,t}$) is a dummy variable which is equal to one if $\varepsilon_{s,t} < 0$ ($\varepsilon_{o,t} < 0$) and zero otherwise. Furthermore $\mu_{s,i}$, $\mu_{o,i}$, $\rho_{s,i}$, and $\rho_{o,i}$ are coefficients in the mean equations, whereas δ_s, δ_o, θ_s, θ_o, α_s, α_o, γ_s and γ_o are coefficients in the variance equations.

The shocks from equation (1) and (2) represent two types of information. The stock index return on day *t* is the gain (loss) from holding the index stocks from the close of the earlier trading day. If an informed investor has information on day $t-1$ about the direction of the stock index on day *t*, profits can be materialised by taking a position in the underlying index stocks on day $t-1$. Here the residual $\varepsilon_{s,t}$ from equation (3) is interpreted as the unexpected stock index return due to directional information during day *t*. For example, this information can be unexpected macro data, or any other information affecting all index stocks or firm-specific information for a subset of the stocks. When the information becomes common knowledge on day *t*, the stock index adjusts accordingly.

Consequently, if an investor on day $t-1$ is informed about the stock index volatility on day *t*, i.e. to what extent the index is expected to move until the close of day *t* or not, upwards or downwards, the investor can utilise the information by buying or selling an options strangle position on day $t-1$. If the informed investor knows that the volatility will increase (decrease), or alternatively that the index is (not) going to move a lot, a long (short) options strangle position is initiated on day $t-1$ and closed on day *t*. A positive (negative) residual $\varepsilon_{o,t}$ measures the unexpected part of the options strangle return, not known to, in a statistical sense, uninformed investors. In this context, the options strangle residual $\varepsilon_{o,t}$ is interpreted as the unexpected options strangle return due to un-directional information.

Previous research reports asymmetry in conditional stock and stock index variance; see e.g. Black (1976), Glosten et al. (1993) and Hansson and Hördahl (1997). Hence, the conditional stock index variance might be related differently to positive and negative index shocks ($\varepsilon_{s,t}$). This potential so-called leverage effect, as labelled by Black (1976), is accounted for in equation (3). For example, if $\alpha_s > 0$ a negative shock increases the conditional variance more than a positive shock. For options strangle returns, there is no prior evidence of asymmetry in the conditional variance, since this study is the first to investigate strangle returns in a GARCH framework. Nevertheless, the coefficient α_o is included in equation (4) to analyse a potential leverage effect in the conditional variance for strangle returns as well.

3.2 Option bid-ask spreads, conditional variance and information shocks

This study investigates the time series properties of option bid-ask spreads. The main prupose is to analyse the dynamic relationship between call and put spreads and the two types of information shocks and conditional variance. The call and put spreads are regressed against stock index and options strangle shocks, as well as conditional stock index and options strangle variance and some other variables, in the following time series regressions:

$$S_{c,t} = \beta_{c,0} + \beta_{c,1}\varepsilon_{o,t} + \beta_{c,2}\varepsilon_{s,t} + \beta_{c,3}h_{o,t} + \beta_{c,4}h_{s,t} + \beta_{c,5}Vol_{f,t} + \beta_{c,6}Vol_{c,t} + \beta_{c,7}C_{t-1} + \beta_{c,8}S_{f,t} + \beta_{c,9}Time_t + \xi_{c,t} - \sum_{i=1}^{5}\phi_{c,i}\xi_{c,t-i} \tag{5}$$

$$S_{p,t} = \beta_{p,0} + \beta_{p,1}\varepsilon_{o,t} + \beta_{p,2}\varepsilon_{s,t} + \beta_{p,3}h_{o,t} + \beta_{p,4}h_{s,t} + \beta_{p,5}Vol_{f,t} + \beta_{p,6}Vol_{p,t} + \beta_{p,7}P_{t-1} + \beta_{p,8}S_{f,t} + \beta_{p,9}Time_t + \xi_{p,t} - \sum_{i=1}^{5}\phi_{p,i}\xi_{p,t-i} \tag{6}$$

where $S_{c,t}$ ($S_{p,t}$) is the call (put) options bid-ask spread on day *t*, $\varepsilon_{o,t}$ ($\varepsilon_{s,t}$) is the options strangle (stock index) shock, $h_{o,t}$ ($h_{s,t}$) is the conditional options strangle (stock index) variance, $Vol_{f,t}, Vol_{c,t}$ and $Vol_{p,t}$ are trading volume of stock index futures, calls and puts, $S_{f,t}$ is the corresponding futures bid-ask spread, and $Time_t$ is time to expiration of the option, on an annual basis. Also, $\beta_{k,0}$, …, $\beta_{k,9}$ and $\phi_{k,i}$, i = 1, …, 5, are regression coefficients, where the lag-length in the moving average formulation for call and put spreads is set to five, $k = c, p$ represent calls and puts, whereas $\xi_{c,t}$ and $\xi_{p,t}$ are residuals. The calls and puts are the same contracts as in the options strangle positions in equation (2). For example, when the options strangle position is sold at the close on a day *t*, the prevailing call and put spreads are used in the spread regressions.

Options spreads are expected to be positively related to options strangle shocks ($\varepsilon_{o,t}$). A large positive (negative) shock can be interpreted as an unexpected volatility increase (decrease), and would cause a market maker to increase (decrease) the quoted option spreads. This supposed behaviour of market makers is in line with an increase in inventory risk and asymmetric information risk. In other words, *ceteris paribus*, an unexpected increase (decrease) in volatility would cause market makers, or limit order traders, to post lower (higher) option bid quotes and higher (lower) ask quotes. Hence, in equations (5) and (6), the coefficients $\beta_{c,1}$ and $\beta_{p,1}$ are expected to be positive.

Stock index shocks ($\varepsilon_{s,t}$), on the other hand, ought to affect call and put spreads differently. For example, an increase in the stock index would imply an increase (decrease) in the value of call (put) options and the bid-ask spread would be expected to increase (decrease) accordingly. Also, positive stock index shocks may cause market makers to increase the call ask quote relatively more than the bid, and decrease the put ask quote more than the corresponding bid. As positive information is revealed through trading, the market maker is more exposed to increases in the stock index. Hence, there could be an additional tendency towards increasing (decreasing) call (put) spreads. As a result, the coefficient for stock index shocks ($\beta_{c,2}$) is expected to be positive, whereas the coefficient for options strangles ($\beta_{p,2}$) is expected to be negative.

The conditional options strangle and stock index variance ($h_{o,t}$ and $h_{s,t}$) are also included as explanatory variables in equations (5) and (6). This is to investigate whether the option spreads are dependent on the variance levels in addition to the shocks. In other words, when market makers quote option bid-ask spreads; do they take into account the simultaneously observed variance levels and/or the shocks?

Trading volumes for the futures and each option contract are variables in equation (5) and (6) measuring trading activity. Previous research has found option volume to be important for option bid-ask spreads. According to Cho and Engle (1999), market makers find it more difficult to hedge inventory if trading activity is low. Market makers are averse to holding unhedged positions, so the spread is expected to widen (narrow) when the option is less (more) actively traded. In other words, the $\beta_{k,6}$-coefficients are expected to be negative.

Following the derivative hedge theory by Cho and Engle (1999), the coefficients for the volume of the stock index futures ($\beta_{k,5}$) are expected to be negative, and the coefficients for the spread of the stock index futures ($\beta_{k,8}$) are expected to be positive. If market makers can hedge option positions in the futures market, then they are not exposed to inventory risk or the presence of informed investors in the options market. Therefore, option spreads are expected to reflect informed trading and inventory risk in the underlying futures market.

George and Longstaff (1993), as well as Cho and Engle (1999), find that option spreads are functions of option-specific variables as e.g. moneyness and time to expiration. Since this study analyses the spreads of calls and puts in a strangle position, taken at-the-money, moneyness is not an issue. However, time to expiration is included as an explanatory variable for the spreads. Based on results from previous studies, that options with longer time to maturity have wider spreads, the regression coefficients ($\beta_{k,9}$) are expected to be positive.

4. Data and empirical results

4.1 The data

The data set consists of daily OMX options and futures closing prices obtained from OM for all contracts between October 24, 1994, and June 29, 2001. In addition, the set of data includes closing bid and ask quotes, high and low prices, trading volume (number of contracts and transacted amount in SEK) and open interest for all available contracts. The closing bid-ask spread represents the best bid and ask quoted in the limit order book at the close of the exchange. Daily OMX stock index values are also obtained from OM, calculated from daily closing stock prices.

The data are subject to a screening process. If an option spread is unreasonably wide, i.e. wider than 10 SEK, the observation is deleted and assigned a missing value in the subsequent spread regressions.[8] Furthermore, the time period is split into two sub-periods, before and after April 27, 1998, when the split in the OMX index occurred. As argued in Bollen et al.

[8] The screening process results in the deletion of 38 call and 38 put spread observations, out of a total of 1,675 daily observations during the sample period.

(2003), the primary argument for reducing the derivatives contract size is to enhance investor accessibility. However, the authors also claim that a split increases trading costs. They support their claim with “anecdotal evidence” from the split in S&P 500 index suggesting that brokerage fees, per contract, for index futures did not change after the split. Consequently, an investor trading the same nominal amount of futures after, as before the split, experience doubled transactions costs. At OM, trading costs per contract were reduced with the same factor as the split, both for market makers and brokers. Hence, the split in the OMX index should not increase options trading costs. Nevertheless, the empirical analysis in this study is performed using data from the two sub-samples, pre and post split, accounting for the possibility that market makers did not alter option spreads in accordance with the split.

4.2 Summary statistics

Table 1 presents summary statistics for the dependent and primary explanatory variables in equation (5) and (6). Panel A and B of Table 1 contains summary statistics of the pre and post split data respectively. The mean of the dependent call spread (S_c) is 2.13 SEK before the split and 2.74 SEK after. Put options have almost exactly the same mean spread as the calls; 2.03 SEK before the split and 2.70 SEK after. Comparing mean relative spreads, i.e. relating absolute mean spreads to average option premium, yields an average relative call (put) spread of about 7.0% (7.6%) before and 11.1% (11.3%) after the split. Hence, on average, there is an increase in options spreads. The standard deviations of the option spreads are about the same before and after the split; 1.87 and 1.83 for calls and 1.79 and 1.76 for puts respectively.

The mean stock index futures spread (S_f) is 2.02 SEK pre split and 1.40 post, i.e. well below the corresponding mean call and put spreads. In contrast to the options spreads, the futures spread has decreased on average after the split. Hence, there appears to be a shift in liquidity from the options to the futures market.

As expected, the mean stock index shock (ε_s) is almost exactly zero, as is the mean options strangle shock (ε_o). More interestingly, the daily standard deviation of stock index shocks is about 1.11% (1.87%) before (after) the split, while the corresponding standard deviation of options strangle shocks is roughly 10% (10.9%). Also, the mean conditional stock index variance (h_s), recalculated to annual figures, is 0.18 (0.28) pre (post) split, whereas the corresponding mean options strangle variance (h_o) is 1.63 (1.65). One interpretation of these figures is that the dispersion or the risk of the options strangle position is a lot higher than for the portfolio of index stocks. Also, the conditional stock index variance is higher in the second sub-sample, whereas the conditional options strangle variance is unchanged.

Among other explanatory variables, the mean call trading volume is 1,308 contracts per day before the split and 206 after, where post split volume figures are divided by the split factor 4 for comparison. Puts are about as actively traded as calls, with a mean pre (post) split daily volume of 1,114 (169) contracts. Evidently, there is a substantial decline in option trading volume, which could explain the increase of the options spreads. As a comparison, the average daily stock index futures volume is 4,814 before the split and 7,088 after. Consequently, the underlying futures contracts are more actively traded than the options, and increasingly so in the second sub-sample.

4.2 GARCH regression results

Table 2 presents the results from the GARCH(1,1) estimations for stock index and options strangle returns in equation (3) and (4). In the stock index mean equation, the coefficients for Mondays and Fridays ($\mu_{s,1}$ and $\mu_{s,5}$) are positive and significant at the 1% level, suggesting a weekend effect. The stock index has a significant autocorrelation coefficient for Mondays ($\rho_{s,1}$), also indicating a weekend effect. In the options strangle equation, the dummy coefficient for Fridays ($\mu_{o,5}$) is negative and significant at the 5% level. Also, the autocorrelation coefficient for Fridays ($\rho_{o,5}$) is significant and positive. Hence, there is a different day-of-the-week pattern for options strangle returns.

Estimated GARCH coefficients for equation (3) and (4) are also provided in Table 2. There is strong evidence of conditional heteroskedasticity in stock index and options strangle returns. The conditional stock index variance exhibits a high level of persistence (as measured by the sum $\theta_s + \gamma_s = 0.93$ for positive shocks, and $\theta_s + \gamma_s + \alpha_s = 0.98$ for negative shocks). Figure 1 illustrates the effect of a positive and negative one unit stock index shock on the conditional stock index variance at different lags. At lag one, the impact of a positive shock corresponds to the coefficient $\theta_s = 0.06$, whereas the impact of a negative shock is $\theta_s + \alpha_s = 0.16$. Thereafter, each shock diminishes at a rate of $\gamma_s^k = 0.82^k$ for lags $k > 1$.

The GARCH(1,1) model for options strangle returns exhibits considerably lower variance persistence, $\theta_o + \gamma_o = 0.50$ for a positive shock and $\theta_o + \gamma_o + \alpha_o = 0.48$ for a negative shock. Furthermore, for options strangle returns there is no evidence of asymmetry in the variance equation. The α_o-coefficient is not significantly different from zero. From Figure 2, it can be seen that the initial impact of options strangle shocks is higher ($\theta_o = 0.21$) for positive shocks than for negative shocks ($\theta_o + \alpha_o = 0.20$) and that shock diminishes faster ($\gamma_o^k = 0.29^k$) relative to stock index shocks. The GARCH(1,1) specifications capture the conditional variance quite well. The Ljung-Box Q-test indicates no remaining autocorrelation in stock index or options strangle residuals at the 5% level.[9]

Engle and Ng (1993) present "news impact curves", a method for measuring the conditional variance response to new information. Their curve shows the implied relation between lagged shocks ("news") and current conditional variance holding earlier information constant. In this study, the conditional stock index and options strangle variance is evaluated at the level of the unconditional variance. Hence, news impact curves for equation (3) and (4) are given by:

(7) $$h_{s,t} = \delta_s + (\theta_s + \alpha_s Q_{s,t-1})\varepsilon_{s,t-1}^2 + \gamma_s \sigma_s^2$$

(8) $$h_{o,t} = \delta_o + (\theta_o + \alpha_o Q_{o,t-1})\varepsilon_{o,t-1}^2 + \gamma_o \sigma_o^2$$

which are quadratic functions with minimum at $\varepsilon_{s,t-1}^2 = 0$ and $\varepsilon_{o,t-1}^2 = 0$ respectively. Here, σ_s^2 is the unconditional stock index variance and σ_o^2 the unconditional options strangle variance. Figure 3 and 4 display news impact curves for the conditional stock index and options strangle variance. The conditional options strangle variance is more sensitive to shocks than the conditional stock index variance. The asymmetric response is clearly demonstrated in Figure 3, whereas in Figure 4 the response is virtually symmetric.

4.3 Spread regression results

Table 3 provides results of the time series regressions for the call spread, according to equation (5), whereas Table 4 contains corresponding results for the put spread regressions formulated in equation (6). Each Table is divided into Panel A and B, which contain regression results for the period before and after the index split respectively.

All coefficients for options strangle shocks ($\beta_{c,1}$ and $\beta_{p,1}$ in both panels) are positive and statistically significant at the 5% level for call spreads and at the 1% level for put spreads. Call and put spreads are similarly related to options strangle shocks. Positive (negative) shocks give wider (narrower) spreads. The magnitudes are roughly the same. However, after the split, put spreads are considerably more sensitive to option strangle shocks than call spreads and also more sensitive than before the split.

Call and put spreads are differently related to stock index shocks. In the call spread equation, the coefficient for stock index shocks ($\beta_{c,2}$) is positive in both panels, so positive (negative) stock index shocks increases (decreases) call spreads in both sub-periods. The corresponding coefficient for stock index shocks ($\beta_{p,2}$) is negative, meaning that positive (negative) stock index shocks decreases (increases) put spreads. These results are in line with the expectations formulated in section 3.

Notably, no coefficient for the conditional options strangle variance ($\beta_{c,3}$ or $\beta_{p,3}$) is significant. The conditional options strangle variance ($h_{o,t}$) does not influence call or put spreads significantly. Evidently, options spreads are related to options strangle shocks, but not to conditional option strangle variance. In contrast, the conditional stock index variance ($h_{s,t}$) affects bid-ask spreads with positive coefficients ($\beta_{c,4}$ and $\beta_{p,4}$). Interestingly, the effect on

[9] The Ljung-Box $Q(12)$-statistic equals 13.12 (18.71), with a p-value of 0.3610 (0.0960), in the stock index

the call spread is significant in both sub-samples, whereas the put spread is significantly related to the conditional stock index variance only in the second sub-sample. Hence, market makers change option spreads not only in response to option strangle and stock index shocks, but also in response to the conditional stock index variance. After the split, the latter response is more significant.

In Table 3, the coefficient for the volume of stock index futures ($\beta_{c,5}$) is positive in both sub-samples, but it is only significant at the 5% level in the first period. Hence, after the split the futures volume has no effect on call spreads, which is inconsistent with the derivative hedge theory. On the other hand, the coefficient for the spread of the stock index futures ($\beta_{c,8}$) is significant and have the expected sign in both sub-samples. This supports the derivative hedge theory. Also, the coefficient for the call option volume ($\beta_{c,6}$) is significant and negative in both sub-samples, supporting inventory models. The corresponding results for the put spread, which are presented in Table 4, show no significant influence from the futures volume ($\beta_{p,5}$), a significantly negative influence from the put volume ($\beta_{p,6}$) and a significantly positive effect from the futures spread ($\beta_{p,8}$). Comparing the results before and after the split, shows more pronounced effects of the futures spread and put trading volume on the option spreads, in particular for the puts, in the second sub-sample.

Each coefficient for lagged option price ($\beta_{c,7}$ and $\beta_{p,7}$ respectively) is also significant, but only in the second sub-sample. In the second sub-sample, the coefficient for time to expiration ($\beta_{c,9}$ and $\beta_{p,9}$) is significant in both equations. Furthermore, moving average terms are included to correct for autocorrelation in each option spread, up to five lags.

4.4 Economic significance of the results

As an illustration of the economic significance of the times series regressions, predicted call and put option spreads from the regression models are presented in Table 5. The prediction equations can be written as:

(strangle) return model.

$$(9) \qquad \hat{S}_{c,t} = \hat{\beta}_{c,0} + \hat{\beta}_{c,1}\tilde{\varepsilon}_{o,t} + \hat{\beta}_{c,2}\tilde{\varepsilon}_{s,t} + \hat{\beta}_{c,3}\overline{h}_{o,t} + \hat{\beta}_{c,4}\overline{h}_{s,t} +$$

$$\hat{\beta}_{c,5}\overline{Vol}_{f,t} + \hat{\beta}_{c,6}\overline{Vol}_{c,t} + \hat{\beta}_{c,7}\overline{C}_{t-1} + \overline{\beta}_{c,8}\overline{S}_{f,t} + \overline{\beta}_{c,9}\widetilde{Time}_t$$

$$(10) \qquad \hat{S}_{p,t} = \hat{\beta}_{p,0} + \hat{\beta}_{p,1}\tilde{\varepsilon}_{o,t} + \hat{\beta}_{p,2}\tilde{\varepsilon}_{s,t} + \hat{\beta}_{p,3}\overline{h}_{o,t} + \hat{\beta}_{p,4}\overline{h}_{s,t} +$$

$$\hat{\beta}_{p,5}\overline{Vol}_{f,t} + \hat{\beta}_{p,6}\overline{Vol}_{p,t} + \hat{\beta}_{p,7}\overline{C}_{t-1} + \overline{\beta}_{p,8}\overline{S}_{f,t} + \overline{\beta}_{p,9}\widetilde{Time}_t$$

where $\hat{S}_{c,t}$ ($\hat{S}_{p,t}$) is the predicted call (put) spread, $\tilde{\varepsilon}_{o,t} = 0.10$ ($\tilde{\varepsilon}_{s,t} = 0.01$) is an example of an options strangle (stock index) shock, $\overline{h}_{o,t}$ ($\overline{h}_{s,t}$) is the average conditional strangle (stock index) variance, $\overline{Vol}_{f,t}, \overline{Vol}_{c,t}$ and $\overline{Vol}_{p,t}$ is the average trading volume for futures, calls and puts respectively, $\overline{C}_t$ ($\overline{P}_t$) is the average call (put) mid-quote, $\overline{S}_{f,t}$ is the average futures spread, $\widetilde{Time}_t = 0.0346$, i.e. two weeks on an annual basis, and $\hat{\beta}_{k,0}$, …, $\hat{\beta}_{k,9}$ ($k = c, p$ for calls and puts respectively) are the estimated regression coefficients from Table 3 (for calls) and Table 4 (for puts).

The results in Table 5 should be interpreted as two examples, fixing the explanatory variables at reasonable values from each period, before and after the split, to illustrate the impact on the spread in SEK. The choice of $\tilde{\varepsilon}_{o,t} = 0.10$ and $\tilde{\varepsilon}_{s,t} = 0.01$ corresponds to roughly one standard deviation of each information shock, according to the summary statistics in Table 1. The choice of two weeks to expiration is arbitrary.

For the period before the split, Panel A in Table 5, the predicted average call spread is 2.03 SEK, including a constant of 0.82 SEK. *Ceteris paribus*, a 10% options strangle shock adds 0.12 SEK to the spread, whereas a 1% stock index shock adds about 0.11 SEK. Evidently, both shocks affect the call spread with economically significant amounts. Decomposing the call spread further, the average conditional options strangle variance reduces the spread with 0.41 SEK while the average conditional stock index variance adds 0.94 SEK. This confirms the result that the conditional stock index variance is significant, both statistically and economically, whereas the conditional options strangle variance is less important. Furthermore, trading activity clearly matters economically, as the average futures trading volume adds 0.29 SEK to the call spread, whereas the average trading volume of the call option reduces the spread with 0.28 SEK. Finally, the average spread of the underlying futures contract has an economic effect on the call spread of about 0.26 SEK and time to expiration, about two weeks, an additional 0.26 SEK.

For the first period, the predicted put spread is 1.44 SEK, with a quite high constant term equal to 1.26 SEK. A similar decomposition of the predicted put spread shows that a 10% options strangle shock adds 0.12 SEK, and a 1% stock index shock reduces the spread with 0.36 SEK. Surprisingly, the average conditional options strangle variance removes 0.11 SEK, but this relatively small number is statistically insignificant. On the other hand, the average conditional stock index variance adds 0.29 SEK, considerably less than for the call spread.

As is the case of calls, trading activity matters for put spreads. The average futures volume adds 0.10 SEK to the put spread, less than the corresponding figure for the call spread. The put option volume decreases the spread, as expected, and as in the case of call options. The average put option volume reduces the put spread with 0.19 SEK. Also, the average stock index futures spread adds 0.20 SEK and a time to expiration of two weeks another 0.10 SEK.

In Panel B of Table 5, the economic interpretation of the times series regressions for the data between April 28, 1998, and June 29, 2001, is presented. For the second period, the predicted average call spread is 2.83 SEK, including a constant of only 0.32 SEK, much higher average call spread than during the first period. Here, *ceteris paribus*, a 10% options strangle shock adds 0.12 SEK to the spread, exactly the same amount as in Panel A. A 1% stock index shock adds 0.23 SEK. Evidently, shocks do affect the call spread with economically significant amounts in Panel B as well. The average conditional options strangle variance now increases the spread with 0.33 SEK while the average conditional stock index variance adds 1.11 SEK. Again, the conditional options strangle and stock index variances are economically important, although the conditional options strangle variance is less important. As in Panel A, trading activity matters economically, although the average futures trading volume now only adds 0.09 SEK, whereas the average call option trading volume reduces the spread with 0.32 SEK.

The average spread of the underlying stock index future increases the call spread with 0.26 SEK and time to expiration, adds an additional 0.32 SEK.

In Panel B, the predicted put spread is 2.45 SEK, much higher than in Panel A. The decomposition of the post split put spread shows that a 10% options strangle shock adds 0.22 SEK, and a 1% stock index shock reduces the spread with 0.25 SEK. The average conditional options strangle variance adds 0.23 SEK, but the coefficient is statistically insignificant. The coefficient for the conditional stock index variance is significant, and the average variance adds 0.83 SEK, considerably more than in Panel A, and more in line with call option results.

The average stock index future volume adds 0.01 SEK to the put spread, much less than the corresponding figure for the call spread and also less than the corresponding figure in Panel A. The put option volume reduces the spread with 0.26 SEK. Also, the average stock index futures spread adds 0.60 SEK and time to expiration another 0.34 SEK.

5. Concluding remarks

This study analyses information asymmetry at the stock market, and its implications for bid-ask spreads of call and put options. The asymmetry is based on two types of information. The first type is where informed investors know if tomorrow's stock price will increase or decrease when the information becomes public. The second type represents information where an informed investor knows that the stock prices either will increase or decrease. Evidently, the first type of investor, often called directional investor, profit from trading stocks, whereas the second type, called un-directional trader, would profit from trading options.

These two types of information are modelled within a GARCH framework, using a data set from OM, of all contracts between October 24, 1994, and June 29, 2001. The GARCH model decomposes the information into unexpected options strangle and stock index shocks and conditional variance. Here, options strangle shocks represent un-directional information and stock index shocks represent directional information, only available to informed un-directional investors and directional investors respectively.

Both options strangle and stock index shocks as well as the conditional options strangle and stock index variance, are explanatory variables in two time series regressions, where the dependent variables are the call and put spreads respectively. In these regressions, other explanatory variables are the volume and spread of the stock index future, the volume of the option and the lagged option premium and time to expiration.

The result is significant relationships between option spreads and stock index and options strangle shocks. For call and put option spreads, the spreads are positively related to options strangle shocks, so option spreads become wider (narrower) when un-directional information is revealed through trading. Furthermore, call and put spreads are differently linked to stock index shocks. Stock index shocks have a significantly positive influence on the call spreads, whereas the relationship is negative for put spreads. Evidently, positive (negative) stock index shocks bring larger (smaller) call spreads, and smaller (larger) put spreads. This is quite obvious, since absolute spreads are analysed. An increase in the stock index increases (decreases) the call (put) option premium and thereby the absolute spread.

Moreover, directional shocks might change bid and ask quotes differently. For example, a positive stock index may cause market makers to increase (decrease) the ask quote of calls (puts) relatively more than the bid quote. As directional information is revealed through trading, the exposure to the stock index increases, and hence a tendency towards increased (decreased) call (put) spreads is possible.

Also, call and put spreads are positively related to the conditional stock index variance, but not to the conditional option strangle variance, apart from unexpected options strangle and stock index shocks. Hence, market makers adjust option bid-ask quotes as unexpected information in revealed trough the trading process, in support of asymmetric information models. Furthermore, the conditional stock index variance determines the evolution of option bid-ask spreads.

The economic interpretation is that after the split, the conditional stock index variance explains the largest part of the observed spreads. The impacts of options strangle and stock index shocks are important as well. In the second period, after the split, the impacts are more similar than before the split. Also, the volume of the option contract is important for the size of the spreads, as is time to expiration.

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Table 1: Summary statistics

Panel A: Data between October 24, 1994, and April 27, 1998

Statistics	$S_{c,t}$	$S_{p,t}$	$\varepsilon_{o,t}$	$\varepsilon_{s,t}$	$h_{o,t}$	$h_{s,t}$	$Vol_{f,t}$	$Vol_{c,t}$	$Vol_{p,t}$	C_{t-1}	P_{t-1}	$S_{f,t}$
Mean	2.13	2.03	-0.0043	0.0002	1.6253	0.1752	4,814	1,308	1,114	30.47	26.63	2.02
Median	1.50	1.50	-0.0151	0.0003	1.5216	0.1614	4,382	790.0	760.0	24.37	20.25	1.50
Standard deviation	1.87	1.79	0.0994	0.0111	0.2929	0.0563	2,168	1,451	1,140	21.46	21.10	2.04
Observations	859	854	876	876	876	876	878	878	878	877	877	878

Panel B: Data between April 28, 1998, and June 29, 2001

Statistics	$S_{c,t}$	$S_{p,t}$	$\varepsilon_{o,t}$	$\varepsilon_{s,t}$	$h_{o,t}$	$h_{s,t}$	$Vol_{f,t}$	$Vol_{c,t}$	$Vol_{p,t}$	C_{t-1}	P_{t-1}	$S_{f,t}$
Mean	2.74	2.70	0.0043	-0.0007	1.6507	0.2776	7,089	205.8	169.1	24.48	23.84	1.40
Median	2.25	2.25	-0.0095	-0.0007	1.5127	0.2625	6,105	150.3	113.0	21.25	20.50	1.00
Standard deviation	1.83	1.76	0.1089	0.0187	0.3938	0.0952	4,469	202.6	176.4	14.39	14.30	1.35
Observations	778	783	797	797	797	797	797	797	797	797	797	797

Table 1 contains summary statistics for call (S_c) and put (S_p) spreads, options strangle shocks (ε_o), stock index shocks (ε_s), conditional options strangle variance (h_o), conditional stock index variance (h_s), futures trading volume (Vol_f), call and put options trading volume (Vol_c and Vol_p), lagged call and put prices (C_{t-1} and P_{t-1}), as well as the futures spread (S_f).

Table 2: Results from the GARCH(1,1) models for stock index and options strangle returns

	Stock index returns			*Options strangle returns*		
Coefficient	*Estimate*	*t-value*	*p-value*	*Estimate*	*t-value*	*p-value*
$\mu_{j,1}$	1.81e-3	2.801	(0.0051)	−4.62e-3	−0.798	(0.4249)
$\mu_{j,2}$	9.67e-4	1.478	(0.1397)	2.59e-3	0.531	(0.5975)
$\mu_{j,3}$	-5.21e-4	-0.821	(0.4116)	6.61e-3	1.226	(0.2204)
$\mu_{j,4}$	5.50e-4	0.888	(0.3744)	9.41e-4	0.167	(0.8677)
$\mu_{j,5}$	1.72e-3	2.619	(0.0089)	−0.0153	−2.331	(0.0198)
$\rho_{j,1}$	0.2038	3.673	(0.0002)	0.0589	1.203	(0.2290)
$\rho_{j,2}$	−0.0959	−1.715	(0.0866)	−0.0050	−0.733	(0.4635)
$\rho_{j,3}$	0.0108	0.191	(0.8488)	−0.0044	−0.060	(0.9518)
$\rho_{j,4}$	−0.0492	−0.796	(0.4263)	0.0098	0.108	(0.9134)
$\rho_{j,5}$	−0.0175	−0.327	(0.7437)	0.2490	3.042	(0.0024)
δ_j	3.75e-6	3.733	(0.0002)	5.71e-3	4.204	(0.0001)
θ_j	0.0563	2.039	(0.0416)	0.2143	3.740	(0.0002)
α_j	0.1059	2.916	(0.0036)	−0.0181	−0.155	(0.8767)
γ_j	0.8189	53.21	(0.0001)	0.2896	2.076	(0.0380)
$\overline{R}^2$	0.0149			0.0159		

Table 2 contains estimation results from the GARCH(1,1) models of stock index returns and options strangle returns respectively. The model equations are of the form:

$$R_{j,t} = \sum_{i=1}^{5} \mu_{j,i} D_{i,t} + \sum_{i=1}^{5} \rho_{j,i} D_{i,t} R_{j,t-1} + \varepsilon_{j,t}$$

$$h_{j,t} = \delta_j + \theta_j \varepsilon_{j,t-1}^2 + \alpha_j \varepsilon_{j,t-1}^2 Q_{j,t-1} + \gamma_j h_{j,t-1}$$

where $j = s$ for stock index returns and $j = o$ for options strangle returns, the $D_{i,t}$'s are dummies representing day of the week ($D_{1,t}$ is equal to one if day t is a Monday, $D_{2,t}$ is equal to one if day t occurs on a Tuesday, and so forth), the $\mu_{j,i}$'s and $\rho_{j,i}$'s are coefficients in the mean equations and the δ_j 's, θ_j 's, α_j 's and γ_j 's are coefficients in the variance equations, $Q_{j,t}$ is a dummy which is equal to one if $\varepsilon_{j,t} < 0$ and zero otherwise, and the $\varepsilon_{j,t}$'s are shocks or residuals in the mean equations. The models are estimated using the quasi-maximum likelihood technique, according to Bollerslev and Wooldridge (1992).

Table 3: Results from call bid-ask spread time series regressions

	Before split			*After split*		
Coefficient	*Estimate*	*t-value*	*p-value*	*Estimate*	*t-value*	*p-value*
$\beta_{c,0}$	0.8246	2.1639	(0.0308)	0.3234	0.7772	(0.4373)
$\beta_{c,1}$	1.2120	2.2374	(0.0255)	1.2277	2.3309	(0.0201)
$\beta_{c,2}$	10.8855	1.9429	(0.0524)	22.9024	6.6140	(0.0000)
$\beta_{c,3}$	-0.2521	-1.4345	(0.1518)	0.1997	1.1287	(0.2594)
$\beta_{c,4}$	5.3610	2.2110	(0.0273)	3.9926	4.5831	(0.0000)
$\beta_{c,5}$	5.98e-5	2.3555	(0.0187)	1.21e-5	0.8828	(0.3776)
$\beta_{c,6}$	-2.16e-4	-6.4261	(0.0000)	−0.0016	-4.4340	(0.0000)
$\beta_{c,7}$	-0.0030	-0.7306	(0.4653)	0.0183	3.0324	(0.0025)
$\beta_{c,8}$	0.1307	3.2491	(0.0012)	0.1522	3.5749	(0.0004)
$\beta_{c,9}$	6.7999	3.3151	(0.0010)	8.3190	3.0001	(0.0028)
$\phi_{c,1}$	0.1721	3.5733	(0.0004)	0.1156	3.2834	(0.0013)
$\phi_{c,2}$	0.1371	3.3263	(0.0009)	0.0059	0.1539	(0.8778)
$\phi_{c,3}$	0.2290	5.8817	(0.0000)	0.1727	3.7346	(0.0002)
$\phi_{c,4}$	0.1200	2.3127	(0.0210)	0.0589	1.6357	(0.1024)
$\phi_{c,5}$	0.1088	2.5593	(0.0107)	0.1451	3.5829	(0.0004)
$\overline{R}^2$			0.5304			0.4149

Table 3 contains results from the time series regression of call spreads. The regression equation is:

$$S_{c,t} = \beta_{c,0} + \beta_{c,1}\varepsilon_{o,t} + \beta_{c,2}\varepsilon_{s,t} + \beta_{c,3}h_{o,t} + \beta_{c,4}h_{s,t} +$$
$$\beta_{c,5}Vol_{f,t} + \beta_{c,6}Vol_{c,t} + \beta_{c,7}C_{t-1} + \beta_{c,8}S_{f,t} + \beta_{c,9}Time_t + \xi_{c,t} - \sum_{i=1}^{5}\phi_{c,i}\xi_{c,t-i}$$

where $S_{c,t}$ is call spread, $\varepsilon_{o,t}$ ($\varepsilon_{s,t}$) is options strangle (stock index) shock, $h_{o,t}$ ($h_{s,t}$) is conditional options strangle (stock index) variance, $Vol_{f,t}$ and $Vol_{c,t}$ are trading volume of stock index futures and calls, C_{t-1} is the lagged mid-quote of the call premium, $S_{f,t}$ is the stock index futures spread, $Time_t$ is time to expiration of the option, $\beta_{c,0}$, …, $\beta_{c,9}$ are regression coefficients, $\phi_{c,1}$, …, $\phi_{c,5}$ are moving average coefficients, whereas $\xi_{c,t}$ is a residual term. The regression is estimated with OLS and corrected for heteroskedasticity and autocorrelation in the residuals (12 lags) according to White (1980) and Newey and West (1987).

Table 4: Results from put bid-ask spread time series regressions

	Before split			*After split*		
Coefficient	*Estimate*	*t-value*	*p-value*	*Estimate*	*t-value*	*p-value*
$\beta_{p,0}$	1.2645	3.4422	(0.0006)	0.4465	1.3957	(0.1632)
$\beta_{p,1}$	1.1793	2.6328	(0.0086)	2.1867	3.7905	(0.0002)
$\beta_{p,2}$	-35.8626	-10.2635	(0.0000)	-25.0742	-8.0181	(0.0000)
$\beta_{p,3}$	-0.0677	-0.1605	(0.6732)	0.1388	0.8143	(0.4158)
$\beta_{p,4}$	1.6397	0.8530	(0.3939)	2.9759	2.7842	(0.0055)
$\beta_{p,5}$	2.09e-5	0.9725	(0.3311)	1.30e-6	0.0918	(0.9269)
$\beta_{p,6}$	-0.0002	-6.0227	(0.0000)	−0.0015	-4.6172	(0.0000)
$\beta_{p,7}$	0.0009	0.1950	(0.8454)	0.0252	4.4156	(0.0000)
$\beta_{p,8}$	0.0970	2.9899	(0.0029)	0.2077	5.2331	(0.0000)
$\beta_{p,9}$	2.6250	1.4338	(0.1520)	9.0292	3.8914	(0.0001)
$\phi_{p,1}$	0.1041	2.6038	(0.0094)	0.0663	1.8177	(0.0695)
$\phi_{p,2}$	0.1775	4.0085	(0.0001)	0.0692	2.0373	(0.0420)
$\phi_{p,3}$	0.1173	2.2573	(0.0243)	0.1131	3.0518	(0.0024)
$\phi_{p,4}$	0.2286	4.7469	(0.0000)	0.0954	2.4199	(0.0158)
$\phi_{p,5}$	0.1998	3.6893	(0.00027)	0.0203	0.4878	(0.6258)
$\overline{R}^2$			0.5817			0.3962

Table 4 contains results from the time series regression of put spreads. The regression equation is:

$$S_{p,t} = \beta_{p,0} + \beta_{p,1}\varepsilon_{o,t} + \beta_{p,2}\varepsilon_{s,t} + \beta_{p,3}h_{o,t} + \beta_{p,4}h_{s,t} +$$
$$\beta_{p,5}Vol_{f,t} + \beta_{p,6}Vol_{p,t} + \beta_{p,7}P_{t-1} + \beta_{p,8}S_{f,t} + \beta_{p,9}Time_t + \xi_{p,t} - \sum_{i=1}^{5}\phi_{p,i}\xi_{p,t-i}$$

where $S_{p,t}$ is put spread, $\varepsilon_{o,t}$ ($\varepsilon_{s,t}$) is options strangle (stock index) shock, $h_{o,t}$ ($h_{s,t}$) conditional options strangle (stock index) variance, $Vol_{f,t}$ and $Vol_{p,t}$ are trading volume of stock index futures and puts, P_{t-1} is the lagged mid-quote of the put premium, $S_{f,t}$ is the stock index futures spread, $Time_t$ is time to expiration of the option, $\beta_{p,0}$, …, $\beta_{p,9}$ are regression coefficients, $\phi_{p,1}$, …, $\phi_{p,5}$ are moving average coefficients, whereas $\xi_{p,t}$ is a residual term. The regression is estimated with OLS and corrected for heteroskedasticity and autocorrelation in the residuals (12 lags) according to White (1980) and Newey and West (1987).

Table 5: Regression results; predicted call and put spreads

Panel A: Before split											
	$\hat{S}_{k,t}$	$\hat{\beta}_{k,0}$	$\hat{\beta}_{k,1}\tilde{\varepsilon}_{o,t}$	$\hat{\beta}_{k,2}\tilde{\varepsilon}_{s,t}$	$\hat{\beta}_{k,3}\overline{h}_{o,t}$	$\hat{\beta}_{k,4}\overline{h}_{s,t}$	$\hat{\beta}_{k,5}\overline{Vol}_{f,t}$	$\hat{\beta}_{k,6}\overline{Vol}_{k,t}$	$\hat{\beta}_{k,7}\overline{K}_{t}$	$\hat{\beta}_{k,8}\overline{S}_{f,t}$	$\hat{\beta}_{k,9}Ti\tilde{m}e_t$
Calls	2.03	0.82	0.12	0.11	-0.41	0.94	0.29	-0.28	-0.09	0.26	0.26
Puts	1.44	1.26	0.12	-0.36	-0.11	0.29	0.10	-0.19	0.02	0.20	0.10
Panel B: After split											
Calls	2.86	0.32	0.12	0.23	0.33	1.11	0.09	-0.32	0.44	0.21	0.32
Puts	2.45	0.45	0.22	-0.25	0.23	0.83	0.01	-0.26	0.60	0.29	0.34

Table 5 contains prediction results from the regressions of call and put spreads respectively. The regression prediction equations are:

$$\hat{S}_{c,t} = \hat{\beta}_{c,0} + \hat{\beta}_{c,1}\tilde{\varepsilon}_{o,t} + \hat{\beta}_{c,2}\tilde{\varepsilon}_{s,t} + \hat{\beta}_{c,3}\overline{h}_{o,t} + \hat{\beta}_{c,4}\overline{h}_{s,t} + \hat{\beta}_{c,5}\overline{Vol}_{f,t} + \hat{\beta}_{c,6}\overline{Vol}_{c,t} + \hat{\beta}_{c,7}\overline{C}_{t-1} + \overline{\beta}_{c,8}\overline{S}_{f,t} + \overline{\beta}_{c,9}Ti\tilde{m}e_t$$
$$\hat{S}_{p,t} = \hat{\beta}_{p,0} + \hat{\beta}_{p,1}\tilde{\varepsilon}_{o,t} + \hat{\beta}_{p,2}\tilde{\varepsilon}_{s,t} + \hat{\beta}_{p,3}\overline{h}_{o,t} + \hat{\beta}_{p,4}\overline{h}_{s,t} + \hat{\beta}_{p,5}\overline{Vol}_{f,t} + \hat{\beta}_{p,6}\overline{Vol}_{p,t} + \hat{\beta}_{p,7}\overline{P}_{t-1} + \hat{\beta}_{p,8}\overline{S}_{f,t} + \overline{\beta}_{p,9}Ti\tilde{m}e_t$$

where $\hat{S}_{c,t}$ ($\hat{S}_{p,t}$) is predicted call (put) spread, $\tilde{\varepsilon}_{o,t} = 0.10$ ($\tilde{\varepsilon}_{s,t} = 0.01$) is an example of an options strangle (stock index) return shock, $\overline{h}_{o,t}$ ($\overline{h}_{s,t}$) is average conditional variance of strangle (stock index) returns during the sample period, $\overline{Vol}_{f,t}, \overline{Vol}_{c,t}$ and $\overline{Vol}_{p,t}$ is average trading volume for futures, calls and puts respectively, $\overline{C}_t$ ($\overline{P}_t$) is average call (put) mid-quote, $\overline{S}_{f,t}$ is average futures spread, $Ti\tilde{m}e_t = 0.0385$, i.e. two weeks an annual basis, and $\hat{\beta}_{k,0}$, …, $\hat{\beta}_{k,9}$ are estimated regression coefficients, $k = c$, p for calls and puts respectively.

Figure 1: Effect of a unit shock on conditional OMX-index variance at different lags

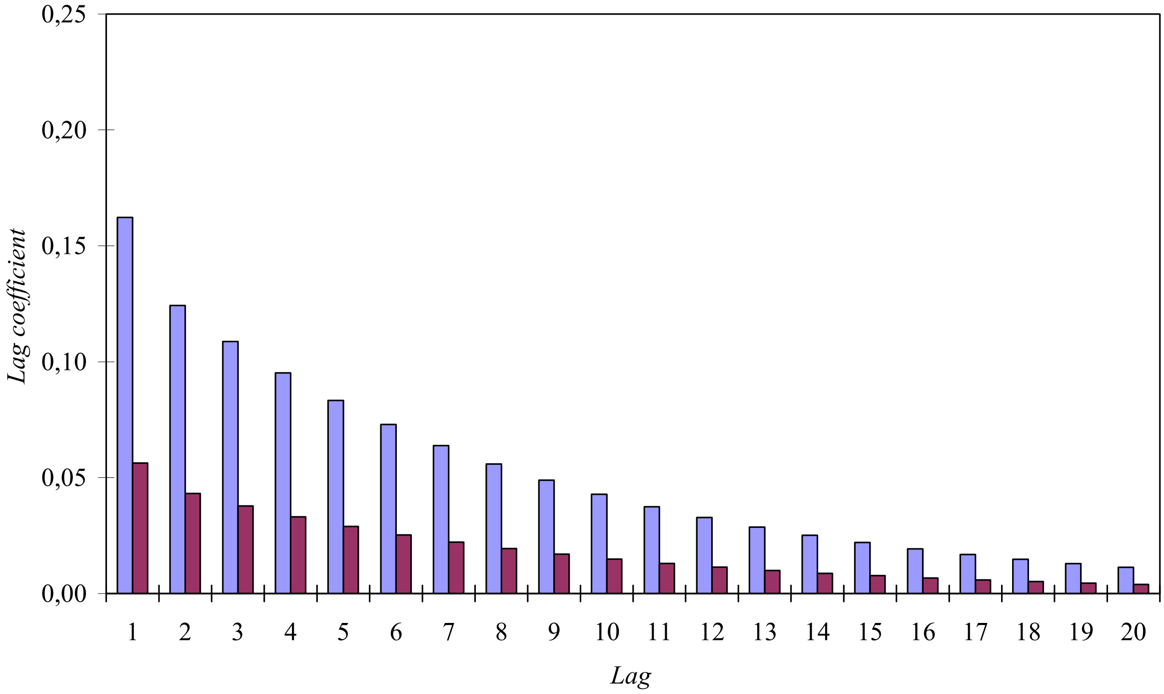

Figure 2: Effect of a unit shock on conditional OMX options strangle variance at different lags

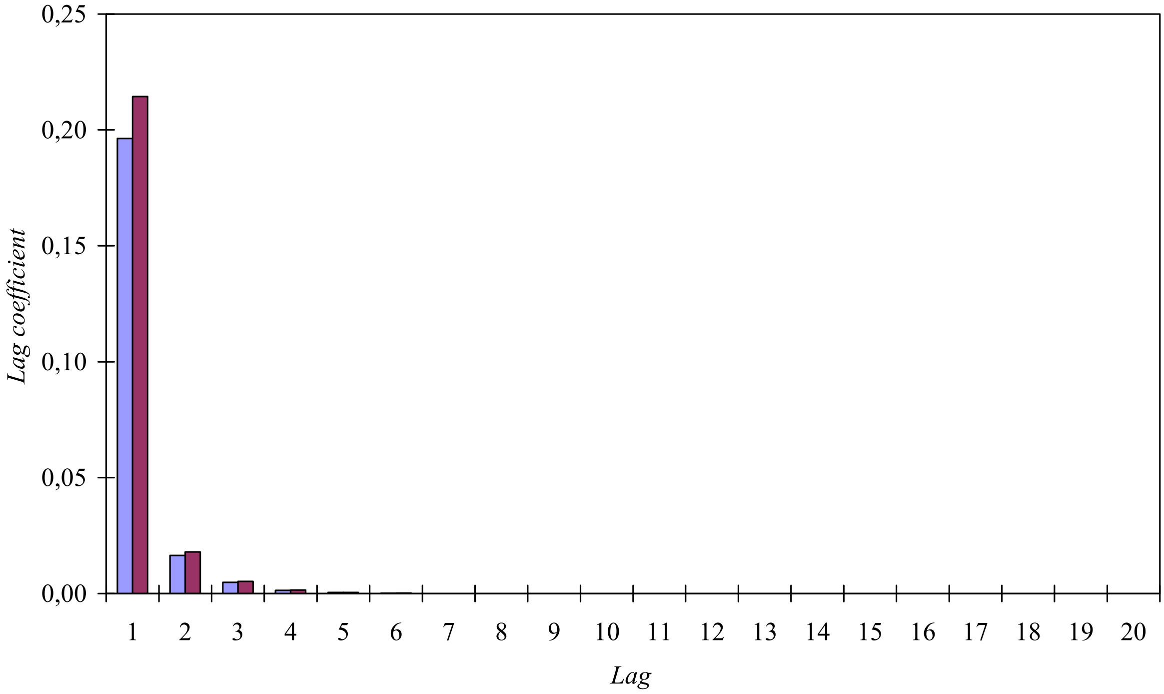

Figure 3: News impact curve for conditional stock index variance

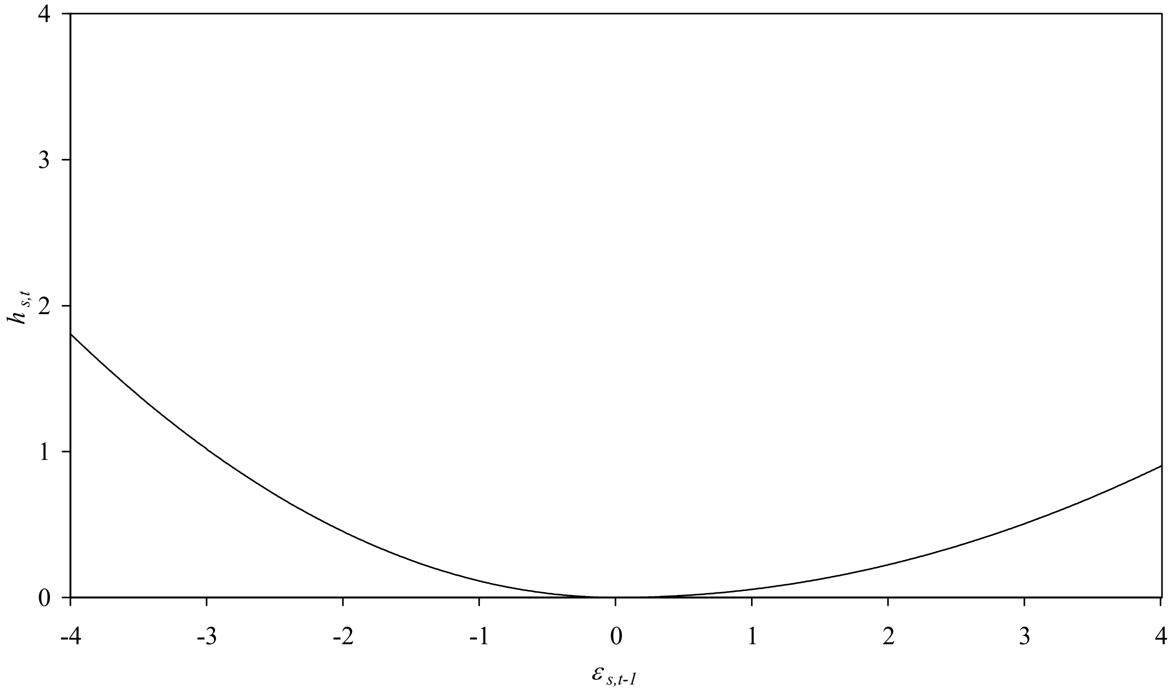

Figure 4: News impact curve for conditional options strangle variance returns