

Informed Trading under Different Market Conditions and Moneyness: Evidence from TXO Options

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JEL classification: G13, G14, E30

Keywords: Information flow; Options; Emerging markets.

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Abstract

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I. Introduction

The informational role of options has attracted considerable attention. Informed traders can choose to trade in the equity market or in the options market. If informed traders prefer to trade in the equity market because of liquidity, we would expect information to flow from that market to other markets such as the options market. Therefore, the equity market should lead the options market. However, informed traders may prefer to trade in the options market because of options' leverage effect, the truncated downside risk of options, and the absence of short-sale constraint in the options market. Thus, information could flow from the options market to the equity market. Alternatively, if informed traders use both markets to take advantage of their private information, a feedback relation should exist between the equity and options markets.

We examine the informational role of options across distinct moneyness under different market cycles. The literature generally analyzes the informational role of options by aggregating market data irrespective of market cycles and options moneyness. The findings in the literature are mixed. We contend that controlling market conditions and options moneyness is critical in analyzing informational role of options.

During a downtrend market, the short-sale constraint in equity markets should make the options market more appealing to informed traders. Although there are no theoretical grounds to assume that informed trades occur exclusively in one particular market cycle. Numerous empirical findings suggest investor behavior is different in bull and bear markets. If favorable market conditions for informed investors to trade differ across options and equity markets during different market cycles, we would expect informed traders to choose the market that maximizes

their gains from trading on their information. Without controlling for market conditions, we will not have a complete picture of informed trading.

The literature also indicates that moneyness affects informed traders' choice among different options. De Jong, Koedijk, and Schnitzlein (2001) suggest informed traders use in-the-money (ITM) options to increase their trading profits because ITM options are more sensitive to underlying equity price changes than other options. Kaul, Nimalendran, and Zhang (2002) argue that at-the-money options (ATM) are more liquid and more sensitive to volatility, and have lower bid-ask spreads than other options. ATM options, thus, are most useful in predicting equity price movements. On the other hand, Chakravarty, Gulen, and Mayhew (2004) show that out-of-the-money (OTM) options play the most significant role in the price discovery process among of all options, because OTM options provide the highest leverage for investors. Hence, if information content of options varies with options' moneyness, pooling all options together could result in mixed findings.

This study employs the tick-by-tick options data from the Taiwan stock index options (TXO) market. The majority of research focuses on mature options markets. It is intriguing to understand information flow and price discovery in the emerging options market for two reasons. First, the typical emerging market usually has different trading regulations from mature markets. It would be informative to examine whether the regulations in a particular emerging market encourage or discourage informed trading activities in options market. The Taiwan stock market is unique for its tight short-sale constraints and a 7% daily price change limit. The TXO market by contrast has no short-sale constraint and daily price limit. We would expect these stringent trading regulations in the equity market to steer informed trading from the equity market to the

TXO options market. The results would have important implications for regulators in other emerging markets.

Second, an emerging market is less efficient than a mature market, and insider trading regulations are lax. Hence, all else equal, trading in an emerging market provides more profitable opportunities for informed traders. Thus, assuming options are a superior instrument to capitalize on private information, informed trading should be more prominent in an emerging options market. An understanding of informed trading in an emerging options market could help options market makers better handle adverse selection risk. If informed trading occurs in the emerging options market, this would give investors signals about future price movements and facilitate regulators monitoring insider trading.

Our findings provide several insights about the informational role of options and informed trading in an emerging options market. When aggregating market data irrespective of market cycles and options moneyness, we find that Taiwan stock equity market leads TXO options market, which is consistent with other findings in the US (see for example, Chan, Chung and Fong, 2002). As options are classified according to different moneyness and market cycles, OTM options in the TXO market lead the equity market up to 90 minutes. These results suggest that leverage effect determines where informed traders trade in Taiwan. The results are more pronounced for OTM options during a bear market. In addition, we find ITM options do not lead the equity return under all market conditions. Thus, options' sensitivity to underlying asset movements is not a major factor affecting informed trading activities in the TXO market. Moreover, because of short-sale constraints and a 7% daily price change limit in the equity market, informed trading in the options market tends to be more active during a bear market.

II. Literature review

The question of where informed traders choose to trade is interesting to academics and practitioners. Black (1975), Diamond and Verrecchia (1987), and Mayhew, Sarin, and Shastri (1995) note options offer investors greater financial leverage without short-sale restrictions. Back (1993), and Cherian (1993) observe that investors can bet on volatility in the options market more easily. Therefore, informed trades could occur in the options market first and information flows from the options market to the equity market. Supporting these arguments, Manaster and Rendleman (1982) report that options prices lead stock prices by up to 24 hours. Anthony (1988) and Pan and Poteshman (2003) present evidence that options volume leads stock volume. Chakravarty, Gulen, and Mayhew (2004) also document that the options market contributes significantly to price discovery. Jennings and Starks (1986) also find that equity prices adjust to new information more rapidly for stocks with exchange-listed options.

On the other hand, researches who argue that informed trades should occur in the equity market first assert that the equity market is more liquid than the options market. The restricted liquidity of the options market discourages informed investors from executing trades there. In a study of transaction data, Stephan and Whaley (1990) report that the equity market leads the options market by more than 15 minutes. Vijh (1990) also reports minimal effects of large options trades suggesting that options trades are not informative.

Chan, Chung, and Johnson (1993), however, point out that Stephan and Whaley's (1990) results are biased because of price discreteness differences in the equity and options markets. Srinivas (1993) also suggests that Vijh's (1990) results suffer from sample selection bias, and report that options trades are informative. Using two months of TAQ data, Easley, O'Hara, and Srinivas (1998) report evidence consistent with a pooling equilibrium, or that informed trades are

executed in both equity and options markets. Nevertheless, Chan, Chung, and Fong (2002) present contrary evidence consistent with a separating equilibrium, where informed traders prefer to trade in the equity market. They report in the three months of data that net trade stock volume predicts contemporaneous and subsequent stock and options quote revisions, but net trade options volume does not predict stock quote revisions.

In sum, recently literature provides mixed results about the information flow between options and equity markets. These conflicting findings could be partially attributed to aggregating options data irrespective of options' moneyness and market cycles. If information content in the options market varies across options' moneyness, pooling all options together could blur the test results. Some studies also suggest that investors behave differently under different market conditions. Hamilton and Lin (1996) find higher volatility in periods of economic recession. This is reinforced by other findings that volatility levels tend to rise more with negative returns than positive returns (e.g., Bekaert and Wu, 2000). Given short-sale constraints, a bear market makes it more attractive for informed traders to trade in the options market than in the equity market. Wood, McNish, and Ord (1985) provide evidence that the equity return generating process differs in bull and bear markets. Lockwood and McNish (1990) find significant more volatile intraday returns during bear markets. Bittlingmayer (1998) also shows that stock volatility jumps during political tension periods. If trading in the options markets offers an advantage in trading information about volatility, informed traders should be more active during a bear market.

III. Relation between equity returns and options trading value ratios

To provide an analytical framework for our analysis, we adopt Chen, Lung and Tay (2004) options trading value ratio model to describe the relation between equity returns and options trading activities. The model provides us a way to mirror good news or bad news embedded in options trades. It assumes a two-state world where informed traders have information about the probabilities of the up and down markets. Informed traders are risk-averse, share the same log utility function, and have homogeneous expectations about market movements.

At time 0, the cash flows incurred by trading call and put options are as follows:

Cashflow = $-Q_C \times P_C$ for trading a call, and

Cashflow = $-Q_P \times P_P$ for trading a put.

where Q_C (Q_P) stands for call (put) trading volume, and P_C (P_P) is the call (put) premium. At the time of expiration, T , payoffs for the call and put options are:

$Q_C \times (S_u - X_C)$ for trading call when $prob(S = S_u) = \pi_u$, and

$Q_P \times (X_P - S_d)$ for trading put when $prob(S = S_d) = \pi_d$.

where S stands for the asset price, and $prob(S = S_u) = \pi_u$ and $prob(S = S_d) = \pi_d$ are the probabilities that the asset price will rise to S_u or fall to S_d at time T in the future. Without loss of generality, we assume the magnitudes of price up-movement and down-movement are the same in this model. X_C represents the exercise price of the call and X_P the exercise price of the put.

Given private information, if an informed trader would like to trade in the options market to maximize his or her expected utility and is subject to an initial wealth constraint of W_0 , the informed trader's objective function and constraints can be specified as follows:

$$\text{Maximize: } \pi_u U(Q_C \times (S_u - X_C)) + \pi_d U(Q_P \times (X_P - S_d)) \quad (1)$$

$$\text{Subject to: } Q_C \times P_C + Q_P \times P_P = W_0, \quad (2)$$

where U is a log utility function. The optimization problem can be represented in a Lagrange equation, L :

$$L = \pi_u \log [Q_C \times (S_u - X_C)] + \pi_d \log [Q_P \times (X_P - S_d)] - \lambda (Q_C \times P_C + Q_P \times P_P - W_0) \quad (3)$$

Where λ is the Lagrange multiplier.

Solving the first-order conditions of Equation (3) leads to the two equations:¹

$$\pi_u = \lambda \times P_C \times Q_C \quad (4)$$

$$\pi_d = \lambda \times P_P \times Q_P \quad (5)$$

Dividing Equation (4) by Equation (5), we obtain the following relation:

$$\pi_u / \pi_d = (Q_C \times P_C) / (Q_P \times P_P) \quad (6)$$

Equation (6) suggests that the ratio of the probability of a price increase (π_u) to the probability of a price decline (π_d) is equal to the ratio of the call trading value ($Q_C \times P_C$) to the put trading value ($Q_P \times P_P$). Therefore, it is possible for the market participants to deduce the relative magnitude of the unobserved probabilities of equity prices changes by observing the ratio of options trading values. When the call-put options trading value ratio (hereafter VR), $(Q_C \times P_C) / (Q_P \times P_P)$, is higher (lower) than unity, stock returns are more likely to be positive (negative). According to our simple model, therefore, the VR is a measure for distinguishing “good” and “bad” news information embedded in options trades.

¹ The optimum condition in Equation (6) has the correct second-order condition. The mathematical proof is available upon request.

Using the put-call volume ratio in technical analysis to measure market sentiment is not new, but our model includes a ratio that considers both options trading volumes and premiums. This is consistent with Chen and Goodhart (1998), who argue that volume alone does not reveal the complete picture regarding market expectations. That is, an increase in demand can be simply offset by an increase in supply, which would leave options premiums unchanged if trades incorporate no information. If an increase in demand (supply) reflects new information, however, options dealers will adjust options premiums upward (downward). An options trading value ratio, therefore, is more informative than trading volume alone.

IV. Data and descriptive statistics

We employ intraday transactions data for the TXO cash index and options from the *Taiwan Economic Journal* (TEJ) database, which records trade-by-trade transactions from January 2, 2002, through May 25, 2004. TXO trading began on December 24, 2001. The underlying asset is the Taiwan Stock Exchange Capitalization Weighted Stock Index. The call options and put options are European style. From the beginning, trading frequency and trading volume of the TXO has exceeded that of many other index options, such as Hong Kong Hang Seng index options and S&P 500 options on futures. The database includes trading time (year, month, date, hour, minute, and second), strike price, expiration date, options transaction price, options type, trading volume, and open interest. The particular sampling period is unique because it consists of a downtrend market, January 2, 2002, through April 30, 2003; an uptrend

market between May 1, 2003, and March 19, 2004; and a period of political tension from March 20, 2004, through May 25, 2004.²

Regular trading hours for TXO options run from 8:45 AM to 1:45 PM (Taipei time) and for Taiwan stocks from 9:00 AM to 1:30 PM. To minimize possible measurement errors arising from the different trading hours, we use TXO options data between the 9:00 AM to 1:30 PM stock trading hours. We also limit the sample to options expiring at between 10 and 90 days. Options with maturities shorter than 10 days are excluded because of position-squaring activities; options with maturities longer than 90 days are excluded because of thin trading.

Additionally, we only employ TXO options with strike prices between 80 percent and 120 percent of the prevailing Taiwan stock index. As options with different moneyness have distinct liquidity, leverage effect, delta (sensitivity to spot price movements), and vega (sensitivity to volatility), we examine the informational role of options across different ranges of options moneyness. We define OTM call (put) options as options with strike prices ranging between 102 (80) percent and 120 (98) percent of the underlying asset price; ATM options as options with strike prices ranging between 98 percent and 102 percent of the underlying asset price; and ITM call (put) options as options with strike prices ranging between 80 (102) percent and 98 (120) percent of the underlying asset price.

To examine intraday informed trading patterns, we use a 15-minute trading interval to measure Taiwan stock index returns and TXO options trading activities. Table 1 presents descriptive statistics of 15-minute returns for the Taiwan stock index. The entire sample is divided into three subperiods: a downtrend market, an uptrend market, and a political tension

² The Taiwan equity market was severely affected by circumstances surrounding the presidential election in late March 2004.

market. We choose April 30, 2003, as the dividing line between the downtrend and uptrend markets because the Taiwan stock index started moving up on that day. We select March 20, 2004, to separate the uptrend and political tension markets as it is around that date that the political tension started. During the entire sample period, 15-minute mean returns are 0.0003% and with a volatility of 0.5473%. The equity market in both downtrend and political tension periods is more volatile than in the uptrend period. This result is consistent with the previous findings that the equity return-generating process differs between downtrend and uptrend markets (Wood, McInish, and Ord, 1985) and that intraday returns are significantly more volatile during bear markets (Lockwood and McInish, 1990) and the political tension period (Bittlingmayer, 1998).

Insert Table 1 about here

To gain a better understanding about the subperiod selection, we plot Taiwan stock index levels and returns in Figure I. Figure I.a shows the index for the complete sample. Figure I.b depicts 15-minute returns for the index. It is worth noting that volatility declines as the market turns into the uptrend in May 2003 and but jumps again when political tension occurs in March 2004. This is consistent with the research findings that volatility during a bear market is higher than in a bull market.

Insert Figure I about here

Table 2 reports descriptive statistics for TXO options trading activities. During the entire sample period, there are 2,651,150 transaction records for call options, and 2,221,894 for puts. The average number of trades per 15-minute interval for call options is 180, and for puts 151. Call options are traded more frequently than put options. Trading volumes also display a similar pattern. This finding is different from other studies in mature options markets where the evidence is that put options are more heavily traded than calls. Bollen and Whaley (2004), for example, show that in S&P 500 index options markets put options account for 55% of overall options trading and call options 45%, because of hedging activities.

With respect to the three subperiods, the results share a similar pattern to the entire sample period. The downtrend period has the lowest trading activities among the three subperiods, because the TXO options market is at its infant stage during the downtrend period. It is also worth noting that during the political tension period, the average trading volume of put options is higher than that of call options. When we classify options in terms of moneyness, we find among ITM and ATM options categories that call options are more heavily traded than put options. For OTM options, the pattern is different. During the entire sample period, average OTM options trading volume per 15-minute interval is 605 for put options compared to 551 for calls. This pattern is particularly pronounced in political tension periods. OTM options also tend to be more liquid than other options; average transaction numbers and trading volume for OTM options are higher than other options across all subperiods.

Insert Table 2 about here

V. Method

To analyze informed trading in the TXO options market, we examine the lead-lag relationship between options trading value ratio and stock index returns for the full sample period and for three subperiods that represent different market cycles. According to the prediction of our model, we use equity returns and options trading value ratios in a bivariate vector autoregression (VAR) system to examine whether the current options market (stock market) conveys information that is useful in predicting future stock market (options market) behavior. The bivariate VAR system is:

$$VR_t = \sum_{i=1}^n \eta_i VR_{t-i} + \sum_{i=1}^n \delta_i R_{t-i} + \xi_t \quad (7)$$

$$R_t = \sum_{i=1}^n \alpha_i R_{t-i} + \sum_{i=1}^n \beta_i VR_{t-i} + \pi_t \quad (8)$$

Equation (7) tests whether lagged stock returns (R_{t-i}) conveys information regarding the behavior of future options trading value ratio (VR). Lagged VR s are included in the equation to account for possible serial correlation in VR . Equation (8) examines whether lagged VR s convey information regarding the behavior of future stock return controlling for lagged stock returns. We determine the optimal number of lags in Equations (7) and (8) using the Akaike information criterion (AIC).³

Following Easley, O'Hara, and Srinivas (1998) and Chan, Chung, and Fong (2002), we standardize all variables (R and VR) in both equations to control for cross-sectional variations across different index levels and options. That is, we subtract the mean from the value of the variable and then divide the de-measured value by the standard deviation of that specific variable.

³ Following the practice in prior studies (e.g., Anthony, 1988), for a robust test, we also set all lag lengths at six. The results are qualitatively similar.

As it has been well documented that stock returns are autocorrelated and heteroskedastic (e.g., Conrad and Kaul, 1988 and Lo and MacKinlay, 1988), we estimate Equations (7) and (8) using the generalized method of moments (GMM) method.

If informed investors initiate trades in the stock market, the stock market will be first to receive the information. Stock returns would therefore include useful information for predicting future transactions in the options market. Thus, at least some of the δ coefficients in Equation (7) will be positive and statistically significant. If informed trades occur instead in the options market first, information will move from that market to the stock market, and VR could predict future stock return changes. Thus, some of the β coefficients in Equation (8) will be positive and statistically significant. Alternatively, if some of the δ and β are both statistically significant, there is a feedback relation between the two markets. Such a result would be consistent with the notion of a pooling equilibrium; that is, informed traders trade in both equity and options markets.

We estimate Equations (7) and (8) for the different periods and different options moneyness, and examine three hypotheses. First, as some research argues that, in a frictionless, dynamically complete market, options are redundant, informed traders would not trade in the options market; and, thus, equity market returns should lead options market value ratios. We examine whether information travels from the equity to the options market, or vice versa. Second, proponents of options market as the preferred trading place for informed trading note that options delta, vega, and leverage could determine the informed traders' choice. Therefore, we also analyze the information content of options as regarding future equity returns across options moneyness. If trading costs and delta play a role in determining where informed traders trade, ITM options should convey more information about future returns; if volatility is a factor

affecting informed trading, ATM options should contribute more to price discovery; if leverage is a factor for informed traders, OTM options should invite more informed trading. Finally, if the short-sale constraint and the 7% price change limit prompt informed traders to change their trading locations during different phases of the market cycles, we would expect TXO options to attract more informed trading during the downtrend and political tension periods in Taiwan. Partitioning the empirical analysis by different moneyness and market conditions, we shed some light on informed trading behavior.

VI. Results

We discuss the results separately for the entire period and for various subperiods.

VI. i. Results based on entire sampling period

We report the results of Equations (7) and (8) in Table 3 for the entire sampling period. To conserve space, we do not report parameter estimates of other variables (i.e., lagged VR in Equation (7), and lagged stock returns in Equation (8)). The Akaike information criterion determines the optimal number of lags.

After aggregating all options, our results for the whole sample are consistent with the argument that informed trades occur in the equity market because virtually all the lag returns significantly and positively impact VR , suggesting that the equity market leads the options market. The p-value for Equation (7) is less than 1%, but it is not significant for Equation (8). This finding is consistent across all options moneyness with the exception of the OTM sample.

For the OTM sample, we find a lead-lag relation from VR to equity returns. The p-value for Equation (8) is less than 1%, and we find that VR_{t-1} , VR_{t-2} , VR_{t-4} , VR_{t-5} , and VR_{t-6} significantly and positively impact R_t . Hence, in the TXO options market, OTM options lead equity returns

up to by 90 minutes (6×15 minutes). We conclude that informed traders view OTM options as a superior instrument for trading their information. Given these OTM results in Table 3, it is interesting to speculate what makes informed traders to execute their trades using OTM options rather than ATM and/or ITM options. We conjecture that the leverage effect and liquidity of OTM options in the TXO options market entices informed traders to use them (see Black, 1975, Meyhew et al., 1995, and Chakravarty et al., 2004). OTM options generally have lower premiums and higher delta-to-premium ratios, letting informed investors maximize their gains per dollar invested.

Insert Table 3 about here

VI. ii. Results for downtrend period

The downtrend period runs from January 2, 2002, through April 30, 2003. In the downtrend period, the equity returns are more volatile than the uptrend period. Accordingly, the short-sale constraint and the 7% price change limit are a crucial concern for investors, we expect such a market environment to confirm the acceptance of the hypothesis that informed trades occur in the TXO options market.

Table 4 reports the results of Equations (7) and (8) for the downtrend period. There are two major differences from results in Table 3. First, although equity returns still lead the options trading value ratio in all equations (with the exception of OTM options), the parameters and statistical significance are lower than the same statistics in Table 3. Second, across all options moneyness, prices adjust more quickly in the options market in the downtrend period than during the overall period; the AIC criterion produces fewer lags for Equation (7) in the regression

equations. For the OTM options results, none of the lagged stock returns are statistically significant. The F-statistics also suggest that lagged R s are not jointly significant in determining the VR . Moreover, the VR s of OTM options lead equity returns by up to 105 minutes ($7 \text{ lags} \times 15 \text{ minutes}$). The test results in Table 4 indicate that the short-sale constraint and the price limit in Taiwan equity markets tend to encourage informed trading in the TXO options market. Informed traders are more active in the options market during the downtrend period.

Insert Table 4 about here

VI. iii. Results for uptrend period

The uptrend period runs from May 1, 2003, through March 20, 2004. The equity return volatility is lower during this period, and investors are less likely to consider short-sale constraints in the equity market. We would expect such a market environment to favor the hypothesis that informed trades occur in the equity market first.

Table 5 reports VAR equation for the uptrend market. As expected, except in OTM options, equity returns (especially one period lagged return) lead options trading value ratios in all equations. This suggests that informed traders trade their private information in the equity market first during a bull market. This result is thus consistent with the separating equilibrium results reported in Chan, Chung, and Fong (2002). Note that Chan, Chung, and Fong use 1995 data examining a bullish market year when large-company stocks earned 37% total returns (see *Stocks, Bonds, Bills, and Inflation*, 2000).

Parameters and t-statistics of R_{t-1} are higher in Table 5, consistent with the argument that trading on information in the equity market is stronger in a bull market. For example, for all

options, the F-statistic is 14.36 for Equation (7) in Table 5 compared to only 2.04 in Table 4. There is a weak feedback relation between OTM options value ratios and equity returns during the uptrend period. The evidence implies that as the short-sale constraint becomes less important, the leverage effect alone does not motivate informed traders to trade their information solely in the options market.

Insert Table 5 about here

VI. iv. Results for the political tension period

The political tension period runs from March 21, 2004, through May 25, 2004.⁴ This period has a more radical drop in the Taiwan stock market than the downtrend period during 2002-2003. Thus, short-sale constraints and the 7% price change limit represent more crucial concern to informed traders. We would expect a political tension environment to encourage more informed trading in the TXO options market.

Table 6 reports the results for this period. Although equity returns still lead all options value ratios, we find the lead-lag relation from R to VR is attributable mainly to ITM options. Not surprisingly, OTM options lead returns by up to 9 lags, about 2 hours and 15 minutes. This indicates again that leverage effect plays a role in determining informed trading. Interestingly, ATM options value ratios in the political tension period also lead equity returns. This suggests that volatility relates to which type of options informed traders trade in the options market. The findings in Table 6 are consistent with the pooling equilibrium results in Easley, O'Hara, and Srinivas (1998), whose study period in 1990 experienced a negative stock market return (-3% for

⁴ When we extend the period through September 2004, results are qualitatively similar.

large-company stocks, and -21% for small-company stocks in *Stocks, Bonds, Bills, and Inflation*, 2000).

Insert Table 6 about here

VII. Summary

We examine the informed trading activities in the Taiwan emerging options market in different market cycles, and for options with different moneyness. The informed trading in the emerging market is intriguing not only to academicians but also to policymakers and practitioners. The literature has provided conflicting findings as to information flow between the equity and the options markets. Our empirical results suggest that, without consideration of different options moneyness and market cycles, we are likely to find information flow from the equity to the options market. Deeper analysis of options moneyness in different market conditions suggest that informed trading does occur in the options market.

The TXO options market offers us an ideal environment to examine whether options vega, delta, liquidity, and leverage affect informed traders' behavior in the equity and the options markets under different market cycles and regulations. The 7% price change limit and loose regulations on insider trading allow a good look at informed trading behavior. The evidence shows that informed trading differs across market conditions and varies with options moneyness; analyzing data without regard to market cycle and options moneyness cannot provide a complete picture of informed trading.

We offer three important findings. First, we show that equity returns lead options trading value ratios during the full sample period, with the exception of OTM options. This result

indicates that informed traders tend to use OTM options to capitalize on their information. Liquidity and leverage effects make OTM options more attractive to informed trades. Second, we find that the leading role of equity markets becomes weaker in the downtrend and political tension periods. Options prices adjust more quickly and OTM options are more likely to be the favored tools by informed traders in a bear market. With the short-sale constraint and price limits in the equity markets, informed traders become more active in options market. Third, during the uptrend market, equity returns lead the options value ratios with the exception that OTM options showing a feedback relation. This suggests a separating equilibrium. When short-sale constraints and price limits are less important, informed trading is more likely to occur in the equity markets. Thus, leverage effect plays a minor role in determining the choice of informed traders.

In sum, our empirical results suggest that the equity market is the preferred place to trade information during an uptrend period, whereas informed trading occurs in both equity and options markets during a downtrend period. Moreover, regardless of the market conditions, informed trading is most likely to occur in OTM options. That lead-lag relation from OTM options value ratios to equity returns is particularly profound in the downtrend and political tension periods. This indicates that leverage effect is interacted with the price limits in affecting where informed traders trade.

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Table 1. Descriptive statistics for Taiwan Stock Index 15-minute returns

This table presents descriptive statistics for Taiwan index returns in 15-minute interval. The entire sample is divided into three subperiods. Downtrend market runs from January, 2002 to April, 2003; uptrend market runs from May, 2003 to March, 2004; and political tension market starts after March 2004. We choose April 2003 as the dividing line between the downtrend and uptrend markets because the Taiwan stock index started moving up in April 2003. We select March 20, 2004, to separate the uptrend and political tension markets as this is around the time when the political tension started.

| | Obs. | Mean | Std. | Min | Max | Skewness |
|--|--------|----------|---------|----------|---------|----------|
| Entire period (01/02/2002~05/25/2004) | 14,742 | 0.0003% | 0.5473% | -6.9255% | 9.3169% | 0.17 |
| Downtrend (01/02/2002~04/30/2003) | 6,992 | -0.0042% | 0.6103% | -6.4511% | 9.3169% | 0.46 |
| Uptrend (05/01/2003~03/19/2004) | 4,809 | 0.0103% | 0.4085% | -3.4921% | 3.4967% | 0.16 |
| Political tension (03/20/2004~05/25/2004) | 2,941 | -0.0052% | 0.5959% | -6.9255% | 6.9268% | -0.59 |

Table 2. Trading activities of Taiwan Index Options

This table presents trading activities for Taiwan stock index options. We define OTM call (put) options as options with strike price ranging between 102 (80) percent and 120 (98) percent of the underlying asset price, ATM options as options with strike price ranging between 98 percent and 102 percent of the underlying asset price, and ITM call (put) options as options with strike price ranging between 80 (102) percent and 98 (120) percent of the underlying asset price.

| | | Call | | | | Put | | | |
|-------------|-------------------|-------------|-------------|------------|-------------|-------------|-------------|------------|-------------|
| | | Transaction | | Volume | | Transaction | | Volume | |
| | | Number | Avg./15-min | Number | Avg./15-min | Number | Avg./15-min | Number | Avg./15-min |
| All options | Entire period | 2,651,150 | 180 | 15,372,811 | 1,043 | 2,221,894 | 151 | 14,067,902 | 954 |
| | Downtrend | 466,171 | 67 | 2,115,801 | 303 | 369,641 | 53 | 1,640,688 | 235 |
| | Uptrend | 1,383,917 | 288 | 9,018,739 | 1,875 | 1,206,526 | 251 | 8,137,747 | 1,692 |
| | Political tension | 801,062 | 272 | 4,238,271 | 1,441 | 645,727 | 220 | 4,289,467 | 1,459 |
| ITM | Entire period | 347,588 | 24 | 1,540,511 | 104 | 177,986 | 12 | 875,488 | 59 |
| | Downtrend | 54,618 | 8 | 197,418 | 28 | 38,784 | 6 | 166,889 | 24 |
| | Uptrend | 197,590 | 41 | 975,961 | 203 | 83,104 | 17 | 387,591 | 81 |
| | Political tension | 95,380 | 32 | 367,132 | 125 | 56,098 | 19 | 321,008 | 109 |
| ATM | Entire period | 1,035,147 | 70 | 5,715,678 | 388 | 786,501 | 53 | 4,273,263 | 290 |
| | Downtrend | 151,283 | 22 | 585,136 | 84 | 115,446 | 17 | 451,389 | 65 |
| | Uptrend | 612,842 | 127 | 3,740,850 | 778 | 482,229 | 100 | 2,916,527 | 606 |
| | Political tension | 271,022 | 92 | 1,389,692 | 473 | 188,826 | 64 | 905,347 | 308 |
| OTM | Entire period | 1,268,415 | 86 | 8,116,622 | 551 | 1,257,407 | 85 | 8,919,151 | 605 |
| | Downtrend | 260,270 | 37 | 1,333,247 | 191 | 215,411 | 31 | 1,022,410 | 146 |
| | Uptrend | 573,485 | 119 | 4,301,928 | 895 | 641,193 | 133 | 4,833,629 | 1,005 |
| | Political tension | 434,660 | 148 | 2,481,447 | 844 | 400,803 | 136 | 3,063,112 | 1,042 |

Table 3. VAR test results for the TXO options market during the entire sample period (01/02/2002~05/25/2004)

$$VR_t = \sum_{i=1}^n \eta_i VR_{t-i} + \sum_{i=1}^n \delta_i R_{t-i} + \xi_t \quad (7)$$

$$R_t = \sum_{i=1}^n \alpha_i R_{t-i} + \sum_{i=1}^n \beta_i VR_{t-i} + \pi_t \quad (8)$$

This table reports the bivariate VAR test results based on the entire sample period. Both returns and options value ratios are calculated in 15-minute intervals. R denotes the Taiwan stock index returns. VR is options trading value ratio estimated according to Equation (6). Equation (7) tests the lead-lag relation from equity returns to VR , and Equation (8) tests the lead-lag relation from VR to equity returns. Optimal lags of the regressors are determined by the AIC criterion, and all equations are estimated using the general methods of moments (GMM) regressions.

| | Lag1 | Lag2 | Lag3 | Lag4 | Lag5 | Lag6 | Lag7 | Lag8 | Obs. | F-statistic | P-value |
|----------------|--------|---------|---------|---------|---------|---------|--------|--------|--------|-------------|---------|
| ALL | | | | | | | | | | | |
| <i>R to VR</i> | 0.0193 | 0.0423 | 0.0466 | 0.0252 | | | | | 12,682 | 5.02 | 0.05% |
| t-statistic | 1.80 | 3.52 | 3.87 | 2.36 | | | | | | | |
| <i>VR to R</i> | 0.0071 | -0.0118 | 0.0009 | -0.0030 | | | | | 12,682 | 0.88 | 47.43% |
| t-statistic | 0.97 | -1.59 | 0.13 | -0.40 | | | | | | | |
| ITM | | | | | | | | | | | |
| <i>R to VR</i> | 0.0389 | 0.0672 | 0.0634 | 0.0232 | 0.0355 | -0.0069 | 0.0123 | 0.0123 | 12,170 | 9.78 | 0.00% |
| t-statistic | 4.11 | 6.29 | 5.89 | 2.15 | 3.30 | -0.64 | 1.14 | 1.29 | | | |
| <i>VR to R</i> | 0.0023 | -0.0061 | -0.0050 | 0.0099 | -0.0069 | 0.0018 | 0.0029 | 0.0114 | 12,170 | 0.58 | 79.62% |
| t-statistic | 0.27 | -0.67 | -0.55 | 1.09 | -0.76 | 0.19 | 0.32 | 1.32 | | | |
| ATM | | | | | | | | | | | |
| <i>R to VR</i> | 0.0248 | 0.0300 | 0.0264 | 0.0206 | 0.0234 | | | | 12,653 | 3.60 | 0.30% |
| t-statistic | 2.59 | 2.79 | 2.44 | 1.91 | 2.45 | | | | | | |
| <i>VR to R</i> | 0.0118 | 0.0020 | 0.0045 | 0.5056 | 0.5859 | | | | 12,653 | 1.66 | 14.03% |
| t-statistic | 1.43 | 0.23 | 0.51 | 0.59 | 1.08 | | | | | | |
| OTM | | | | | | | | | | | |
| <i>R to VR</i> | 0.0041 | -0.0065 | -0.0096 | -0.0094 | 0.0114 | 0.0077 | | | 12,245 | 1.58 | 14.95% |
| t-statistic | 1.87 | -0.97 | -1.42 | -1.38 | 1.70 | 1.29 | | | | | |
| <i>VR to R</i> | 0.0246 | 0.0229 | 0.0200 | 0.0129 | 0.0382 | 0.0368 | | | 12,245 | 3.28 | 0.32% |
| t-statistic | 1.96 | 1.71 | 1.24 | 1.79 | 2.36 | 2.94 | | | | | |

Table 4. VAR test results for the TXO options market during the downtrend sample period (01/02/2002~04/30/2003)

$$VR_t = \sum_{i=1}^n \eta_i VR_{t-i} + \sum_{i=1}^n \delta_i R_{t-i} + \xi_t \quad (7)$$

$$R_t = \sum_{i=1}^n \alpha_i R_{t-i} + \sum_{i=1}^n \beta_i VR_{t-i} + \pi_t \quad (8)$$

This table reports the bivariate VAR test results based on the downtrend sample period. Both returns and options value ratios are calculated in 15-minute intervals. R denotes the Taiwan stock index returns. VR is options trading value ratio estimated according to Equation (6). Equation (7) examines lead-lag relation from equity returns to VR, and Equation (8) tests the lead-lag relation from VR to equity returns. Optimal lags of the regressors are determined by the AIC criterion, and all equations are estimated using the general methods of moments (GMM) regressions.

| | Lag1 | Lag2 | Lag3 | Lag4 | Lag5 | Lag6 | Lag7 | Lag8 | Obs. | F-statistic | P-value |
|-------------|--------|---------|---------|---------|---------|--------|---------|------|-------|-------------|---------|
| ALL | | | | | | | | | | | |
| R to VR | 0.0191 | 0.0466 | 0.0566 | 0.0335 | 0.0078 | | | | 6,972 | 2.04 | 7.05% |
| t-statistic | 1.09 | 2.37 | 2.86 | 1.70 | 0.45 | | | | | | |
| VR to R | 0.0058 | -0.0124 | 0.0004 | 0.0503 | -0.4509 | | | | 6,972 | 0.78 | 56.42% |
| t-statistic | 0.70 | -1.51 | 0.05 | -0.45 | -0.93 | | | | | | |
| ITM | | | | | | | | | | | |
| R to VR | 0.0274 | 0.0409 | 0.0457 | 0.0140 | 0.0473 | | | | 6,464 | 21.16 | 0.00% |
| t-statistic | 3.96 | 5.25 | 5.83 | 1.79 | 6.80 | | | | | | |
| VR to R | 0.0056 | -0.0002 | -0.0017 | -0.0712 | -0.0067 | | | | 6,464 | 0.06 | 99.81% |
| t-statistic | 0.25 | -0.01 | -0.07 | -0.01 | 0.26 | | | | | | |
| ATM | | | | | | | | | | | |
| R to VR | 0.0330 | 0.0368 | 0.0323 | 0.0215 | 0.0309 | | | | 6,944 | 2.27 | 4.53% |
| t-statistic | 2.13 | 2.10 | 1.84 | 1.23 | 1.99 | | | | | | |
| VR to R | 0.0112 | 0.0041 | 0.0055 | 0.5502 | 0.7468 | | | | 6,944 | 1.71 | 12.85% |
| t-statistic | 1.21 | 0.42 | 0.55 | 0.75 | 1.05 | | | | | | |
| OTM | | | | | | | | | | | |
| R to VR | 0.0023 | -0.0088 | -0.0142 | -0.0133 | 0.0162 | 0.0049 | -0.0086 | | 6,535 | 1.16 | 32.02% |
| t-statistic | 0.23 | -0.78 | -1.26 | -1.18 | 1.44 | 0.44 | -0.86 | | | | |
| VR to R | 0.0213 | -0.0225 | 0.0205 | -0.0127 | 0.0384 | 0.0364 | 0.0452 | | 6,535 | 2.91 | 0.30% |
| t-statistic | 2.14 | -1.14 | 1.13 | -0.70 | 2.12 | 1.85 | 2.03 | | | | |

Table 5. VAR test results for the TXO options market during the uptrend sample period (05/01/2003~03/19/2004)

$$VR_t = \sum_{i=1}^n \eta_i VR_{t-i} + \sum_{i=1}^n \delta_i R_{t-i} + \xi_t \quad (7)$$

$$R_t = \sum_{i=1}^n \alpha_i R_{t-i} + \sum_{i=1}^n \beta_i VR_{t-i} + \pi_t \quad (8)$$

This table reports the bivariate VAR test results based on the uptrend sample period. Both returns and options value ratios are calculated in 15-minute intervals. R denotes the Taiwan stock index returns. VR is options trading value ratio estimated according to Equation (6). Equation (7) examines lead-lag relation from equity returns to VR , and Equation (8) tests the lead-lag relation from VR to equity returns. Optimal lags of the regressors are determined by the AIC criterion, and all equations are estimated using the general methods of moments (GMM) regressions.

| | Lag1 | Lag2 | Lag3 | Lag4 | Lag5 | Lag6 | Lag7 | Lag8 | Obs. | F-statistic | P-value |
|-------------|--------|---------|---------|---------|---------|---------|---------|---------|-------|-------------|---------|
| ALL | | | | | | | | | | | |
| R to VR | 0.0136 | 0.0231 | 0.0146 | 0.0137 | 0.0104 | 0.0050 | | | 4,810 | 14.36 | 0.00% |
| t-statistic | 5.46 | 8.15 | 5.05 | 4.73 | 3.66 | 2.00 | | | | | |
| VR to R | 0.1469 | -0.0523 | 0.0356 | -0.0355 | 0.0602 | -0.0374 | | | 4,810 | 1.02 | 40.79% |
| t-statistic | 1.74 | -0.57 | 0.39 | -0.39 | 0.66 | -0.45 | | | | | |
| ITM | | | | | | | | | | | |
| R to VR | 0.0738 | 0.1465 | 0.1192 | 0.0531 | 0.0549 | 0.0159 | | | 4,810 | 5.37 | 0.00% |
| t-statistic | 2.88 | 5.02 | 4.03 | 1.79 | 1.88 | 0.62 | | | | | |
| VR to R | 0.0029 | -0.0073 | -0.0091 | 0.0106 | -0.0097 | 0.0153 | | | 4,810 | 1.23 | 28.72% |
| t-statistic | 0.36 | -0.87 | -1.09 | 1.27 | -1.16 | 1.89 | | | | | |
| ATM | | | | | | | | | | | |
| R to VR | 0.0129 | 0.0253 | 0.0202 | 0.0244 | 0.0149 | 0.0111 | 0.0186 | 0.0137 | 4,810 | 7.78 | 0.00% |
| t-statistic | 2.97 | 5.19 | 4.07 | 4.92 | 3.01 | 2.25 | 3.79 | 3.17 | | | |
| VR to R | 0.1052 | 0.0141 | 0.0212 | -0.0163 | 0.0111 | -0.0624 | -0.0376 | -0.0086 | 4,810 | 1.13 | 34.21% |
| t-statistic | 2.17 | 0.27 | 0.41 | -0.31 | 0.21 | -1.20 | -0.73 | -0.18 | | | |
| OTM | | | | | | | | | | | |
| R to VR | 0.0000 | 0.0000 | 0.0000 | 0.0000 | | | | | 4,571 | 2.19 | 7.50% |
| t-statistic | 1.69 | 1.83 | -2.07 | -0.61 | | | | | | | |
| VR to R | 0.0166 | 0.01278 | -0.0578 | 0.0746 | | | | | 4,571 | 2.86 | 1.92% |
| t-statistic | 2.25 | 1.93 | -0.42 | 2.18 | | | | | | | |

Table 6. VAR test results for the TXO options market during the political tension sample period (03/20/2004~05/25/2004)

$$VR_t = \sum_{i=1}^n \eta_i VR_{t-i} + \sum_{i=1}^n \delta_i R_{t-i} + \xi_t \quad (7)$$

$$R_t = \sum_{i=1}^n \alpha_i R_{t-i} + \sum_{i=1}^n \beta_i VR_{t-i} + \pi_t \quad (8)$$

This table reports the bivariate VAR test results based on the political tension sample period. Both returns and options value ratios are calculated in 15-minute interval. R denotes the Taiwan stock index returns. VR is options trading value ratio estimated according to Equation (6). Equation (7) examines lead-lag relation from equity returns to VR, and Equation (8) tests the lead-lag relation from VR to equity returns. Optimal lags of the regressors are determined by the AIC criterion, and all equations are estimated using the general methods of moments (GMM) regressions.

| ALL | Lag1 | Lag2 | Lag3 | Lag4 | Lag5 | Lag6 | Lag7 | Lag8 | Lag9 | Obs. | F-statistic | P-value |
|-------------|---------|---------|---------|---------|---------|--------|--------|--------|--------|------|-------------|---------|
| R to VR | 0.0054 | 0.0096 | 0.0095 | 0.0049 | 0.0002 | | | | | 899 | 4.54 | 0.04% |
| t-statistic | 2.46 | 3.78 | 3.75 | 1.92 | 0.08 | | | | | | | |
| VR to R | 0.6183 | -0.3857 | -0.2914 | -0.5252 | -0.2587 | | | | | 899 | 0.58 | 71.87% |
| t-statistic | 1.20 | -0.69 | -0.53 | -0.26 | 0.93 | | | | | | | |
| ITM | | | | | | | | | | | | |
| R to VR | 0.0308 | 0.0282 | 0.0333 | 0.0301 | | | | | | 899 | 3.54 | 6.78% |
| t-statistic | 1.86 | 1.70 | 0.83 | 0.85 | | | | | | | | |
| VR to R | -0.0156 | -0.0058 | 0.0260 | 0.0066 | | | | | | 899 | 0.26 | 90.46% |
| t-statistic | -0.50 | -0.17 | 0.76 | 0.21 | | | | | | | | |
| ATM | | | | | | | | | | | | |
| R to VR | 0.0063 | 0.0112 | 0.0056 | | | | | | | 899 | 1.00 | 39.27% |
| t-statistic | 1.07 | 1.69 | 0.96 | | | | | | | | | |
| VR to R | 0.2085 | 0.4770 | -0.1653 | | | | | | | 899 | 3.69 | 1.17% |
| t-statistic | 1.78 | 2.18 | -0.86 | | | | | | | | | |
| OTM | | | | | | | | | | | | |
| R to VR | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 899 | 1.35 | 20.31% |
| t-statistic | -1.48 | -1.28 | 0.80 | 0.30 | -0.62 | -1.48 | -0.35 | -0.55 | 1.68 | | | |
| VR to R | 0.0224 | 0.0217 | 0.0634 | 0.0302 | 0.0510 | 0.0701 | 0.1153 | 0.0221 | 0.0566 | 899 | 2.63 | 5.17% |
| t-statistic | 1.84 | 2.56 | 1.96 | 0.78 | 1.31 | 2.18 | 2.97 | 0.57 | 1.66 | | | |

Figure I. Taiwan Stock Index from 01/02/2002 through 05/25/2004

This figure depicts Taiwan stock index spot levels and returns in a 15-minute interval from January 2002 through May 2004.

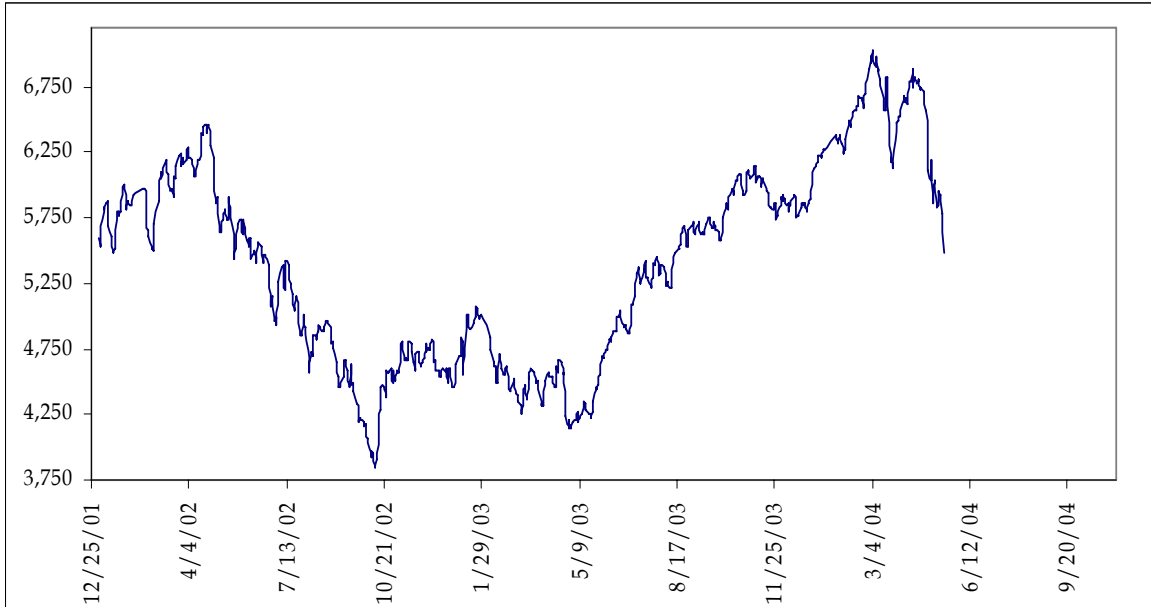


Figure I.a Taiwan Stock Index Spot

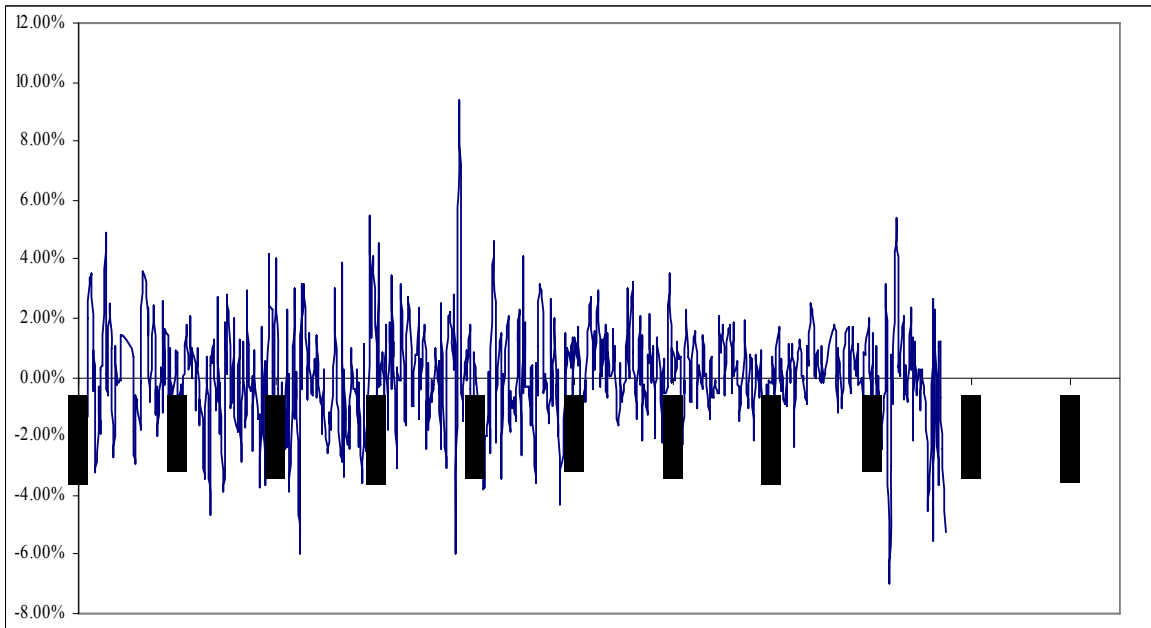


Figure I.b Taiwan Stock Index Return