INFORMATION FLOWS AND OPTION BID/ASK SPREADS

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This study analyzes two types of information flows in financial markets. The first type represents return information, where informed investors know whether the stock price will increase or decrease. The second type is labeled volatility information, where the direction of the stock price is unknown, but informed investors know that the stock price either will increase or decrease. Both information flows are estimated within the GARCH framework, approximated with the use of Swedish OMX stock-index and options strangle return shocks, respectively. The results show significant conditional stock-index and options strangle variance, although with notable differences. Stock-index return shocks exhibit a high level of variance persistence and an asymmetric initial impact to the variance. Option strangle shocks have a relatively low persistence level, but a higher and more symmetric initial impact. A time-series regression of call and put option bid/ask spreads is performed, relating the spreads to the information flows and other explanatory variables. The results show that call and

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put option bid/ask spreads are related to stock-index and options strangle return shocks, as well as the conditional stock-index variance. This is consistent with the view that market makers alter option spreads in response to return and volatility information flows, as well as the conditional stock-index variance. © 2005 Wiley Periodicals, Inc. Jrl Fut Mark 25:1147–1172, 2005

INTRODUCTION

There is extensive evidence of time-varying bid/ask spreads in the market microstructure literature. Inventory models (see Amihud & Mendelson, 1980, 1982; Ho & Stoll, 1981; Stoll, 1978) 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 Back, 1993; Copeland & Galai, 1983; Easley & O'Hara, 1987; Foster & Viswanathan, 1994; Glosten & Milgrom, 1985; Kyle, 1983), market makers have an informational disadvantage relative to informed investors. Therefore, they quote spreads wide enough to compensate for expected losses from trading with informed investors. Accordingly, bid/ask spreads should be relatively larger when informed investors are active.

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

According to inventory and asymmetric information models, options bid/ask spreads are related to the volatility of the underlying security. First, a higher volatility of the underlying security increases the risk of an unhedged options inventory, and is 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 active in the options market, widening option spreads. The second argument is consistent with the derivative hedge theory. If informed trading is the cause of higher volatility in the underlying security, the spreads of the underlying securities will increase. Consequently, as the underlying market becomes less liquid in terms of wider spreads, so should the option market, because it thereby is more costly to hedge option positions.

In this study, the information flow in the stock market is divided into two categories, and investors are allowed to have access to different degrees of the information. First, as recognized by Cherian and Jarrow (1998) and Nandi (1999), an informed investor may know whether the stock price will increase or decrease. This type of investor is called a directional investor, or an investor with return information. Second, an investor might have information about the future volatility of the stock, or more precisely, the investor knows that the stock price will either increase or decrease. Accordingly, this type of investor has undirectional or volatility information. According to Cox and Rubinstein (1985), these two types of information can exist independently at the same time, leading to a kind of information asymmetry. Supposedly, in order to profit from the information, the first type of investor would trade stocks and the second would trade options, combined in, for example, a strangle position.[1]

The decomposition of the information flow into two types is investigated empirically. When an investor acts on return information, he or she is likely to take a long or short position in the stock, depending on the nature of the information. Likewise, an investor with volatility information will take either a long or short options strangle position. To the rest of the market participants, that is, uninformed investors and market makers, the two information types will be revealed as stock and options strangle return shocks, respectively. Both information shocks are estimated empirically within the GARCH framework, which allows for a dynamic formulation of the conditional stock-index and options strangle variance.[2] Hence, new return information is measured as stock-index shocks and new volatility information as options strangle shocks.

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 information shocks and spreads. This makes it possible to investigate the importance of the two types of information flows for determining the size of the option bid/ask spreads. Moreover, the

[1]More specifically, when an investor is in possession of return 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 volatility information, he/she wishes to have a delta-neutral position, but with a nonzero gamma or vega, which is exactly what an options strangle position constitutes.

[2]GARCH is short for generalized autoregressive conditional heteroskedasticity (see Bollerslev, 1986).

GARCH framework allows an empirical analysis of whether option spreads are related to the conditional variances or the information shocks. Notably, the conditional options strangle variance can be viewed as a measure of the variance of the variance (see Nandi, 1999), whereas the conditional stock variance has the usual interpretation of expected variance given the prevailing information set; see, for example, Bollerslev (1987).

This study contributes to previous research in several ways. First, the empirical decomposition of the information flows into two different types, using GARCH specifications of stock and strangle return shocks, constitutes a new idea. Second, a time-series regression analysis relating option bid/ask spreads to these two types of information shocks has not been conducted before.[3] Third, previous studies have concluded, theoretically and empirically, that stock-index volatility is important for index option spreads. This study, however, is the first to analyze whether the conditional variance level and/or the information shocks determine option spreads. Moreover, the empirical analysis is conducted with a new data set from the Swedish OMX stock-index option market, presently one of the 10 largest stock-index option markets in the world.

The GARCH estimations results show significant conditional variance in OMX stock-index and option strangle returns, although with notable differences. Stock-index return shocks exhibit a high level of variance persistence, as observed in previous studies.[4] Also, there is evidence of asymmetry; negative stock-index shocks have a significantly larger impact on the conditional stock-index variance than positive shocks. Strangle return shocks have a relatively lower variance persistence, but a considerably higher initial impact of shocks to variance. Moreover, there is no significant asymmetry; positive and negative option strangle shocks have a similar impact on the conditional strangle return variance.

The time-series regressions with call and put bid/ask spreads as dependent variables confirm significant relationships between option spreads and the stock-index and option strangle shocks on a daily basis. For both calls and puts, the bid/ask spread is positively related to option

[3]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, Chung, and Johnson (1995) compare the intraday behavior of spreads of CBOE equity options and NYSE stocks. Fahlenbrach and Sandås (2003) use panel data methods to analyze whether inventory risk can rationalize the bid/ask spreads for FTSE 100 stock-index options.

[4]See, for example, Bollerslev (1987) for some early U.S. evidence, and Hansson and Hördahl (1997) for evidence from the Swedish stock market.

strangle shocks. This is consistent with option spreads becoming wider on days when volatility information is revealed through the trading process. However, option spreads are not significantly related to the conditional option strangle variance. Evidently, options spreads are related to unexpected option strangle shocks, but not to the conditional options strangle variance. With the alternative interpretation of the conditional options strangle variance, the variance of the variance of stock-index returns is not important for option 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 effect, whereas in the put spread model, the relationship is significantly negative. This is expected, because the value of a call (put) option 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, market makers are more exposed to increases in the stock index. Hence, there could be a tendency toward increasing (decreasing) call (put) spreads. Finally, option spreads are positively related to the conditional stock-index variance. Evidently, market makers alter option spreads in response to changes in the stock return variance as well as to stock-index shocks, where the latter represent new return information.

The remainder of the study is organized as follows. The following section briefly describes the Swedish market for OMX stock-index options and futures. The methodology is then presented in two steps. First, the focus is on capturing the return and volatility information flows with the use of stock-index and options strangle return shocks in a GARCH framework. Second, two time-series regression models for call and put option bid/ask spreads, relating spreads to the information flows, are presented. A description of the data set and a presentation of the empirical results are then given. This section also contains a discussion of the economic significance of the results. The study ends with some concluding remarks.

THE 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. The OMX is a value-weighted 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 security for trading in standardized European options and futures. At OM, all derivatives are traded within an electronic limit order book system. If possible, incoming orders are automatically matched against orders already in the limit order book. If no matching orders can be found, incoming orders are added to the limit order book. Only members of the exchange can trade directly through OM, and members are either ordinary dealers or market makers.[5] The trading environment constitutes a combination of an electronic limit order book and a market making system.[6] Market makers supply liquidity to the market by posting bid/ask spreads on a continuous basis. Trading based only on an electronic limit order book could be problematic, as a high degree of transparency might adversely affect the willingness to place limit orders. The trading system at StSE is also based on a limit order book. However, there are no formal market makers at the Swedish stock market.

The Swedish OMX stock-index derivatives market consists of European calls, puts, and futures contracts with different maturities.[7] Throughout a calendar year, trading is possible in at least three contract series, with up to 1, 2, and 3 months to expiration, respectively. On the fourth Friday of each month, if the exchange is open, one contract series expires and another series with 3 months to expiration is initiated. For example, at the end of September, the September contracts expire and are replaced with December contracts. At that time, the October contracts (with time to expiration of 1 month) and the November contracts (with time to expiration of 2 months) are still listed. In addition to this basic maturity cycle, options and futures with up to 2 years until maturity exist. These long contracts always expire in January and are included in the basic maturity cycle when they have less than 3 months to expiration.

The same expiration cycle applies to all OMX call and put option contract series. Furthermore, for each option series, a range of strike prices is available. Before November 28, 1997, strike prices were set at 20 index-point intervals. Thereafter, starting with the contracts expiring in

[5]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.

[6]Compare, for example, the trading system at the CBOE, which is a continuous open-outcry auction among competitive traders: floor brokers and market makers.

[7]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 same maturity. For instance, OM uses option valuation formulas according to Black (1976b) for assessing margin requirements.

February 1998, new rules apply, where strike prices were set at 40 index-point intervals. Furthermore, on April 27, 1998, OM decided to split the OMX stock index with a factor of 4:1.[8] After the split, strike prices below 1000 points are set at 10 index-point intervals, whereas strikes above 1,000 points are set at 20 index-point intervals. When new option series are introduced strike prices are centred round the value of the OMX stock index. Moreover, new strike prices are introduced as the stock-index value increases or decreases. Thus, the prevailing range of strike prices depends on the development of the index during the time to expiration.

METHODOLOGY

Two Different Types of Information Shocks

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

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

A delta-neutral options strangle position is initiated on day $t-1$ by buying $w_{c,t-1}$ fractions of an out-of-the-money call, with the nearest strike above the stock-index level, and $w_{p,t-1}$ of an out-of-the-money put, with a strike just below the stock-index level. The options strangle position is held until day t, when it is closed and the return ($R_{o,t}$) is calculated as

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

In Equation (2), C_t is the midquote of the call option on day t, that is, the average of the bid/ask quotes, and P_t the corresponding put option midquote. The options strangle weights are obtained as $w_{c,t-1} = -\Delta_{p,t-1}/(\Delta_{c,t-1} - \Delta_{p,t-1})$ and $w_{p,t-1} = \Delta_{c,t-1}/(\Delta_{c,t-1} - \Delta_{p,t-1})$, where $\Delta_{c,t-1}$ ($\Delta_{p,t-1}$) is the estimated delta of the call (put) on day $t-1$. Each delta is calculated with the use of the Black (1976b) model, with the corresponding OMX-index futures contract as the underlying security, and an option-specific implied volatility. The implied volatilities are obtained from call (put) midpoint quotes and simultaneous futures midpoint quotes. Daily

[8]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.

rates of Swedish 1-month Treasury bills are used as a proxy for the risk-free interest rate.

The time series of option strangle returns is obtained by initiating a new options strangle position each trading day, using the options with strike prices closest to the current stock-index value. The option series closest to expiration is always used, except during expiration weeks. Each Thursday before the expiration week, the position 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 midquotes. Then, a new options strangle position is initiated with the use of the February contracts, at the Thursday midquotes. 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.

The stock-index and option strangle returns are modeled as moving-average processes of order 1 with GARCH(1,1) errors, allowing asymmetry in the conditional variance equations. Hence, the conditional variance is allowed to respond differently to positive and negative shocks, in accordance with Glosten, Jagannathan, and Runkle (1993):

$$\begin{aligned} R_{s,t} &= \mu_s + \varepsilon_{s,t} - \rho_s \varepsilon_{s,t-1} \\ h_{s,t} &= \delta_s + \theta_s \varepsilon^2_{s,t-1} + \alpha_s \varepsilon^2_{s,t-1} Q_{s,t-1} + \gamma_s h_{s,t-1} \end{aligned} \tag{3}$$

$$\begin{aligned} R_{o,t} &= \mu_o + \varepsilon_{o,t} - \rho_o \varepsilon_{o,t-1} \\ h_{o,t} &= \delta_o + \theta_o \varepsilon^2_{o,t-1} + \alpha_o \varepsilon^2_{o,t-1} Q_{o,t-1} + \gamma_o h_{o,t-1} \end{aligned} \tag{4}$$

Here $\varepsilon_{s,t}$ ($\varepsilon_{o,t}$) is the stock-index (options strangle) return shock, or residual, assumed to be independently, identically distributed with the conditional stock-index (options strangle) variance $h_{s,t}$ ($h_{o,t}$). In the conditional stock-index variance equation, $Q_{s,t}$ is a dummy variable equal to 1 if $\varepsilon_{s,t} < 0$ and 0 otherwise. Moreover, μ_s, μ_o, ρ_s, and ρ_o 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.

Each shock, from Equations (3) and (4), respectively, represents one type of information flow or news. The stock-index return on day t is the gain (or loss) from holding the index stocks from the close of the previous trading day. If an informed investor on day $t - 1$ has information about the direction of the stock index on day t, profits can be made by taking a position in the index stocks on day $t - 1$. When the information becomes common knowledge on day t, the stock index adjusts accordingly. To uninformed investors and market makers, the information is revealed as a stock-index return shock. Hence, the residual $\varepsilon_{s,t}$ from Equation (3) is interpreted as the unexpected stock-index return due to return information during day t. The return information can be unexpected news releases, affecting all index stocks, or firm-specific information that affects a subset of the stocks.

Likewise, if an investor on day $t - 1$ is informed about the stock-index volatility on day t, the investor can utilize this information by buying or selling an options strangle position on day $t - 1$. If the informed investor knows that the volatility will increase (decrease), a long (short) options strangle position is initiated on day $t - 1$ and closed on day t. A positive (negative) residual $\varepsilon_{o,t}$ signals an increase (decrease) in volatility, not known to uninformed investors. In this context, the options strangle residual $\varepsilon_{o,t}$ is interpreted as the unexpected options strangle return due to volatility information.

Previous research reports asymmetry in the conditional stock and stock-index variance; see, for example, Black (1976a), Glosten et al. (1993), and Hansson and Hördahl (1997). Hence, the conditional stock-index variance is expected to be differently related to positive and negative stock-index shocks ($\varepsilon_{s,t}$). This so-called leverage effect, as labeled by Black (1976a), is accounted for in Equation (3). For example, if $\alpha_s > 0$ a negative shock increases the conditional variance more than a positive shock. Because this study is the first to analyze option strangle returns within the GARCH framework, there is no prior evidence that would suggest asymmetry in the conditional strangle variance. Moreover, the interpretation of asymmetry as a leverage effect does not apply to the options strangle variance. Nevertheless, the coefficient α_o is included in Equation (4) to analyze a possible asymmetry effect in the conditional options strangle variance equation.

Equations (3) and (4) are estimated in a dynamic fashion. In other words, at day t, the coefficients in both equations are estimated using all prior information available, including the information released during day t. Hence, the shocks $\varepsilon_{s,t}$ and $\varepsilon_{o,t}$, and conditional variances $h_{s,t}$ and $h_{o,t}$, are generated dynamically, conditional on the information available at time t. Moreover, the following day $t + 1$, the coefficients are reestimated with an updated set of information. This is important for the analysis of option bid/ask spreads, where stock-index and strangle shocks represent the current return and volatility information, respectively.[9]

[9]At-the-money option straddles returns were also used as an alternative to option strangle returns in Equation (4). However, because the subsequent option spread regressions show the same results, irrespective of whether straddle or strangle returns are used to capture volatility information, only the results from the analysis of strangle returns are presented and discussed in the text.

Option Bid/Ask Spreads, Conditional Variance, and Information Shocks

This study investigates time-series properties of option bid/ask spreads. The main purpose is to analyze the relationship between call and put spreads and the two types of information shocks and conditional variance. Call and put spreads are regressed against stock-index and option strangle shocks, as well as the conditional stock-index and option strangle variance and a set of control variables, in the following regressions:

$$S_{c,t} = \beta_{c,0} + \beta_{c,1}\varepsilon_{o,t} + \beta_{c,2}\varepsilon_{s,t} + \beta_{c,3}h_{o,t} + \beta_{c,4}h_{s,t} + \beta_{c,5}\mathrm{Vol}_{f,t} + \beta_{c,6}\mathrm{Vol}_{c,t} + \beta_{c,7}C_{t-1} + \beta_{c,8}S_{f,t} + \beta_{c,9}\mathrm{Time}_t + \xi_{c,t} - \sum_{i=1}^{5}\phi_{c,i}\xi_{c,t-i} \quad (5)$$

$$S_{p,t} = \beta_{p,0} + \beta_{p,1}\varepsilon_{o,t} + \beta_{p,2}\varepsilon_{s,t} + \beta_{p,3}h_{o,t} + \beta_{p,4}h_{s,t} + \beta_{p,5}\mathrm{Vol}_{f,t} + \beta_{p,6}\mathrm{Vol}_{p,t} + \beta_{p,7}P_{t-1} + \beta_{p,8}S_{f,t} + \beta_{p,9}\mathrm{Time}_t + \xi_{p,t} - \sum_{i=1}^{5}\phi_{p,i}\xi_{p,t-i} \quad (6)$$

Here, $S_{c,t}$ ($S_{p,t}$) denotes the bid/ask spread of the call (put) on day t; $\varepsilon_{o,t}$ ($\varepsilon_{s,t}$) the options strangle (stock-index) shock; $h_{o,t}$ ($h_{s,t}$) the conditional options strangle (stock-index) variance; $\mathrm{Vol}_{f,t}$, $\mathrm{Vol}_{c,t}$, and $\mathrm{Vol}_{p,t}$ the trading volume of stock-index futures, calls, and puts, respectively; $S_{f,t}$ the corresponding futures bid/ask spread; C_{t-1} (P_{t-1}) the lagged call (put) midquote; and Time_t the annualized time to expiration of the option. Also, $\beta_{k,0}, \ldots, \beta_{k,9}$, and $\phi_{k,i}$, $i = 1, \ldots, 5$, are regression coefficients, where the lag length in the moving-average formulation for call and put spreads is set to 5, $k = c, p$ 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 option strangle positions in Equation (2). When the options strangle position is sold at the close on day t, the prevailing call and put spreads are used in the regressions according to Equations (5) and (6).

Options spreads are expected to be positively related to option strangle shocks ($\varepsilon_{o,t}$). A large positive (negative) shock can be interpreted as an unexpected volatility increase (decrease), causing market makers to increase (decrease) option spreads. This behavior is in line with an increased (decreased) inventory 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, the coefficients $\beta_{c,1}$ and $\beta_{p,1}$ in Equations (5) and (6) are expected to be positive.

Stock-index shocks ($\varepsilon_{s,t}$), on the other hand, should affect call and put spreads differently. For example, an increase in the stock-index increases (decreases) the value of call (put) options, and the bid/ask spread is 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 return information is revealed through trading, market makers should be more exposed to further increases in the stock index. Hence, there could be an additional tendency towards increasing (decreasing) call (put) spreads. Therefore, the coefficient for stock-index shocks ($\beta_{c,2}$) is expected to be positive in the call regression, and the corresponding coefficient in the put regression ($\beta_{p,2}$) 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 how the call and put spreads depend on the conditional variance levels. In other words, when market makers quote option bid/ask spreads, do they take into account the simultaneously observed variance levels and/or information shocks? Higher conditional stock-index or options strangle variance implies higher inventory risk and asymmetric information costs for market makers. Hence, the coefficients associated with option strangle variance ($\beta_{c,3}$ and $\beta_{p,3}$), and with stock-index variance ($\beta_{c,4}$ and $\beta_{p,4}$) are expected to be positive.

Trading volumes for the option and the futures contracts are included in Equations (5) and (6) as variables measuring trading activity. Previous research has found option volume to be important for option spreads. According to Cho and Engle (1999), market makers find it more difficult to balance inventories if the trading activity is low. Market makers are averse to holding unbalanced positions, so option spreads are expected to widen (narrow) when the option trading activity is low (high). In other words, the coefficients for own option trading volume ($\beta_{c,6}$ and $\beta_{p,6}$ for calls and puts, respectively) are expected to be negative. Moreover, following the derivative hedge theory by Cho and Engle (1999), the coefficients for the futures volume ($\beta_{c,5}$ and $\beta_{p,5}$) are expected to be negative. If market makers can hedge option positions in the futures market, 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 alone. Following the same reasoning, the coefficients for the futures spread ($\beta_{c,8}$ and $\beta_{p,8}$) are expected to be positive. Given that the asymmetric information and inventory costs theories predict a negative relation between options spreads and option volume, whereas the derivative hedge theory predicts no such relation, it is possible to evaluate the theories against one another in this regression framework.[10]

George and Longstaff (1993), as well as Cho and Engle (1999), find that option spreads are functions of option-specific variables, for example, moneyness and time to expiration. Because this study analyzes call and put spreads in an at-the-money strangle position, moneyness is not an issue. However, time to expiration is included as an explanatory variable. Based on results from previous studies, options with longer time to expiration tend to have wider spreads and the regression coefficients $\beta_{c,9}$ and $\beta_{p,9}$ are expected to be positive.

Finally, each regression equation contains the lagged option midquote on the right-hand side. This explanatory variable is needed in order to account for the dependence of each option bid/ask spread to the corresponding option price level. As the option value increases so does the absolute bid/ask spread. Here, two regression model considerations are made. The first choice is to use the absolute option bid/ask spread in the regressions, as in George and Longstaff (1993), rather than the relative spread, following Cho and Engle (1999).[11] Second, the lagged option midquote is used rather than the current. The reasoning behind this decision is that the current option value is highly correlated with other explanatory variables in Equations (5) and (6). Hence, using the lagged option midquote as an instrumental variable for the current option value avoids the risk of exposing the regressions to multicollinearity problems.

DATA AND EMPIRICAL RESULTS

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 data set includes closing bid and ask quotes, and trading volume (number of contracts and transacted amount in SEK) for all contracts. The closing bid/ask spread represents the best

[10]Note, however, that the main purpose at hand is to evaluate the effects of information flows on option bid/ask spreads. Hence, the different theories for bid/ask spreads in the market microstructure literature are primarily used for finding appropriate control variables in the regressions.

[11]Actually, both model specifications are tried in the subsequent estimations, with virtually no differences in the results. As the regression models for absolute bid/ask spreads are slightly easier to interpret, these are preferred throughout the analysis.

bid and ask quoted in the limit order book at the close of the exchange. Daily OMX stock-index values are obtained from OM and calculated from daily closing stock prices.

The data set is subject to a screening process. If an options spread is unreasonably wide, the observation is deleted and assigned a missing value in the subsequent spread regressions.[12] Furthermore, the time period is divided into two subperiods, before and after April 27, 1998, when the OMX stock index was split by a factor 4:1. As argued in Bollen, Smith, and Whaley (2003), the primary argument for splitting an index is to reduce the contract size of the derivatives in order to enhance their accessibility to investors. However, the authors also claim that a split increases the trading costs. They support their claim with anecdotal evidence from the split of the S&P 500 index suggesting that brokerage fees per index futures contract remained unchanged after the split. Consequently, an investor trading the same nominal amount of futures after, as before the split, experience doubled transaction costs. At OM, the fixed trading costs per contract were reduced with the same factor as the split, both for market makers and dealers. Hence, the split should not have increased index options' trading costs. Nevertheless, the split date is used as a natural division point of the sample. The first part of the sample is used as a start-up period for the dynamic estimations of the GARCH models in Equations (3) and (4), whereas the second part is used to dynamically update the parameters in the GARCH models, so that the resulting shocks and conditional variances represent the current daily return and volatility information flows in the dynamic regression models for the call and put options bid/ask spreads.[13]

Summary Statistics

Table I presents summary statistics for the stock-index and options strangle returns, the option bid/ask spreads, as well as some other variables used in the subsequent regression analysis. The daily standard deviation of stock-index returns (R_s) is about 1.89%, whereas the corresponding standard deviation of option strangle returns (R_o) is 10.38%.

[12]The screening process results in the deletion of 19 call and 14 put spread observations, showing spread values in excess of 10 SEK, out of a total of 797 daily observations during the sample period.
[13]On the first day in the second part of the sample, April 27, 1998, the GARCH estimations are carried out using all data during the first part of the sample (from October 24, 1994 until April 27, 1998). Thereafter, the GARCH models are reestimated every day, using an additional day's data. Adding observations on a daily basis, the GARCH estimations for the final day in the sample (June 29, 2001) make use of all data during the entire sample period.

TABLE I

Summary Statistics

Statistics	$S_{c,t}$	$S_{p,t}$	$R_{o,t}$	$R_{s,t}$	$Vol_{f,t}$	$Vol_{c,t}$	$Vol_{p,t}$	C_{t-1}	P_{t-1}	$S_{f,t}$
Mean	2.74	2.70	0.0023	0.0002	7,089	823.2	676.4	24.48	23.84	1.40
Median	2.25	2.25	−0.0082	0.0006	6,105	601.2	452.0	21.25	20.50	1.00
Standard deviation	1.83	1.76	0.1038	0.0189	4,469	810.4	705.6	14.39	14.30	1.35
Observations	778	783	797	797	797	797	797	797	797	797
Unit root test	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0011	0.0001

Note. Table I contains summary statistics for call (S_c) and put (S_p) spreads, options strangle returns ($R_{o,t}$), stock index returns ($R_{s,t}$), 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). Note that h_o and h_s are expressed as annual standard deviations. Data are from the period between April 28, 1998 and June 29, 2001. The augmented Dickey-Fuller test (Fuller, 1996) is used to test the null hypothesis that each time series has a unit root. For each series, a MacKinnon (1996) one-sided p value under each null hypothesis is reported.

One interpretation of these figures is that holding a delta-neutral options strangle position is a lot riskier than holding the portfolio of index stocks.

The mean of the dependent call spread (S_c) is 2.74 SEK. Put options have almost exactly the same mean spread as the calls: 2.70 SEK. Comparing mean relative spreads, that is, relating absolute mean spreads to average option premiums, yields an average relative call spread of about 11.1%, and 11.3% for puts. The standard deviations of the option spreads are about the same; 1.83 for calls and 1.76 for puts. The mean stock-index futures spread (S_f) is 1.40, that is, far more narrow than corresponding mean option spreads. Hence, based on these figures, the futures appear to exhibit higher liquidity than the options. A similar pattern can be seen in the trading-volume statistics. The mean call trading volume is 824 contracts per day. Puts are about as actively traded as calls, with a mean daily volume of 676 contracts. As a comparison, the mean daily stock-index futures volume is 7088, implying that the futures contracts are much more actively traded than the options.

Table I also contains results from a unit root test for stationarity of each variable. An augmented Dickey-Fuller test (see Fuller, 1996) is used to test each individual null hypothesis that the time series has a unit root. With the use of the p values according to MacKinnon (1996), it is possible to reject each null hypothesis of a unit root at any reasonable significance level. Hence, all variables used in the subsequent analysis can be considered stationary.

GARCH Regression Results

Table II presents results from the GARCH estimations of stock-index and option strangle returns in Equations (3) and (4) for the entire sample period from October 24, 1994, to June 29, 2001. The results represent the final step in the dynamic estimation of the coefficients. As a further illustration of the daily dynamic estimation technique, Figures 1 and 2 display the updated coefficients in the conditional stock-index and options strangle variance equation, respectively. The daily updated coefficients are graphed during the postsplit period, between April 28, 1998, and June 29, 2001. During this period, the coefficients provide the basis for computing return shocks and conditional variances, which are used as explanatory variables in the option spread regressions.

In Table II, the moving-average coefficient ρ_s is not significantly different from 0 in the stock-index mean equation. On the other hand, in the options strangle mean equation, the coefficient ρ_o is significantly positive at the 5% level. There is also strong evidence of conditional

TABLE II
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*
μ_j	9.38e-4	3.263	(0.0011)	−3.13e-3	−1.321	(0.1867)
ρ_j	0.0089	0.340	(0.7341)	0.0638	2.048	(0.0406)
δ_j	3.89e-6	3.782	(0.0002)	5.10e-3	4.629	(0.0001)
θ_j	0.0604	2.199	(0.0279)	0.2620	4.571	(0.0001)
α_j	0.1037	2.896	(0.0038)	−0.1029	−0.991	(0.3215)
γ_j	0.8159	53.51	(0.0001)	0.2815	2.227	(0.0260)
Ljung-Box Q(12)	13.422		(0.2650)	11.579		(0.1710)
Log likelihood	4,856.2			1,545.2		

Note. Table II contains estimation results from the GARCH(1,1) models of stock-index returns and options strangle returns, respectively. The coefficients are estimated using data from the entire sample period October 24, 1994, through June 29, 2001. The model equations are of the form

$$R_{j,t} = \mu_j + \varepsilon_{j,t} - \rho_j \varepsilon_{j,t-1}$$

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

where $j = s$ for stock index returns and $j = o$ for options strangle returns, the μ_j'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 variable that is equal to 1 if $\varepsilon_{j,t} < 0$ and 0 otherwise, and the $\varepsilon_{j,t}$'s are shocks or residuals in the mean equations. The models are estimated with the use of the quasimaximum-likelihood technique, according to Bollerslev and Wooldridge (1992). The Ljung-Box Q(12) statistic is chi-square distributed under the null hypothesis that each residual time series exhibits no remaining autocorrelation within 12 lags.

heteroskedasticity in both the stock-index and options strangle variance equations. 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). At lag one, the impact of a positive shock corresponds to $\theta_s = 0.06$, 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 option strangle returns exhibits considerably lower persistence—$\theta_o + \gamma_o = 0.54$ for positive shocks and $\theta_o + \gamma_o + \alpha_o = 0.44$ for negative shocks. Moreover, for options strangle shocks there is no evidence of asymmetry as the α_o coefficient is not significantly different from 0. The initial impact of options strangle shocks is higher ($\theta_o = 0.26$) for positive shocks than for negative shocks ($\theta_o + \alpha_o = 0.16$), and the effect of the shocks diminish at a faster rate ($\gamma_o^k = 0.28^k$) relative to stock-index shocks. The GARCH(1,1) specifications capture the conditional variances quite well. The Ljung-Box Q test

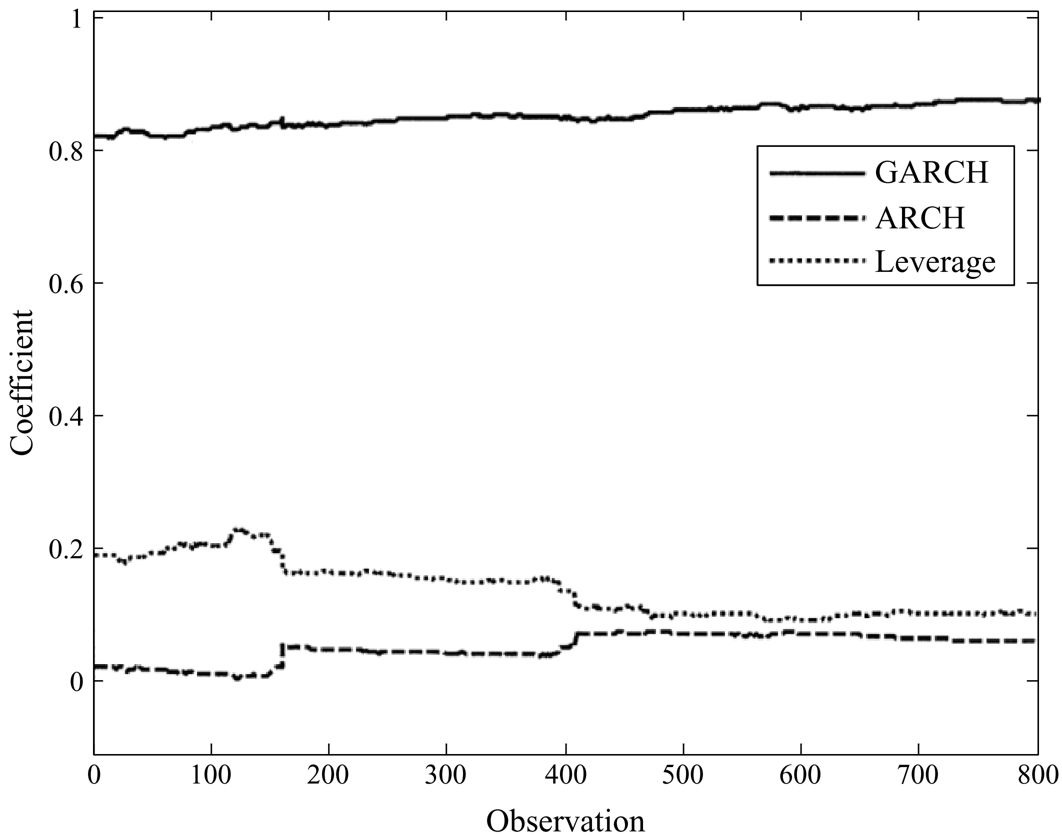

FIGURE 1
Time-varying coefficients in the conditional OMX-index variance equation.

indicates no remaining autocorrelation in either the stock-index or options strangle residuals at reasonable significance levels.

Spread Regression Results

Table III provides results for the call and the put spread regressions in Equations (5) and (6). The coefficients for option strangle shocks ($\beta_{c,1}$ and $\beta_{p,1}$) are positive and statistically significant at the 5% level for call option spreads and at any reasonable level for put option spreads. Hence, positive (negative) shocks induce larger (smaller) for both call and put bid/ask spreads. Moreover, the $\beta_{p,1}$ coefficient is about twice as large as the $\beta_{c,1}$ coefficient, which indicates that put spreads are more sensitive to option strangle shocks than call spreads.

Call and put spreads are differently related to stock-index shocks. In the call spread regression, the coefficient for stock-index shocks ($\beta_{c,2}$) is positive and statistically significant, indicating that positive (negative)

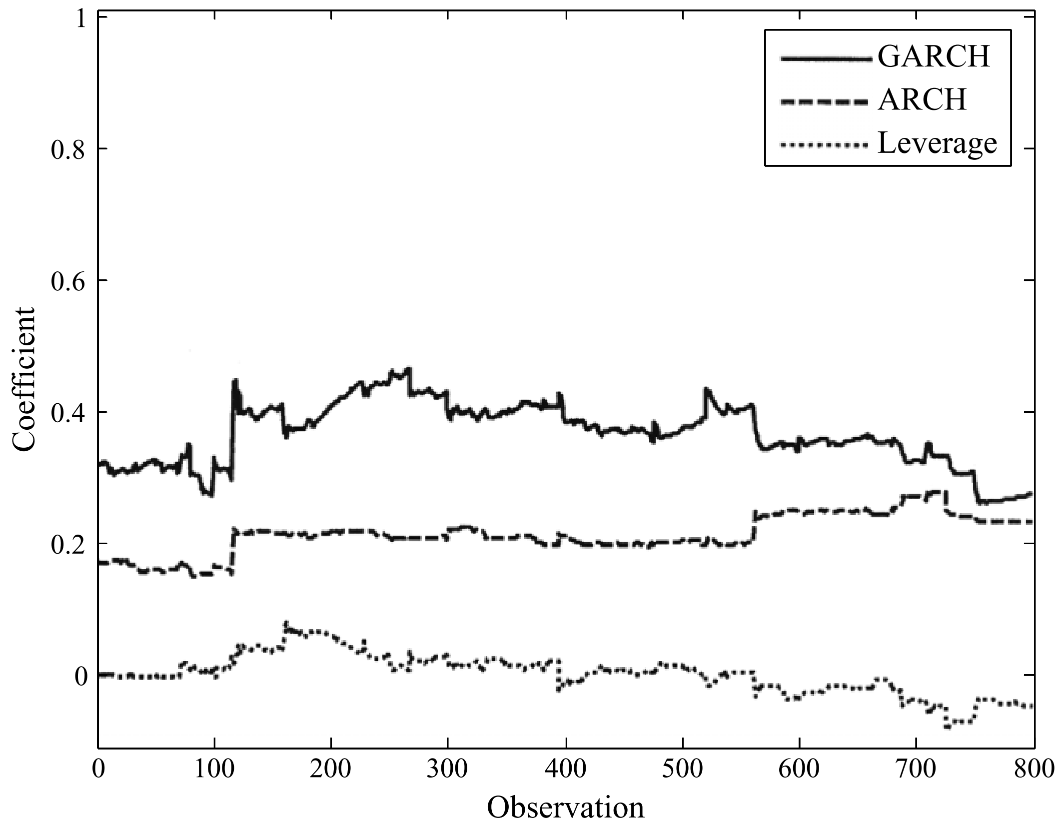

FIGURE 2
Time-varying coefficients in the conditional OMX options strangle variance equation.

stock-index shocks increase (decrease) call spreads. The corresponding relationship between put spreads and stock-index shocks, as measured by the negative and significant coefficient $\beta_{p,2}$, is consistent with the view that positive (negative) shocks decrease (increase) put spreads. The results that call (put) spreads are positively (negatively) related to stock-index shocks are in line with the expectations formulated in the Methodology section.

The coefficients for the conditional options strangle variance ($\beta_{c,3}$ and $\beta_{p,3}$) are not significantly different from 0 in either the call or the put spread regression. Evidently, options spreads are positively related to option strangle shocks, but unrelated to the level of the conditional option strangle variance ($h_{o,t}$). In contrast, the conditional stock-index variance ($h_{s,t}$) affects option spreads with significantly positive coefficients ($\beta_{c,4}$ and $\beta_{p,4}$), at any reasonable significance level. Hence, market makers change option spreads not only in response to option strangle and stock-index shocks, but also in response to changes in the conditional stock-index variance. The latter response appears to be slightly

TABLE III

Results From Call and Put Option Bid Ask Spread Time-Series Regressions

	Call options			*Put options*		
Coefficient	*Estimate*	*t value*	*p value*	*Estimate*	*t value*	*p value*
$\beta_{k,0}$	0.4205	1.1900	(0.2345)	0.4158	1.5089	(0.1318)
$\beta_{k,1}$	1.1411	2.2006	(0.0281)	2.2592	4.0271	(0.0001)
$\beta_{k,2}$	23.630	6.8952	(0.0000)	−25.057	−8.2874	(0.0000)
$\beta_{k,3}$	0.1534	1.0789	(0.2811)	0.0899	0.6191	(0.5361)
$\beta_{k,4}$	4.3014	5.1858	(0.0000)	3.5082	3.5290	(0.0004)
$\beta_{k,5}$	1.07e-5	0.7946	(0.4272)	−2.02e-6	−0.1420	(0.8872)
$\beta_{k,6}$	−0.0016	−4.5354	(0.0000)	−0.0015	−4.5047	(0.0000)
$\beta_{k,7}$	0.0173	3.0547	(0.0023)	0.0241	4.3387	(0.0000)
$\beta_{k,8}$	0.1466	3.5048	(0.0005)	0.2050	5.2255	(0.0000)
$\beta_{k,9}$	8.1344	2.9726	(0.0031)	9.4169	4.1710	(0.0000)
$\phi_{k,1}$	0.1136	3.2555	(0.0012)	0.0622	1.7122	(0.0837)
$\phi_{k,2}$	−0.0058	−0.1543	(0.8774)	0.0633	1.8395	(0.0663)
$\phi_{k,3}$	0.1769	3.7195	(0.0002)	0.1112	2.9736	(0.0030)
$\phi_{k,4}$	0.0602	1.6597	(0.0974)	0.0891	2.2930	(0.0221)
$\phi_{k,5}$	0.1459	3.5612	(0.0004)	0.0151	0.3625	(0.7171)
$\overline{R}^2$			0.4308			0.4012

Note. Table III contains results from the regressions of call and put option spreads. The regression models are

$$S_{c,t} = \beta_{c,0} + \beta_{c,1}\varepsilon_{o,t} + \beta_{c,2}\varepsilon_{s,t} + \beta_{c,3}h_{o,t} + \beta_{c,4}h_{s,t} + \beta_{c,5}\mathrm{Vol}_{f,t} + \beta_{c,6}\mathrm{Vol}_{c,t}$$
$$+ \beta_{c,7}C_{t-1} + \beta_{c,8}S_{f,t} + \beta_{c,9}\mathrm{Time}_t + \xi_{c,t} - \sum_{i=1}^{5}\phi_{c,i}\xi_{c,t-i}$$
$$S_{p,t} = \beta_{p,0} + \beta_{p,1}\varepsilon_{o,t} + \beta_{p,2}\varepsilon_{s,t} + \beta_{p,3}h_{o,t} + \beta_{p,4}h_{s,t} + \beta_{p,5}\mathrm{Vol}_{f,t} + \beta_{p,6}\mathrm{Vol}_{p,t}$$
$$+ \beta_{p,7}P_{t-1} + \beta_{p,8}S_{f,t} + \beta_{p,9}\mathrm{Time}_t + \xi_{p,t} - \sum_{i=1}^{5}\phi_{p,i}\xi_{p,t-i}$$

where $S_{c,t}$ ($S_{p,t}$) is call (put) 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; $\mathrm{Vol}_{f,t}$, $\mathrm{Vol}_{c,t}$, and $\mathrm{Vol}_{p,t}$, are trading volumes of stock-index futures, calls, and puts; C_{t-1} (P_{t-1}) is the lagged midquote of the call (put) premium; $S_{f,t}$ is the futures spread; Time_t is time to expiration of the option; $\beta_{k,0}, \ldots, \beta_{k,8}$ are regression coefficients; $\phi_{k,1}, \ldots, \phi_{k,5}$ are moving average coefficients; $k = c, p$ for calls and puts, respectively, whereas $\xi_{c,t}$ and $\xi_{p,t}$ are residual terms. Each regression is corrected for heteroskedasticity and autocorrelation in the residuals (12 lags) according to White (1980), and Newey and West (1987).

stronger for calls than for puts, as the $\beta_{c,4}$ coefficient is estimated at 4.30, whereas the $\beta_{p,4}$ coefficient estimate equals 3.51.[14]

In Table III, the coefficients for the stock-index futures volume ($\beta_{c,5}$ and $\beta_{p,5}$) are not significantly different from 0 in either the call or put spread regression. Hence, the futures volume appears to have no effect

[14]The index return and options strangle return shocks are first estimated in a dynamic fashion according to Equations (3) and (4), and then used as explanatory variables in the options bid/ask spread regressions in Equations (5) and (6). The two-step estimation procedure might induce a problem with errors in variables, making it less likely to have significant coefficients for the two information shocks, and the conditional variances, at the expense of the other explanatory variables. In other words, the might be a downward bias in the regression coefficients of these variables, relative the other explanatory variables, due to a potential error in variables problem. However, because the regression coefficients of index and options strangle shocks, and the conditional index variance, are large and highly significant, errors in these variables are not considered to be a major concern in this study.

on option spreads, which is inconsistent with the derivative hedge theory. On the other hand, the futures spread coefficients ($\beta_{c,8}$ and $\beta_{p,8}$) are significant in both the call and put spread regressions. This supports the derivative hedge theory, as the coefficients have the expected positive sign in both equations. Moreover, the coefficients for the call option volume ($\beta_{c,6}$) and put option volume ($\beta_{p,6}$) are significant and negative to a similar degree in both regressions, supporting inventory and asymmetric information models. Consequently, the regression results provide mixed results regarding the option spread theories.

Both coefficients for the lagged option price ($\beta_{c,7}$ and $\beta_{p,7}$, respectively) are also significant. The coefficient for time to expiration ($\beta_{c,9}$ and $\beta_{p,9}$) is significantly positive in both the call and put spread regression. This is in line with expectations and previous empirical findings. Finally, moving-average terms are included to correct for autocorrelation in the regressions.

Economic Importance of the Results

As an illustration of the economic importance of the regression results, predicted call and put option spreads are presented in Table IV. The prediction equations are

$$\begin{aligned}\hat{S}_{c,t} &= \hat{\beta}_{c,0} + \hat{\beta}_{c,1}\tilde{\varepsilon}_{o,t} + \hat{\beta}_{c,2}\tilde{\varepsilon}_{s,t} + \hat{\beta}_{c,3}\overline{h}_{o,t} + \hat{\beta}_{c,4}\overline{h}_{s,t} + \hat{\beta}_{c,5}\overline{\mathrm{Vol}}_{f,t} \\ &\quad + \hat{\beta}_{c,6}\overline{\mathrm{Vol}}_{c,t} + \hat{\beta}_{c,7}\overline{C}_{t-1} + \hat{\beta}_{c,8}\overline{S}_{f,t} + \hat{\beta}_{c,9}\widetilde{\mathrm{Time}}_t \qquad (7)\end{aligned}$$

$$\begin{aligned}\hat{S}_{p,t} &= \hat{\beta}_{p,0} + \hat{\beta}_{p,1}\tilde{\varepsilon}_{o,t} + \hat{\beta}_{p,2}\tilde{\varepsilon}_{s,t} + \hat{\beta}_{p,3}\overline{h}_{o,t} + \hat{\beta}_{p,4}\overline{h}_{s,t} + \hat{\beta}_{p,5}\overline{\mathrm{Vol}}_{f,t} \\ &\quad + \hat{\beta}_{p,6}\overline{\mathrm{Vol}}_{p,t} + \hat{\beta}_{p,7}\overline{C}_{t-1} + \hat{\beta}_{p,8}\overline{S}_{f,t} + \hat{\beta}_{p,9}\widetilde{\mathrm{Time}}_t \qquad (8)\end{aligned}$$

The results in Table IV could be interpreted as an example, fixing explanatory variables at reasonable values, illustrating the impacts on the option spreads in SEK. The value of each explanatory variable is chosen to reflect either the sample average or as an example based on the descriptive statistics in Table I. In Equations (7) and (8), $\hat{S}_{c,t}$ ($\hat{S}_{p,t}$) is the predicted call (put) spread; $\tilde{\varepsilon}_{o,t} = 0.10\,(\tilde{\varepsilon}_{s,t} = 0.01)$ an options strangle (stock-index) shock that roughly corresponds to one standard deviation of each information shock; $\overline{h}_{o,t}$ ($\overline{h}_{s,t}$) the average conditional strangle (stock-index) variance; $\overline{\mathrm{Vol}}_{f,t}$, $\overline{\mathrm{Vol}}_{c,t}$, and $\overline{\mathrm{Vol}}_{p,t}$ the average stock-index futures, call, and put trading volume respectively; $\overline{C}_{t-1}$ ($\overline{P}_{t-1}$) the average call (put) midquote; $\overline{S}_{f,t}$ the average stock-index futures spread; $\widetilde{\mathrm{Time}}_t = 0.0346$ an arbitrary chosen time to expiration of the option contract, equal to 2 weeks on an annual basis; and $\hat{\beta}_{k,0},\ldots,\hat{\beta}_{k,9}$ ($k = c, p$ for

TABLE IV

Regression Results; Predicted Call and Put Spreads

	$\hat{S}_{k,t}$	$\hat{\beta}_{k,0}$	$\hat{\beta}_{k,1}\tilde{\varepsilon}_{o,t}$	$\hat{\beta}_{k,2}\tilde{\varepsilon}_{s,t}$	$\hat{\beta}_{k,3}\overline{h}_{o,t}$	$\hat{\beta}_{k,4}\overline{h}_{s,t}$	$\hat{\beta}_{k,5}\overline{Vol}_{f,t}$	$\hat{\beta}_{k,6}\overline{Vol}_{k,t}$	$\hat{\beta}_{k,7}\overline{K}_{t}$	$\hat{\beta}_{k,8}\overline{S}_{f,t}$	$\hat{\beta}_{k,9}Ti\tilde{m}e_t$
Calls	2.9075	0.4205	0.1141	0.2363	0.2532	1.1945	0.0758	−0.3282	0.4228	0.2055	0.3129
Puts	2.4715	0.4158	0.2259	−0.2506	0.1484	0.9743	−0.0143	−0.2507	0.5730	0.2874	0.3622

Note. Table IV contains prediction results from the regressions of call and put spreads, respectively. The prediction models are

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

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

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; $\overline{\mathrm{Vol}}_{f,t}$, $\overline{\mathrm{Vol}}_{c,t}$, and $\overline{\mathrm{Vol}}_{p,t}$ is average trading volume for futures, calls, and puts, respectively; $\overline{C}_t$ ($\overline{P}_t$) is average call (put) midquote; $\overline{S}_{f,t}$ is average futures spread; $\mathrm{Ti\tilde{m}e}_t = 0.0385$, that is 2 weeks on an annual basis; and $\hat{\beta}_{k,0}, \ldots, \hat{\beta}_{k,9}$ are estimated regression coefficients, $k = c, p$ for calls and puts, respectively.

calls and puts, respectively) the estimated regression coefficients from Table III.

The results in Table IV show that the predicted call spread is 2.91 SEK, including a constant of 0.42 SEK. *Ceteris paribus,* a 10% options strangle shock increases the spread with 0.11 SEK, whereas a 1% stock-index shock adds 0.24 SEK. Evidently, both types of information flows do affect the call spread with economically important amounts. If the predicted call option spread is decomposed further, the average conditional options strangle variance increases the spread with 0.25 SEK, and the average conditional stock-index variance adds 1.19 SEK. This implies that the conditional stock-index variance, apart from being statistically significant, also is economically important, whereas the conditional options strangle variance is statistically insignificant and less important than the stock-index variance.

In Table IV, the predicted put spread is 2.47 SEK with a constant of 0.42 SEK. A decomposition shows that a 10% options strangle shock adds 0.23 SEK to the spread, and a 1% stock-index shock decreases the spread with 0.25 SEK. The average conditional options strangle variance adds 0.23 SEK, but the coefficient is statistically insignificant. The average conditional stock-index variance adds 0.97 SEK, which is in line with the results from the call spread regression. Again, the conditional stock-index variance and both information flows are economically important, whereas the conditional options strangle variance is less important.

The trading activity also matters economically. For example, the average call trading volume reduces the spread with 0.33 SEK and the average stock-index futures trading volume adds 0.08 SEK. The latter effect, that higher futures trading volume increases the call spread, is inconsistent with the bid/ask spread theories. However, this coefficient is insignificant in the call spread regression. More consistent is that the average stock-index futures spread increases the call spread with 0.21 SEK. Moreover, the trading activity is important for put spreads as well. The average put trading volume reduces the spread with 0.25 SEK and the average stock-index futures volume with only 0.01 SEK. Also, the average stock-index futures spread adds 0.29 SEK to the predicted put spread.

In summary, the analysis in Table IV confirms that the statistically significant regression results from Table III are economically important as well. Typical examples of return and volatility information flows affect option spreads by considerable amounts. Also, on average, the conditional stock-index variance is an economically important variable for market makers to consider when they quote option spreads.

CONCLUDING REMARKS

In the market microstructure literature, asymmetric information is known to be one of several determinants of the bid/ask spread of stocks as well as options written on stocks. Likewise, previous research provides plenty of empirical evidence regarding the importance of stock return volatility for option bid/ask spreads. In this study, two types of information flows at the stock market are analyzed, and their implications for call and put option spreads are assessed. The first type of information flow concerns stock returns, where informed investors know whether the stock price will increase or decrease. The second type of information represents volatility information where informed investors know if the stock return volatility will increase or decrease.

The decomposition of information flows into return and volatility information is investigated empirically with the use of a data set from the Swedish OMX stock-index options market. When an investor acts upon index return information, the investor is likely to initiate long or short positions in the index stocks, depending on the nature of the information. Similarly, an investor with volatility information is likely to take either a long or short position in an index options strangle. To the rest of the market participants, that is, to uninformed investors and market makers, the two different types of information flows will appear as stock-index and option strangle returns shocks, respectively. These two types of information flows are estimated empirically within the GARCH framework, allowing a dynamic formulation of the conditional stock-index and options strangle variance. Hence, stock-index shocks represent return information and options strangle shocks represent volatility information, previously available only to informed investors.

Stock-index and option strangle shocks, as well as the conditional options strangle and stock-index variance, are explanatory variables in two regressions with call and put option bid/ask spreads as dependent variables. In both regressions, other explanatory variables are the corresponding stock-index futures contract's trading volume and bid/ask spread, the trading volume for each option contract, the lagged option premium, and the time to expiration of the option. The regression results show significant relationships between call and put option spreads and stock-index and option strangle shocks. For calls as well as puts, the spread is positively related to option strangle shocks. This is consistent with option spreads becoming wider (narrower) when volatility information is revealed through the trading process.

Call and put spreads react differently to stock-index shocks. Stock-index shocks have a positive effect on call spreads, whereas the effect is negative on put spreads. Accordingly, positive (negative) stock-index shocks bring larger (smaller) call spreads, and smaller (larger) put spreads. This result is not surprising, because absolute spreads are analyzed. An increase in the stock index increases (decreases) the call (put) option value and thereby the absolute spread. Moreover, it is also consistent with the view that stock-index shocks change option bid and ask quotes differently. For example, a positive stock-index shock may cause market makers to increase (decrease) the ask quote of calls (puts) relatively more than the bid quote. As return information is revealed through the trading process, the exposure to the stock-index increases. Hence, there is a tendency toward increased (decreased) call (put) spreads. Moreover, the empirical analysis implies that call and put spreads are positively related to the conditional stock-index variance, but not to the conditional option strangle variance. One interpretation of this latter result is that the variance of the variance of stock-index returns is unimportant for option spreads.

The results are consistent with the view that market makers adjust option bid/ask spreads as unexpected information is revealed through the trading process. This is the case both for return and volatility information flows, which supports asymmetric information models. Apart from unexpected information shocks, market makers seem to monitor changes in the underlying conditional stock-index variance when quoting option bid/ask quotes. These results are statistically significant as well as economically important and reasonable. An analysis of the economic importance shows that a considerable amount of call and put spreads can be accounted for by information shocks and conditional stock-index variance. Hence, these results should be important not only for academic researchers, but also for market makers and investors.

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