International Review of
Accounting, Banking and Finance
Vol 2, No. 2, Summer 2010 Page 50~83

IRABF
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The Effect of Net Buying Pressure on Implied Volatility: Empirical Study on Taiwan's Options Market

Chang-Wen Duan[a] , Ken Hung[b]

a. Department of Banking and Finance, Tamkang University, Taiwan
b. Sanchez School of Business, Texas A&M International University, Laredo Texas

Abstract: We examine the implied volatility of TAIEX options with the net buying pressure hypothesis. Empirical results find that the implied volatility of TAIEX options exhibits negative skewness, which is caused by the net buying pressure and is dependent on the time-to-maturity of the options contract. The effect of net buying pressure is most significant in options with longer maturity. After controlling the information flow and leverage effect, our empirical results show that net buying pressure is attributed to limits to arbitrage in the Taiwan options market. As institutional investors have greater hedging demand for out-of-the-money puts, we also conclude that net buying pressure has the biggest influence on the implied volatility of out-of-the-money puts. The trading simulation results support the net buying pressure hypothesis. Finally, we also show that Taiwan's option investors are volatility traders.

1. Introduction

Based on the Black-Scholes (BS) model, options with the same underlying asset and the same expiration date should have the same implied volatility function (IVF), meaning that the IVF is constant. However MecBeth and Merville (1979) and Rubinstein (1985) provide persuasive evidence that rejects such an assumption. However, There is no doubt about the high correlation between implied volatility (IV) and moneyness in the options market. Many prior many literatures find that the IV and moneyness of options show a smile or smirk pattern. Since the 1987 market crash, the shape of index options IV across different exercise prices tends to be downward sloping. That is, IV shows the negative skew or sneer pattern. Sheikh (1991), and Bollen and Whaley (2004) have all found negative skew in IV of index options, that is, IV and moneyness are inversely related.

Many attempts are made to explain the volatility smile. But those studies are short of providing a complete and satisfactory explanation. First of all, most literature attributes the volatility smile to the strict assumptions of the BS model and then attempt to modify the BS model with a one factor stochastic model assumption to describe volatility smile. (e.g., the general CEV process of Cox and Ross (1976); the exact-fitting dynamics of Dupire (1994) and Derman and Kani (1998); the implied binomial tree model of Rubinstein (1994), stochastic volatility model of Hull and White (1987) and Heston (1993); and the jump-diffusion model of Merton (1976)).

Some recent literature set out from the assumption of a perfect market and attempts to explain volatility smile by market failures, such as discrete trades, transaction costs, non-synchronized trading, and market order imbalance. Hestschel (2003) points out that even if the price of the underlying asset follows the BS assumption of lognormal distribution, market imperfection would generate volatility smile. Dennis and Mayhew (2002) employs call-put volume ratio as a proxy variable of trading pressure to explain the risk-neutral skewness of volatility. Bollen and Whaley (2004) contend that order imbalance is the main cause of volatility smile. They quantify the investor demands for S&P 500 index options, define it as net buying pressure, and conclude that the inverse relation between IV and moneyness is attributed to the net buying pressure from order imbalance. Chan, Cheng, and Lung (2004) extend the net buying pressure hypothesis of Bollen and Whaley (2004) and observe the relationship between IV and moneyness based on Hong Kong HIS options. They conclude that net buying pressure can well explain the negative skew of IV.

The paper extends the approach of Bollen and Whaley (2004). First, we measure net buying pressure based on the method of Chan, Cheng, and Lung (2004) to observe whether volatility smile results from market unequilibrum. Second, much of the literature considers the dependence of IV on time to maturity of options.[27] Therefore our analysis not only explores the relation between IV and net buying pressure but also classifies IV by time to maturity to observe the

[27] For example: Xu and Taylor (1994), Campa and Chang (1995), Jorion (1995), and Amin and Ng (1997)

magnitude of effect of net buying pressure on IV across different maturities. Third, we distinguish between the volatility trader and the direction trader based on the effect of net buying pressure on IV and examine whether serial correlation exists between changes in IV. Finally, we use the index options as data to confirm the existence of net buying pressure hypothesis.

TAIEX options (TXO) listed on December 24, 2001. The daily trading volume of TXO in the first year averaged merely 856 contracts a day. But by 2007, the average trading volume reached 416,197 contracts a day, registering a nearly 485-fold increase in five years and making TXO the fastest growing derivatives in Taiwan's futures market. The 2008 survey of the Futures & Option Week (FOW) on derivative exchanges around the world shows that Taiwan ranks twenty-forth in terms of derivatives trading volume, an impressive performance for a developing market. The majority of studies on volatility smile in the past focus on mature options market. This paper uses TXO to observe whether the shape of the IVF shows a smile or sneer[28] and to examine whether an emerging market also supports the hypothesis of net buying pressure.

The results in the paper show that Taiwan's market supports the net buying pressure hypothesis. Tests present the negative skew of the implied volatility of TXO, and the magnitude of negative skew is influenced by the time to maturity of options. The magnitude of negative skew tends to increase with the time to maturity for short-term options, while the reverse is observed for long-term options. After controlling for information flow and leverage effect, we find that net buying pressure results from limits to arbitrage. Hence the impact of net buying pressure is most prominent in out-of-the-money puts, and the leverage effect is also most significant in out-of-the-money puts. Finally, our empirical results strongly support net buying pressure hypothesis in Taiwan options markets.

The remainder of this paper is organized as follows. Section 2 touches on the theoretical background of volatility smile and net buying pressure. Section 3 presents our hypotheses and a simulated trading strategy. Section 4 describes the sample and methodologies. The empirical results are presented in Section 5, with the summarizes drawn from the paper being provided in the final section.

[28] It also called negative skewness.

2. Implied Volatility and Net Buying Pressure

Earlier studies of option pricing focused on the mispricing of Black-Scholes (BS) model. For instance, MacBeth and Merville (1979, 1980) contend that BS model systematically overprices deep out-of-the-money calls and underprices deep in-the-money calls. Black (1975) finds that the biases are in the opposite direction. Rubinstein (1985) indicates that the direction of mispricing changes over the life of options. Regardless, these papers on the biases of mispricing prompt subsequent researchers to focus their studies on the pattern of the IVF, in particular over different exercise prices.

In the BS model, volatility is assumed constant, which however departs from the real world. MacBeth and Merville (1979) and Rubinstein (1985) find that implied volatility is not a constant, and it exhibits a smile pattern. To explain a volatility smile, many studies focus on relaxing one or several BS assumptions. The first set of these theories, such as Rubinstein (1994), relax the assumption of constant volatility by allowing time- and state-dependent volatility functions to fit the volatility smile pattern. Dumas, Fleming, and Whaley (1998) point out that the aforementioned model and market prices have large mean square errors. They conclude that a time- and state-dependent volatility approach is not effective for explaining observable option prices, and thus its explanation of volatility smile is incomplete.

The second set of these models[29] also relaxed the BS assumptions. They simulate the distribution pattern of stock returns on the basis of stochastic volatility and obtain results with left skew and kurtosis to explain the volatility smile. But the proposed model is complex and results in inconsistent volatility smiles for short-term and long-term options. Naik and Lee (1990), Duffie, Pan, and Singleton (2000), and Chernov, Gallant, Ghysels and Tauchen (2003) also undertake related studies. Bates (1996) tests Deutsche Mark options and finds that the stochastic volatility model is an ill fit to explain the volatility smile. Subsequently many scholars include jump-diffusion in the stochastic model to better capture the distribution of equity index returns. Similar studies along this line include Jorion (1989), Bates (2000), and Anderson, Benzoni, and Lund (2002). Bakshi, Cao, and Chen (1997) include stochastic volatility, stochastic volatility with jumps, and stochastic volatility with stochastic interest rate in the model to depict a volatility smile.

[29] Such as Hull and White (1987) and Heston (1993).

In a perfect market, liquidity suppliers can perfectly and costlessly hedge their inventories, so supply curves will be flat. Neither time variation in the demand to buy or sell options nor public order imbalance for particular option series will affect market price and, hence, implied volatility. In the BS model, demands of options are independent of implied volatility.

Recent studies switch their focus to observing the supply and demand on options market. They quantify trading imbalance and attempt to use the dynamics of buyer demand or seller supply to explain the volatility smile. Bollen and Whaley (2004) divide the market into buyer-motivated and seller-motivated groups by the prevailing bid/ask midpoint, and they further define the trading volume difference between the two groups as net buying pressure to illustrate market supply and demand. They find that the IV of index options exhibits negative skew; that is, there is an inverse relationship between IV and exercise price. They also find that negative skew is caused by net buying pressure. According to Bollen and Whaley, two hypotheses support the positive relationship between demand and implied volatility. The two hypotheses are the limits to arbitrage hypothesis and the learning hypothesis.

The first hypothesis relates to limits to arbitrage and suggests that the supply curve of options has upward slope. Thus every option contract has a supply curve with positive slope, and IV determines the demand for every option series. As such, IV is related to moneyness. Bollen and Whaley propose that the positive slope of supply curve results from limits to arbitrage in the market. Shleifer and Vishny (1997) argue that the ability of professional arbitrageurs to exploit mispriced options is limited by their power to absorb intermediate losses. Liu and Longstaff (2000) demonstrate that margin requirements limit the potential profitability. Under the mark-to-market system, the risk-averse market makers might need to liquidate their positions before contracts expire, and they cannot sell unlimited amount of options even if the deal presents profit opportunity. Thus when liquidity suppliers must keep larger positions on a particular option series, the costs of hedging and risk exposure rise due to the portfolio imbalance. Consequently, market makers will demand higher price for that particular option, and the implied volatility rises. Thus, given a supply curve with positive slope, excess demand will lead to rising prices and implied volatility, while excess supply brings about a drop in implied volatility.

The second hypothesis is the learning hypothesis that assumes that the supply curve of an option is flat. For the prices of options to change, there must be new information generated from the trading activities of investors for market makers to learn continuously about the dynamics of underlying assets. The net buying pressure hypothesis of Bollen and Whaley (2004) implies that option investors are volatility traders who focus only on volatility shocks. If a volatility shock occurs and an order imbalance functions as a signal of shock to investors, then the order imbalance will change the investor's expectation of future volatility. Therefore, the implied volatility will change, and such change should be permanent. The positive relation between net buying pressure and implied volatility also becomes observable.

Bollen and Whaley (2004) suggest two empirical tests to differentiate the limits to arbitrage hypothesis from learning hypothesis. The first test is a regression includes the lagged change in implied volatility as an independent variable, which assesses the relationship between implied volatility and net buying pressure. According to the limits to arbitrage hypothesis, since market makers supply liquidity to the market and hold risk, they would want to rebalance their portfolio. Thus, changes in implied volatility of the next term will reverse, at least temporarily. Therefore, negative serial correlation is expected between changes in implied volatility. But according to learning hypothesis, new information reflects prices and volatility through the trading activities of investors, so there is no serial correlation in changes in implied volatility.

For the second test, because at-the-money options possess most information about future volatility, the impact of net buying pressure of at-the-money options on the changes in implied volatility of other option series may be observed to verify whether the market supports the presence of learning hypothesis or limits to arbitrage hypothesis. Under the learning hypothesis, since at-the-money options possess the highest vega and is more informative about future volatility, its demand should be the dominant factor determining the implied volatility of all options. Therefore, changes in the implied volatility of all options should move in concert and in the same direction. In contrast, limits to arbitrage hypothesis suggests that the implied volatility of an option is affected by the demand for that particular option, not by the demands for different series. As such, the implied volatilities of different option series do not necessarily move together.

The learning hypothesis of Bollen and Whaley (2004) implies that investors are volatility traders. Although Bollen and Whaley does not mention explicitly the term "direction trader," it is found in their examination of learning hypothesis that the effect of call/put net buying pressure on implied volatility can be used to distinguish whether the investor is a volatility or direction trader. A direction trader is defined as a trader who possesses information on future price movement of underlying asset and bases his trading decision primarily on such information instead of future volatility. If an option trader obtains new information on the anticipated rise in the price of underlying asset rising faster than the underlying asset market and the IVF is measured based on the price of underlying asset, the IVF of call options will rise and that of put options will fall to reflect the expected price increase. The magnitude of the changes in IVF will narrow until the next price of underlying asset accurately reflects the new information. Thus there is negative serial correlation in implied volatilities. A direction trader engages in trading due to the expected price of underlying asset. Thus when the price of underlying asset is expected to rise, the implied volatility and premium of call/put are expected to rise/fall; the demand for calls will increase/decrease, indicating the positive/negative relation between call IVF and call/put net buying pressure and the negative/positive relation between put IVF and call/put net buying pressure.

3. Hypothesis and Simulation

Many literatures find that the implied volatility of options and moneyness are related. If low exercise price and high exercise price have higher IV, the IV has smile or smirk pattern. If low exercise price has higher IV and high exercise price has lower IV, the IV exhibits negative skew or sneer. Volatility smile or smirk tends to happen to stock options, while negative skew often occurs with index options. But it is also likely for the volatility of stock options to have negative skew. For example, Toft and Prucyk (1997) finds that the volatility of individual stock option often exhibits downward-sloping smiles. Rubinstein (1994), Shimko (1993), Das and Sundaram (1999), Dupire (1994), Jackwerth (2000), Dennis and Mayhew (2002) and Bakshi, Kapadia, and Madan (2003), Bollen and Whaley (2004), and Chan, Cheng, and Lung (2004) all demonstrate that the implied volatility of index options are negatively skewed.

It is commonly known that institutional investors hold mostly index puts in their portfolio. In practice, such traders lack enough natural counterparties in the market such that market makers need to step in to absorb these trades. Since market makers shoulder more risk in order to provide liquidity, they would demand higher premium for put options. Consequently, the supply curve of options will be positively sloped, the implied volatilities and premium will rise, and the implied volatility will be higher than the real volatility.

In the options market, the trading of nearby contracts is most active. Theoretically, as time to maturity gets longer, investors would then prefer cheaper out-of-the-money options, and the volatility smile pattern or the degree of skewness should be more significant. But in observing the S&P500 index options, Bakshi, Cao, and Chen (1997) find inverse relation between volatility smile and maturity. Dumas, Fleming, and Whaley (1998), and Jackwerth (2000) have similar empirical results. However, the empirical study of Chan, Cheng, and Lung (2004) on Hong Kong Hang Seng Index (HSI) options finds that volatility skew is more pronounced as maturity increases. Thus, this paper constructs its first hypothesis as follows:

H1: The implied volatility of TXO exhibits negative skew, which is most significant in put options, and the magnitude of negative skew differs by maturities.

Bollen and Whaley (2004) propose that the limits to arbitrage hypothesis and learning hypothesis support the positive correlation between net buying pressure and implied volatility. The limits to arbitrage hypothesis suggests that the supply curve of options has a positive slope, the implied volatility of a particular option depends largely on its demand, and the relationship between implied volatility and moneyness is observable. When liquidity suppliers must absorb more positions, option premium and implied volatility rise synchronistically under their hedging costs and desired compensation for risk exposure. According to limits to arbitrage hypothesis, although at-the-money options are more informative regarding future volatility, each IVF is affected by the demand for that particular option series but is not affected by the demands for other option series. Thus, the IVF of different option series do not necessarily move together as demands change In addition, since market makers supply liquidity on market and hold risk, they would want to rebalance their portfolio, which leads to a reverse in implied volatility in the next term, at least temporarily Therefore, negative serial correlation is expected in changes in implied volatility.

Therefore, the second hypothesis is as follows:

H2: If negative serial correlation exists in changes in implied volatility, and the net buying pressure of each moneyness has positive effect on the implied volatility of particular option series, then the market supports the limits to arbitrage hypothesis.

The learning hypothesis holds that the supply curve of options is flat; hence IVF and the demand for an option contract are unrelated, and the supply curve changes only when new information turns up. Therefore, when demands change, changes in the implied volatility of all options should move together and in the same direction. The learning hypothesis also argues that new information is reflected in price and volatility through trading activity, and such volatility change is permanent. Thus there should be no serial correlation in changes in implied volatility. The third hypothesis of this paper is:

H3: If there is no serial correlation in changes in implied volatility and the net buying pressure of at-the-money options produces a positive effect on implied volatility, then the market supports the learning hypothesis

In the options market, a trader is a direction trader if he bases his trading decision primarily on the information of future price movement of the underlying asset. A trader is a volatility trader if he bases his trading decision on the volatility of future price. If new information on the future price movement of underlying asset arrives in the option market before it arrives in the spot market, the IVF of call options will rise and that of put options will fall to reflect the expected price increase. The changes in IVF will narrow until the next price of underlying asset correctly reflects the new information; the change in IV will be reversed. Thus there is negative serial correlation in implied volatilities, positive correlation between the net buying pressure of calls or puts and implied volatility, and negative correlation between the implied volatility of calls and net buying pressure of puts, or the net buying pressure of calls and implied volatility of puts.

The fourth hypothesis is

H4: If there is no serial correlation in the changes in implied volatilities, and the net buying pressure of calls and puts have respectively positive effect on their own implied volatility and negative effect on the implied volatility of counterparty, the trader is a direction trader. Otherwise, the trader is a volatility trader.

To test the above hypothesis, we construct a model using the function of Bollen and Whaley (2004) model. The independent variables in the model include two net buying pressure variables and a lagged change in implied volatility. In addition, the model includes the return and trading volume on the contemporaneous price of the underlying asset to eliminate the other noise factors:

$$\Delta IV_t = \beta_0 + \beta_R R_t + \beta_{VOL} VOL_t + \beta_{NBP_1} NBP_{1,t} + \beta_{NBP_2} NBP_{2,t} + \beta_{\Delta IV_{t-1}} \Delta IV_{t-1} + \varepsilon_t , \qquad (1)$$

where ΔIV_t, R_t, VOL_t, NBP_1, NBP_2, and ΔIV_{t-1} are the change in implied volatility, the return on underlying asset, the trading volume of underlying asset, the two net buying pressure variables, and a lagged change in implied volatility, respectively; β and ε are the regressive coefficients and the error term, respectively.

Black (1975), Christie (1982), Schwert (1990), and Cheung and Ng (1992) contend that the contemporaneous volatility change and return are inversely related, which can be explained by leverage effect. This theory concludes that change in spot price would lead to volatility change, which however is not a feedback to stock price. In other words, change in stock price is the cause of volatility change. Leverage effect means that a drop (rise) in the stock price drives the firm to increase (decrease) financial leverage, thereby leading to an increase (decrease) in the firm's stock risk and a rise (decline) in stock volatility.[30] Fleming, Ostdiek, and Whaley (1995) and Dennis and Mayhew (2002) find empirically that there is an inverse relationship between volatility and return. Duffee (1995) counters by finding a strong positive correlation between contemporaneous return and volatility in smaller firms or firms with low financial leverage. Geske (1979) and Toft and Prucyk (1997) derive pricing models based on the assumptions of proportional, constant variance processes for the firm's assets. But their models depict explicitly the impact of risky debt on the dynamics of the firm's equity. Given that their models are built on the notion of greater return volatility at lower stock price level, it implies that OTM puts have higher implied volatilities than ITM calls. Bakshi, Kapadia, and Madan (2003) show that the leverage effect implies that the skewness of the risk-neutral density for individual stock should be more negative than that of the index. However, they also find the opposite to be true. The fifth hypothesis of the paper is as follows:

H5: If the leverage effect exists, there is negative relation between volatility and return on underlying asset, which is more pronounced in out-of-the-money puts than other moneyness categories.

Many studies on trading activities in financial markets suggest using volume to measure market trading activity. For example, Ying (1966), Epps and Epps

[30] Financial leverage is the ratio of debt to equity.

(1976), Gallant, Rossi, and Tauchen (1992), and Hiemstra and Jones (1994) use the total number of shares to observe the trading activity in the NYSE. Karpoff (1987), Gallant, Rossi, and Tauchen (1992), and Blume, Easley, and O'Hara (1994) maintain the important role of volume in financial markets. Some studies that examine the impact of an information event on trading activity and use individual turnover for observation did find that trading volume conveys significant information content. The information flow effect proposed by Bollen and Whaley (2004) points to the positive relationship between change in price and trading volume, implying that trading volume is representative of information flow, which increases with rising trading volume, and price volatility increases along with it. Thus, the sixth hypothesis is:

H6: If the information flow effect exists, there should be positive correlation between the trading volume of underlying asset and implied volatility.

Given that trading volume increases gradually over time, suggesting the nonstationarity of trading volume variable. Lo and Wang (2000) suggests using shorter measurement intervals when analyzing trading volume. This problem will not occur in this study, because our measurement interval is less than four years.

To examine whether the potential profitability of options is brought about by net buying pressure, we carry out trading simulations by selling options with different maturities in different moneyness categories, and we test the net buying pressure hypothesis with the abnormal returns generated by options sold. According to the net buying pressure hypothesis, selling out-of-the-money puts is expected to generate greater positive return than other categories of options.

In the trading simulations, we use two trading strategies to compare the abnormal rates of return of hedge and non-hedge trading strategies. With the delta hedge, delta units of underlying security are purchased for each option contract sold. To reduce volatility risk, positions are held until expiration. The underlying asset of TAIEX options are non-traded assets. We use MiNi-TAIEX futures (MTX) as proxy variable of the TAIEX spot for delta hedge, consistent with the practice of Bollen and Whaley (2004) and Chan, Cheng, and Lung (2004). The profit in index points from the naked trading strategy is as follows:

$$ProfitPoint^{Naked} = Prem_0 e^{rT} - Prem_T \,, \tag{2}$$

where $Prem$ is the premiums for short position of options, when it is opened. P = calls (C), $C_T = Max(0,\ S_T - K)$; P = puts, $P_T = Max(0,\ K - S_T)$, where S_T and T are settlement price and expiration date, respectively. Next, we compute the profit ratio from the naked trading strategy, relative to the initial premiums:

$$Return^{Naked} = \frac{ProfitPoint^{Naked}}{Prem_0}, \tag{3}$$

In the hedge trading simulation, the delta-hedge is revised each day to reduce the underlying asset's price risk to short options position, and the profit in terms of index points is computed as follows:

$$\begin{aligned} ProfitPoint^{Hedge} &= ProfitPoint^{Naked} \\ &+ \Delta_0 \left(S_T + \sum_{t=0}^{T} D_t e^{r_f (T-t)} - S_0 e^{r_f T} \right) + \sum_{t=0}^{T-1} \Delta_t \left(S_{t+1} + D_t - S_t \right) e^{r_f (T-t)} \end{aligned} \tag{4}$$

where Δ_t, S_t, and D are the delta value of shorting options, the closing price of MTX, and dividend of the underlying asset, respectively. The percentage profit is:

$$Return^{Hedge} = \frac{ProfitPoint^{Hedge}}{\left| \Delta_0 S_0 - Prem_0 \right|}, \tag{5}$$

We perform the sign tests and the mean tests to test the profit probability of shorting options. The sign test examines the probability that a positive/negative abnormal profit of a short options position occurs, which is suitable to testing the profitability of simulated trades in this paper. The mean test examines whether the profit from selling options is significantly different from zero. Because the distribution of profit from shorting options is asymmetric, conventional statistical tests are not applicable. The modified t-test by Johnson (1978) can sidestep the problem of the asymmetrical distribution.

4. Data and Methodology

4.1 Data Specification

This paper samples the intraday quotes and trades of TXO traded on Taiwan Futures Exchange (TAIFEX) over the period of December 24, 2001 through June 30, 2005, totaling 753 trading days to examine the net buying pressure hypothesis proposed by Bollen and Whaley (2004). The estimation of implied volatility requires the risk-free interest rate, the Taiwan Capitalization Weighted Stock Index (TAIEX), and the expected dividends paid during an option's life. We use the average rate of repo and reverse repo trades of government bonds with higher liquidity as our proxy for the risk-free interest rate. The data are collected from GreTai Securities Market, Taiwan. The TAIEX index and dividend data are drawn from the Taiwan Economic Journal (TEJ) database. The MTX data required for simulating the hedging strategy came from TAIFEX.

The TAIEX is traded from 9:00 to 13:30 each day, while TXO are traded from 8:45 to 13:45 daily. To synchronize the trading data, we omitted the TXO data from 8:45 - 9:00 and 13:30 - 13:45. Since the trading time of the options and the underlying indexes during the day is nonsynchronous, it is important to identify the method of matching the trading time in order to accurately estimate implied volatility. Because Minspan suggested by Harris, Mclnish, Shoesmith, and Wood (1995) is applicable to the matching of high and low frequency trading, many subsequent papers also use Minspan to synchronize trading data on different exchanges. Available data show that the average trading frequency in Taiwan's options market is higher than that of the spot market, while the Minspan procedure can help lower the empirical error. Thus we employ Minspan for pairing TAIEX and TXO.

4.2 Implied Volatility and Historical Volatility Computations

TXO are European-style options. To compute the IV of each trade in a day, we use the BS model with the following formulas:

$$C = Se^{-\delta\times\tau}\cdot N\left(d_1\right) - Ke^{-r_f\times\tau}\cdot N\left(d_2\right), \tag{6}$$

$$P = Ke^{-r_f\times\tau}\cdot N\left(-d_2\right) - Se^{-\delta\times\tau}\cdot N\left(-d_1\right), \tag{7}$$

and

$$d_1 = [\ln(S/K) + (r_f - \delta + \sigma^2/2) \times \tau] / \sigma\sqrt{\tau} \, , \tag{8}$$

$$d_2 = d_1 - \sigma\sqrt{\tau} \, , \tag{9}$$

where σ, τ, and δ are the volatility of underlying asset, the time to maturity, and the dividend yield, respectively, with N(·) as the normal cumulative density function..

For option traders, the IV only reveals the current information on options. Thus historical volatility data also provide important reference for investors. When the IVF is significantly higher (lower) than historical volatility, it suggests the price of option might be over/under-estimated. Chiras and Manaster (1978), Poterba and Summers (1986), Schwert (1990), and Brailsford and Faff (1996) use non-continuously compounded rate of return on asset to estimate historical volatility. Cho and Frees (1988) find that volatilities derived from continuously compounded rate of return are unbiased and valid. The formula for computing historical volatility is as follows:

$$\sigma_t = \sqrt{(day/n-1)\sum_{t=1}^{n}\left(u_t - \bar{u}_t\right)^2} \, , \tag{10}$$

where $u_t = \ln(S_t / S_{t-1})$, (i.e. continuously compounded rate of return on stock price); day and $\bar{u}_t$ are days of trading in a year and average daily return, respectively.

4.3 Measure of Net Buying Pressure

To quantify order imbalance, it is necessary to distinguish each trade as buyer-motivated or seller-motivated. Easley, O’Hara, and Srinivas (1998) and Chordia, Roll, and Subrahmanyam (2002) use the level of proximity of transaction price to the prevailing ask/bid quotes to determine whether a trade is buyer or seller motivated. Bollen and Whaley (2004) extend this concept and use the midpoint of the prevailing ask/bid quotes to determine whether a trade is buyer or seller motivated. If the transaction price is higher than the midpoint of prevailing ask/bid quotes, the trade is treated as buyer-motivated; if the transaction price is below the midpoint of prevailing ask/bid quotes, the trade is treated as seller-motivated. Net buying pressure is the total number of buyer-motivated contracts during the day less total number of seller-motivated contracts during the day. When net buying pressure is greater than zero, it means that the market is buyer dominated; if the net buying pressure is less than zero, the market is seller dominated.

Taiwan's futures market is order driven. Thus using the midpoint of ask/bid quotes might not be suitable for Taiwan's futures market. Chan, Cheng, and Lung (2004) contend that change in the price of underlying asset will affect the option contract premium and using the prevailing options prices to determine buyer or seller motivated trade introduces more measurement errors in estimating net buying pressure. Thus, they use implied volatility to determine buyer or seller-motivated trade. Based on the same reasoning, we use implied volatility to determine whether a trade is buyer or seller motivated in the computation of net buying pressure.

After pairing by Minspan procedure, we estimate the IVF of each trade. If the IVF is higher than that of the previous trade, it means the option premium is expected to go up, and the trade is buyer-motivated; if the IVF is less than that of the previous trade, the trade is seller-motivated.[31] The net buying pressure is the day's total buyer-motivated contracts minus day's total seller-motivated contracts.

4.4 Classification of Options

We categorize the implied volatilities of calls and puts by moneyness, exercise price, and time to maturity to observe the effect of net buying pressure on different groups. Moneyness of an option is conventionally classified by the ratio of spot price to exercise price. But such approach fails to account for the fact that the likelihood the option is in the money also depends on volatility and time to maturity. Bollen and Whaley (2004) use delta to categorize moneyness.[32] Delta reflects not only the ratio of spot price to exercise price, it is also sensitive to volatility and time to maturity. Delta is calculated as follows:

$$Delta^{C} = N\left(d_1\right), \tag{11}$$

[31] A previous trade is identified as an option with same exercise price and expiration dates.

[32] Delta is a measure of the effect of underlying asset's price change on the price of option.

$$Delta^P = N\left(-d_1\right), \qquad (12)$$

where $Delta^C$ and $Delta^P$ are call delta value and put delta value, respectively; standard deviation is the volatility of continuously compounded return sixty days prior to the trading day. The absolute value of delta ranges between 0 and 1, representing the probability that an option will be exercised at expiration. It is the positive correlation between exercise price and spot price for call options and the negative correlation for put options. We classify the moneyness of options into five categories by delta: 0.02 < delta < 0.2, deep out-of-the-money (DOTM); 0.2 < delta < 0.4, out-of-the-money (OTM); 0.4 < delta < 0.6, at-the-money (ATM); 0.6 < delta < 0.8, in-the-money (ITM); and 0.8 < delta < 0.98, deep in-the-money (DITM). Samples with delta below 0.02 or above 0.98 are discarded because their lack of liquidity tends to invite distortions of price discreteness. Rubinstein (1985) uses similar cut-off standard when classifying moneyness based on the ratio of spot price to exercise price, while Chan, Cheng, and Lung (2004) adopt the same approach in sample exclusion.

Next, we classify the samples by five exercise price groups; DOTM puts and DITM calls are in low exercise price (Low K) category; OTM puts and ITM calls are in medium-low exercise price (Med-Low K) category; ATM calls and puts are in medium exercise price (Med K) category; ITM puts and OTM calls are in medium-high exercise price (Med-High K) category; and DITM puts and DOTM calls are in high exercise price (High K) category.

Bollen and Whaley (2004) observe the effect of net buying pressure hypothesis using options with one month time to maturity. But as many studies point out that volatility smile is dependent on maturity, we further divide options into maturities ranging from one week to two months to examine the net buying pressure hypothesis.[33]

5. Empirical Results

Table 1 shows the historical volatilities of continuous compounding rate of returns of TAIEX index, where the returns are non-dividend adjusted and then dividend adjusted. The historical volatilities are shown for five different holding

[33] We use five maturity classes - one week, two weeks, three weeks, one month, and two months.

periods (one week, two weeks, three weeks, one month, and two months). We find that realized volatility for our adjusted sample rises as the holding period gets longer. This can be seen in the adjusted returns where the mean increases from 21.83% for holding period of one week to 23.67% for holding period of two months.[34]

Table 1

Summary Statistic of Return and Realized Volatility for TAIEX Index

This table reports the descriptive statistics for TAIEX index returns and realized volatility across the five holding intervals. Adjusted is the adjusted TAIEX index return when occurring ex-right on individual stock. Non-adjusted uses the TAIEX index returns without any adjustments.

Variables		N	Mean	Standard deviation	Min	Max
Non-Adjusted	Daily return	752	0.02%	1.53%	-7.02%	5.50%
	Annualized return	752	0.36%	24.21%	-110.75%	86.87%
	One week volatility	748	21.49%	--	3.62%	65.18%
	Two week volatility	743	22.46%	--	8.41%	51.76%
	Three week volatility	738	22.79%	--	8.23%	49.68%
	One month volatility	732	23.04%	--	8.82%	43.90%
	Two month volatility	711	23.37%	--	12.47%	36.86%
Adjusted	Daily return	752	0.02%	1.55%	-6.91%	5.48%
	Annualized return	752	0.36%	24.47%	-109.07%	86.54%
	One week volatility	748	21.83%	--	3.46%	62.69%
	Two week volatility	743	22.80%	--	8.66%	51.98%
	Three week volatility	738	23.12%	--	8.23%	50.52%
	One month volatility	732	23.35%	--	8.82%	44.29%
	Two month volatility	711	23.67%	--	13.21%	37.88%

Tables 2 to 4 present the IVF estimates of options grouped by options, moneyness, and maturity. If the net buying pressure hypothesis holds, we can expect the IV of OTM options, in particular put options, to be higher than other moneyness categories as well as historical volatilities.

Table 2 shows the implied volatilities (σ^{Mean}, σ^{Min}, σ^{Max}) of put options ctaegorized by maturity (one week, two weeks, three weeks, one month, and two months) then by moneyness (DOTM, OTM, ATM, ITM, and DITM) in columns five through seven. In addition, trading volume and proportion of total volume for each category of puts are presented in columns three and four.[35] Except for DITM puts and puts with two months, the implied volatilities of all other put options are higher than the historical volatility of Table 1, suggesting the over-pricing of put premium. Moreover, the implied volatility estimates from other maturities illustrate similar patterns. The implied volatilities (σ^{Mean}) of put options with shorter

[34] Adjusted returns are the adjusted TAIEX index return when occurring ex-right on individual stock. Non-adjusted uses the TAIEX index returns without any adjustments.

[35] The σ^{Mean}, $\sigma^{Min,}$ and σ^{Max} are mean, minimum, and maximum of volatilities, respectively.

maturities (one week to three weeks) decline as exercise price rises, indicating negative skew in the volatility of TAIEX puts. But the implied volatilities of put options with longer maturities of one/two months are inconsistent. Notwithstanding, the implied volatilities of all OTM puts are higher than those of ITM puts. For example, the IV (σ^{Mean}) of DOTM puts with three weeks averages 27.09%, while that of DITM puts is 22.45%. These results support the Hypothesis 1.

Table 2

Summary Statistics of Implied Volatility for Put Options*

This table shows the trading volume and mean, minimum, and maximum for implied volatility (σ) across five moneyness and five maturities in TAIEX index put options. DOTM, OTM, ATM, ITM, and DITM are deep out-of-the-money, out-of-the-money, at-the-money, in-the-money, and deep in-the-money, respectively.

Maturity	Moneyness	Trading Volume (V)	Prop. of Total V	σ^{Mean}	σ^{Min}	σ^{Max}
1-week	DOTM	1,051,749	23.84%	27.41%	11.62%	54.71%
	OTM	1,069,555	24.24%	27.73%	10.62%	66.29%
	ATM	1,102,172	24.98%	25.99%	7.60%	66.21%
	ITM	719,531	16.31%	25.32%	3.88%	84.49%
	DITM	468,778	10.63%	23.90%	12.03%	121.73%
2-week	DOTM	1,876,777	32.64%	28.96%	12.18%	56.33%
	OTM	2,091,448	36.37%	29.11%	9.08%	54.85%
	ATM	1,251,293	21.76%	28.58%	5.39%	61.62%
	ITM	406,891	7.08%	28.43%	7.71%	64.10%
	DITM	124,269	2.16%	24.67%	10.43%	93.63%
3-week	DOTM	1,609,809	28.57%	27.09%	12.98%	51.16%
	OTM	2,299,149	40.80%	28.27%	10.12%	54.71%
	ATM	1,286,845	22.84%	28.46%	7.92%	58.41%
	ITM	366,312	6.50%	28.14%	5.38%	66.64%
	DITM	72,542	1.29%	22.84%	9.56%	90.50%
1-month	DOTM	1,885,933	28.65%	26.66%	12.89%	56.27%
	OTM	2,956,606	44.92%	28.23%	11.06%	65.66%
	ATM	1,384,511	21.03%	28.62%	10.73%	63.25%
	ITM	293,435	4.46%	28.14%	8.88%	67.66%
	DITM	61,544	0.94%	23.99%	10.21%	81.46%
2-month	DOTM	1,269,475	28.75%	25.26%	11.63%	76.41%
	OTM	2,107,448	47.73%	27.60%	10.54%	82.15%
	ATM	876,569	19.85%	27.78%	9.02%	76.43%
	ITM	144,184	3.27%	27.49%	6.13%	83.60%
	DITM	17,599	0.40%	21.87%	8.13%	75.41%

Note: *Options where the absolute deltas are below 0.02 or above 0.98 and with maturities longer than two months are omitted from our sample.

In addition, the gap of IV estimates between DOTM and DITM puts becomes wider as maturity changes from a 1-week to a 3-week horizon. The gap increases from 3.51% (= 27.41% - 23.90%) to 4.25% (= 27.09%-22.84%) for the 1-week and the 3-week holding periods, respectively. Then, the gap has a decline from 4.25% for three weeks to 2.67% (=26.66%-23.99%) for one month. This shows that the net buying pressure caused by hedging activities is more likely at DOTM and DOM categories with maturity of three weeks in Taiwan’s options market.

Examining the trading volume shown in the third column, OTM puts of all maturities have the largest trading volumes. The combined proportions of OTM and DOTM puts by volume (shown in the fourth column) rise gradually from 48.08% for puts of one week to maturity to a high of 76.48% for two months to maturity, indicating the preference of institutional investors for cheaper OTM puts.

Table 3

Summary Statistics of Implied Volatility for Call Options*

This table shows the trading volume and mean, minimum, and maximum for implied volatility (σ) across five moneyness and five maturities in TAIEX index call options. DOTM, OTM, ATM, ITM, and DITM are deep out-of-the-money, out-of-the-money, at-the-money, in-the-money, and deep in-the-money, respectively.

Maturity	Moneyness	Trading Volume (V)	Prop. of Total V	σ^{Mean}	σ^{Min}	σ^{Max}
	DOTM	1,519,444	25.44%	27.17%	14.23%	55.74%
	OTM	1,525,468	25.54%	26.13%	12.72%	43.50%
1-week	ATM	1,380,863	23.12%	25.41%	10.01%	49.35%
	ITM	828,426	13.87%	23.82%	7.91%	58.53%
	DITM	718,153	12.02%	22.48%	9.48%	84.82%
	DOTM	1,714,584	20.85%	27.23%	12.50%	38.87%
	OTM	2,621,593	31.88%	26.69%	11.49%	42.82%
2-week	ATM	2,373,382	28.86%	26.34%	11.47%	44.45%
	ITM	1,170,775	14.24%	23.58%	7.89%	45.47%
	DITM	344,126	4.18%	19.43%	15.58%	71.68%
	DOTM	1,552,789	19.39%	27.51%	15.18%	39.84%
	OTM	3,129,555	39.08%	26.19%	14.49%	39.47%
3-week	ATM	2,319,891	28.97%	25.64%	15.12%	45.37%
	ITM	825,468	10.31%	22.75%	7.50%	55.86%
	DITM	180,875	2.26%	20.81%	10.99%	78.22%
	DOTM	1,756,953	19.15%	28.39%	13.29%	45.05%
	OTM	4,060,047	44.26%	26.82%	13.07%	43.74%
1-month	ATM	2,632,395	28.69%	26.07%	13.15%	44.75%
	ITM	633,102	6.90%	24.40%	9.12%	65.62%
	DITM	91,612	1.00%	21.69%	12.20%	66.61%
	DOTM	922,764	18.22%	28.52%	13.01%	46.78%
	OTM	2,563,500	50.62%	26.58%	12.17%	44.42%
2-month	ATM	1,343,328	26.53%	26.27%	11.87%	46.59%
	ITM	200,160	3.95%	26.16%	8.06%	43.75%
	DITM	34,342	0.68%	24.87%	5.48%	46.30%

Note: *Options where the absolute deltas are below 0.02 or above 0.98 and with maturities longer than two months are omitted from our sample.

The implied volatilities of call options are shown in Table 3, grouped by maturity and moneyness similar to Table 2. Based on the put-call parity, we expect that the performance of the implied volatilities of calls to mirror that of puts. But this is not the case. As shown in the table, the implied volatilities of calls of all maturities exhibit negative skew, as the IV (σ^{Mean}) decreases as moneyness increases. For all maturities, OTM calls have the highest trading volume (as seen in the third and fourth columns), and the combined trading volume of OTM and

DPTM categories as a percentage of total trading volume of call options rise gradually from 50.98% for one week to 68.84% a high of for the two month maturity group. By comparison, the implied volatilities of puts are significantly higher than calls, suggesting investor's tendency towards put options over calls in their portfolio.

Table 4

Summary Statistics of Implied Volatility for TAIEX Index Options*

This table shows the trading volume (V) and mean, minimum and maximum for implied volatility (σ) grouped by five moneyness classes and five maturities in TAIEX index options. To pool put and call options together, we classify the samples by exercise price.

Maturity	Moneyness	Trading Volume (V)	Prop. of Total V	σ^{Mean}	σ^{Min}	σ^{Max}
1-week	Low K	1,769,902	17.04%	24.95%	9.48%	84.82%
	Med-Low K	1,897,981	18.28%	25.78%	7.91%	66.29%
	Med K	2,483,035	23.91%	25.70%	7.60%	66.21%
	Med-High K	2,244,999	21.62%	25.73%	3.88%	84.49%
	High K	1,988,222	19.15%	25.53%	12.03%	121.73%
2-week	Low K	2,220,903	15.89%	22.61%	12.18%	71.68%
	Med-Low K	3,262,223	23.34%	27.82%	7.89%	54.85%
	Med K	3,624,675	25.94%	27.53%	5.39%	61.62%
	Med-High K	3,028,484	21.67%	26.28%	7.71%	64.10%
	High K	1,838,853	13.16%	25.95%	10.43%	93.63%
3-week	Low K	1,790,684	13.13%	23.95%	10.99%	78.22%
	Med-Low K	3,124,617	22.90%	27.17%	7.50%	55.86%
	Med K	3,606,736	26.44%	27.05%	7.92%	58.41%
	Med-High K	3,495,867	25.62%	25.48%	5.38%	66.64%
	High K	1,625,331	11.91%	25.18%	9.56%	90.50%
1-month	Low K	1,977,545	12.55%	24.17%	12.20%	66.61%
	Med-Low K	3,589,708	22.78%	27.48%	9.12%	65.66%
	Med K	4,016,906	25.49%	27.34%	10.73%	63.25%
	Med-High K	4,353,482	27.63%	26.32%	8.88%	67.66%
	High K	1,818,497	11.54%	26.19%	10.21%	81.46%
2-month	Low K	1,303,817	13.75%	25.07%	5.48%	76.41%
	Med-Low K	2,307,608	24.34%	27.04%	8.06%	82.15%
	Med K	2,219,897	23.42%	27.03%	9.02%	76.43%
	Med-High K	2,707,684	28.56%	26.88%	6.13%	83.60%
	High K	940,363	9.92%	25.20%	8.13%	75.41%

Note: *Options where the absolute deltas are below 0.02 or above 0.98 and with maturities longer than two months are omitted from our sample.

Table 4 classifies the implied volatilities of all optionsby exercise price and time to maturity. As with tables 2 and 3, puts and calls and categorized by maturity and moneyness, and the further grouped by exercise price, as determined by moneyness. We find that, except for Low K, σ^{Mean} drop as exercise price rises, indicating negative skew. The magnitude of negative skew becomes more significant as time to maturity increases, which peaks for options with three weeks to maturity, and options with maturity longer than three weeks display inconsistent trends. The gap of IV estimates between Med-Low K and High K options becomes wider as maturity changes from a 1-week to a 3-week horizon. The gap increases from 0.25% to 1.99% for the 1-week and the 3-week holding periods, respectively. Then, the gap declines from 1.99% for three weeks to 1.84% for two month.

Table 5

The Average Daily Net Buying Pressure across Difference Moneyness

This table shows the averages for daily net buying pressure (NBP) in term of number of net buying contract and net buying ratio (proportion of total contracts) across the moneyness traded in the TAIEX index options. The number of contracts is defined as the number of buying contracts minus the number of selling contracts. The net buying ratio is defined as the net buying contracts divided by total option trading contracts.

Moneyness	Average Daily Net Buying Pressure					
	Put		Call		All	
	No. of Contract	Prop. of Total	No. of Contract	Prop. of Total	No. of Contract	Prop. of Total
Low K	7,788	29.63%	1,296	19.49%	9,084	29.39%
Med-Low K	10,904	33.31%	3,434	24.03%	14,338	32.89%
Med K	5,983	31.61%	9,676	29.83%	15,659	31.92%
Med-High K	1,815	24.09%	14,234	31.33%	16,049	31.50%
High K	823	17.75%	8,021	28.08%	8,844	27.99%

Table 5 presents the means for daily net buying contracts and net buying ratio computed based on the number of contracts traded daily for each series of options. The results show inverse relation between net buying pressure (as seen in the number of contracts and proportion of total contracts) and exercise price (as implied by moneyness), where the number of net buying contracts is the highest for out-of-the-money puts, (Med-Low K) with a mean of more than 10,000 contracts a day and indicating Taiwan investor's preference for out-of-the-money puts. Moreover, put options have the highest net buying ratio, average daily reaching 33.31%.

Next, we run eight regression equations based on equation (1), with 8 different dependent variables, and the results are shown in Table 6. Equation (1) is run with all options in out sample and also with different net buying pressure. We see that the coefficient signs of two control variables - contemporaneous underlying asset's return (R_t) and trading volume (VOL_t) are consistent with the theoretical signs, suggesting the presence of leverage effect and information flow effect in Taiwan's securities markets. The regression results find that β_R are negatively significant for all nine regressions, suggesting that the decline of index return drives firms to increase their financial leverage, leading to greater financial risk and volatility. The regression results, after controlling for the variables affecting ATM net buying pressure, are seen in Table 6. The β_R estimate is the highest for OTM puts; the value of coefficient reaches -0.8269, indicating that leverage effect is most significant in OTM puts. This result supports Hypothesis 5 in this paper. Coefficient β_{VOL} is also positively significant, implying that more new information in the market leads to higher volatility, as a result of higher trading volume. Such result supports the existence of information flow effect as proposed in Hypothesis 6.

Table 6

Regression Results of the Impact of Net Buying Pressure on Change in Implied Volatility[1]

Model:

$$\Delta IV_t = \beta_0 + \beta_R R_t + \beta_{VOL} VOL_t + \beta_{NBP_1} NBP_{1,t} + \beta_{NBP_2} NBP_{2,t} + \beta_{\Delta IV_{t-1}} \Delta IV_{t-1} + \varepsilon_t ,$$

where ΔIV_t and ΔIV_{t-1} are the change of the options implied volatility at time *t* and at time *t-1*, respectively. R_t and *VOLt* are the return of TAIEX index at time *t* and the trading volume of TAIEX index at time *t*, respectively. $NBP_{1,t}$ and $NBP_{2,t}$ are the first and second net buying pressure variables at time *t*, respectively. β and ε are the regression coefficient and error term, respectively

Model	ΔIV	β_0	β_R	β_{VOL}	β_{NBP_1}	β_{NBP_2}	$\beta_{\Delta IV_{t-1}}$	R^2	NBP_1	NBP_2
1	$Call^{ATM}$	-0.0022	-0.6124	0.7566	1.0564	1.0254	-0.2576	0.08	ATMcall	ATMput
		(-0.25)	(-5.71)***	(2.56)**	(1.01)	(1.69)*	(-2.55)***			
2	Put^{ATM}	-0.0019	-0.7548	0.2564	-1.0025	1.2561	-0.3568	0.08	ATMcall	ATMput
		(-0.12)	(-6.09)***	(1.21)	(-0.95)	(2.41)**	(-2.94)***			
3	$Call^{OTM}$	-0.0115	-0.3985	0.7812	3.0125	1.0041	-0.3428	0.12	OTMcall	ATMcall
		(-0.92)	(-3.16)***	(1.75)*	(1.66)*	(1.01)	(-5.27)***			
4	$Call^{OTM}$	-0.0065	-0.4218	0.7651	2.6571	1.5489	-0.4154	0.10	OTMcall	ATMput
		(-0.22)	(-5.15)***	(1.05)	(1.47)*	(1.20)	(-5.89)***			
5	Put^{OTM}	-0.0107	-0.8269	0.8508	2.4515	1.8389	-0.4343	0.19	OTMput	ATMput
		(-0.49)	(-6.85)***	(3.17)***	(2.44)**	(1.66)*	(-10.73)***			
6	Put^{OTM}	-0.0089	-0.3035	0.1788	1.7504	-2.0814	-0.2618	0.08	OTMput	ATMcall
		(-0.26)	(-3.07)***	(1.65)*	(2.97)***	(-1.83)*	(-6.93)***			
7	Put^{OTM}	-0.0211	-0.7512	0.8122	1.7986	-2.0187	-0.2548	0.19	OTMput	OTMcall
		(-0.65)	(-6.01)***	(3.21)***	(2.84)***	(-1.05)	(-6.55)***			
8	$Call^{OTM}$	-0.0236	-0.4629	0.7935	2.1817	3.9521	-0.2335	0.11	OTMcall	OTMput
		(-0.66)	(-4.41)***	(2.47)**	(1.68)*	(2.59)***	(-5.41)***			

Note: [1] T statistic in the parenthesis; ***, **, and * significant at the 1%, 5%, and 10% level, respectively

In Table 7, we find that the coefficients ($\beta_{\Delta IV_{t-1}}$) of lagged change in implied volatilities are all negative and significant at the 5% level, indicating the negative serial correlation in changes in implied volatilities and illustrating the positive slop of supply curve in Taiwan's options market. According to Bollen and Whaley (2004), this negative value is not a measurement error but a result of market makers rebalancing their portfolio.

Table 7

Regression Results of Profit Ratio as a Function of Moneyness[1]

Model: $ProfitRatio = \alpha_0 + \alpha_1 \left(K/S\right) + \varepsilon$,

where *ProfitRatio* is the percentage of profit in index point computed based on the initial amount. *K*, *S*, α, and ε are exercise price, spot price, regression coefficient and error term, respectively.

Option	Maturity	All	1-week	2-week	3-week	1-month	2-month
Put	α_0	0.0523	0.0396	0.0477	0.0073	0.0312	0.0836
		(8.28) ***	-1.59	(2.35) **	(2.44) **	(6.17) ***	(7.95) ***
	α_1	-0.0462	-0.0335	-0.0483	-0.0398	-0.0514	-0.0629
		(-7.05) ***	(-1.72) *	(-2.39) **	(-3.11) **	-(5.86) ***	(-4.58) ***
	R^2	0.0167	0.0015	0.0033	0.01	0.0103	0.0142
Call	α_0	-0.0435	-0.0148	-0.0579	-0.0339	-0.0976	-0.3679
		(-1.45)	(-0.55)	(-1.80) **	(-1.66) *	(-5.23) ***	(-0.77)
	α_1	0.0176	0.0162	0.0253	0.0462	0.0333	0.0383
		(2.57) **	0.6	1.08	(2.29) **	(2.08) **	(1.83) *
	R^2	0.0014	0.0004	0.0059	0.0026	0.0104	0.0004

Note: [1]T statistic in the parenthesis; ***, **, and * significant at the 1%, 5%, and 10% level, respectively.

Regressions 1 and 2 of Table 6 illustrates the regression relation between ATM net buying pressure and implied volatilities for ATM calls and ATM puts, respectively. Regressions 3 to 6 of shows how OTM net buying pressure affect OTM implied volatilities after controlling for the ATM net buying pressure variable. These results point to the fact that the ATM (OTM) implied volatilities are driven by the demand for ATM (OTM) puts, indicating a positive relation between them. By further comparing the degree to which OTM and ATM net buying pressures affect OTM implied volatility, it is found the effect is most significant in OTM options. For instance, the net buying pressure coefficient of OTM call options is statistically significantly positive under 1% level, while the control variable of ATM net buying pressure is negative insignificantly.

Regressions 7 and 8 present the similar results after controlling the variables affecting OTM net buying pressure. The net buying pressure of OTM puts produces the greatest influence on implied volatility. But it can be observed that the implied volatility of each option series is primarily driven by its own net buying pressure, which indicates the positive slope of supply curve in Taiwan's options market. As such, we believe our empirical results are more consistent with the limits to arbitrage hypothesis, hence supporting hypothesis 2, not hypothesis 3.

The net buying pressure hypothesis implies that options investors are volatility traders, suggesting that option investors base their trading decision mainly on volatility, instead of the information about the future price movement of options. If the investors refer mainly to price information, the effect of net buying pressure of ATM calls on the implied volatility of ATM calls (puts) should have positive (negative) sign, while the effect of net buying pressure of ATM puts on the implied volatility of ATM calls (puts) should show positive (negative) sign. But the coefficient signs of ATM net buying pressure as shown in the model 1 and 2 of Table 6 does not support the claim that Taiwan's investors refer to future price movement information when making trading decision.[36] Thus our results are consistent with the conclusion of Bollen and Whaley (2004) that options investors are volatility traders. (Hypothesis 3)

The empirical results as shown in Table 6 indicate that OTM put options have the highest net buying pressure, but whether net buying pressure means profits in options trading is an empirical question. Thus if we simulate the trading strategy of shorting put options with prices distorted by net buying pressure, it is likely that we will obtain positive abnormal profit, and the profit from shorting call options will not exceed that from shorting put options. In the hedge strategy, we adjust the position of MTX daily according to delta value, hold the positions until the options expire, and settle the gain or loss on expiration date.

In Taiwan, the costs of trading options and futures include service charge, transaction tax, and cost of capital on margin. The service charge for trading one lot of MTX is NT$150, and the transaction tax amounts to 0.025% of contract value. The service charge for trading one lot of TXO is NT$80, and the transaction tax is 0.025% of the option premium. If the option is settled by spread in price at the time the option expires, the transaction tax amounts to 0.025% of settlement price. Because this paper intends to compare abnormal returns, the cost of capital on margin is not expected to affect the simulation result and hence ignored in the simulation.

To observe whether the profit margin of OTM options is higher than that of ITM options, we first use the ratio of exercise price to the spot price of underlying asset (K/S) as independent variable to perform the following regression:

$$ProfitRatio = \alpha_0 + \alpha_1 \left(K / S \right) + \varepsilon \,, \tag{17}$$

[36] The coefficients are β_{NBP1} and β_{NBP2}.

where *ProfitRatio* is the percentage of profit in index point computed based on the initial amount. α and ε are regression coefficient, and error term, respectively. When $K/S > 1$, the option is an OTM call or ITM put. When $K/S<1$, the option is an ITM call or OTM put. When $K/S=1$, the option is ATM. In Table 7, options are grouped by option type (put and call) and the time to maturity, as in previous tables. We see that the α_1 values of calls across five maturities are all positive, while the α_1 values of puts are all negative and significant at 5% level, suggesting the lower the exercise price will be higher the profit ratio. It also implied that selling deep OTM options will generate greater profit. According to the results in all intervals, the trading profit ratio decreases by 0.0462% for put options if the K/S ratio increases by one unit. As suggesting in Bollen and Whaley (2004), this negative relation confirms the empirical results in Table 6 that the net buying pressure drives the OTM and DOTM put options premiums.

Table 8

Test Results of Trading Simulations[1]

The naked trading strategy does not hedge the short position over the entire holding period. The delta-hedging strategy is to buy/sell |delta| units of the MTX for a call/put short position, and the underlying asset position is revised by changing the number of units in the underlying asset at p.m. 1:45 daily. The positions are held until expiration. The profit is carried forward until the options expiration day. Profit probability is the chance of positive return in trading simulations. Sign test is for testing the probability of positive return. Profit in index indicates the mean of trading profit in terms of mini-TAIEX index points. Profit ratio is the average ratio of profit in index points to initial investment amount.

Trading Strategy	Option	N.	Profit Probability	Profit in Index	Profit Ratio
Naked Trading	Put	18,357	79.34% †††	24.19 ***	19.48% ***
	Call	18,357	68.48% †††	5.29 **	3.20%
	All	36,714	72.91% †††	14.74 ***	8.14% ***
Delta-Hedging	Put	18,357	66.81% †††	36.31 ***	3.75% ***
	Call	18,357	62.28% †††	11.34 *	1.74%
	All	36,714	64.55% †††	22.48 **	2.51% *

Note: [1]The †, ††, and ††† for profit probability indicate whether the probability of positive profit is significantly greater than 50% at the 10%, 5% and 1% level, respectively. The *, **, and *** for profit in index and profit ratio show whether the number is significantly greater than zero at the 1%, 5%, and 10% level, respectively. The test rules are based on Johnson's modified t-test.

Table 8 presents the results of trading simulations. Profit probability is the chance of positive return in trading simulations. Sign test is for testing the probability of positive return. Profit in index indicates the mean of trading profit in terms of MTX index points. Percentage of profit is the average ratio of profit in index points to initial investment amount. Those two measures allow us to determine whether profit is greater than zero.

Table 9

Test Results on Selling Option Trading Simulations by Moneyness and Maturity[1]

The naked trading strategy does not hedge the short position over the entire holding period. The delta-hedging strategy is to buy/sell |delta| units of the MTX for a call/put short position, and the underlying asset position is revised by changing the number of units in the underlying asset at p.m. 1:45 daily. The positions are held until expiration. The profit is carried forward until the options expiration day. Profit probability is the chance of positive return in trading simulations. Sign test is for testing the probability of positive return. Profit in index indicates the mean of trading profit in terms of mini-TAIEX index points. Profit ratio is the average ratio of profit in index points to initial investment amount.

Option	Moneyness	N.	Naked trading			Delta-Hedging		
			Profit probability	Profit in index	Profit ratio	Profit probability	Profit in index	Profit ratio
1-week								
	DOTM	302	96.88% †††	4.62 ***	23.85% ***	72.19% †††	2.37 **	2.44% **
	OTM	147	80.52% †††	6.2 ***	16.12% ***	67.94% †††	3.01 **	0.39% **
Put	ATM	131	64.89% †††	5.43 ***	10.49% **	55.10% †††	3.12 *	0.16% **
	ITM	154	52.38% ††	3.12 **	6.17%	52.88% ††	0.99	0.04%
	DITM	288	47.68%	1.2 ***	2.60%	50.99%	1.53	0.19%
	DOTM	288	95.36% †††	3.26 *	15.67% ***	67.71% †††	2.35 *	1.94% *
	OTM	154	76.87% †††	3.42 *	14.29% **	65.99% †††	1.82 *	0.23%
Call	ATM	131	64.12% †††	4.78 **	6.65%	66.41% †††	1.67	0.36%
	ITM	147	57.79% †	2.3 ***	5.54%	57.14% ††	1.05	0.13%
	DITM	302	50.69%	1.34	2.79%	49.31%	-0.5	-0.07%
	Low K	590	71.52% †††	3.09 ***	12.32% **	61.59% †††	1.94 **	1.65% ***
	Med-Low K	301	64.63% †††	4.23 ***	9.83% *	62.54% †††	2.84 **	0.26% *
All	Med K	262	64.50% †††	4.92 **	9.58%	60.18% †††	2.57 **	0.21%
	Med-High K	301	69.16% †††	3.15 **	9.23% *	59.01% ††	1.42 *	0.15%
	High K	590	73.78% †††	2.07 *	8.53%	57.51% ††	1.65	0.97%
2-week								
	DOTM	479	96.15% †††	11.34 ***	41.02% ***	74.73% †††	12.49 ***	1.83% **
	OTM	270	78.60% †††	7.58 ***	22.67% ***	73.15% †††	8.09 ***	0.97% **
Put	ATM	240	67.50% †††	6.53 *	7.13% *	73.75% †††	8.83 ***	1.14% *
	ITM	257	62.65% †††	3.3	9.35% **	58.15% †††	4.07 ***	0.78%
	DITM	467	52.68% †	-2.12	-1.17%	52.19% †	0.69	0.04%
	DOTM	467	94.15% †††	8.42 ***	38.43% **	71.53% †††	7.76 ***	1.61% **
	OTM	257	78.52% †††	3.61 **	12.90% **	69.63% †††	6.62 **	1.35% *
Call	ATM	240	63.33% †††	4.93 **	12.82% *	68.75% †††	5.88 **	0.53%
	ITM	270	55.19% ††	2.39	3.93%	63.04% †††	2.32	0.44%
	DITM	479	50.73%	-1.63	-6.47%	51.39%	3.4	0.35%
	Low K	946	72.44% †††	4.97 ***	16.74% ***	63.36% †††	7.44 *	1.11% ***
	Med-Low K	527	66.85% †††	4.47 ***	9.87% **	66.89% †††	5.2 **	0.87% **
All	Med K	480	65.42% †††	5.95 **	6.16% *	70.25% †††	5.36	0.85%
	Med-High K	527	70.62% ††	3.84 **	5.92%	63.09% †††	5.85 *	1.00% *
	High K	946	73.41% †††	3.75	14.13% **	62.06% †††	4.46	0.87%

Note: [1]The †, ††, and ††† for profit probability indicate whether the probability of positive profit is significantly greater than 50% at the 10%, 5% and 1% level, respectively. The *, **, and *** for profit in index and profit ratio show whether the number is significantly greater than zero at the 1%, 5%, and 10% level, respectively. The test rules are based on Johnson's modified t-test.

Table 9(Continued)

Test Results on Selling Option Trading Simulations by Moneyness and Maturity[1]

Option	Moneyness	N.	Naked trading			Delta-Hedging		
			Profit probability	Profit in index	Profit ratio	Profit probability	Profit in index	Profit ratio
3-week								
	DOTM	538	97.03% †††	10.98 ***	60.49% **	79.18% †††	17.88 ***	1.50% ***
	OTM	341	77.13% †††	19.62 ***	55.49% **	75.45% †††	19.44 *	1.32% ***
Put	ATM	303	65.02% †††	20.89 **	37.34%	67.36% †††	10.35 *	0.92%
	ITM	334	60.48% †††	-7.96	-13.45%	60.78% †††	11.9	0.72% **
	DITM	528	55.30% ††	-0.52	-16.62%	52.65% †	-7.54	-0.37%
	DOTM	528	92.80% †††	9.51 ***	46.88% *	70.27% †††	8.74 *	0.95%
	OTM	334	79.34% †††	5.4 *	33.12%	71.55% †††	9.63 *	1.07% *
Call	ATM	303	62.05% †††	10.74 *	25.82%	66.34% †††	11.98	0.73%
	ITM	341	53.96% †	-3.27	-4.76%	55.13% †	4.1	0.23% *
	DITM	538	46.28%	-2.13	-9.09%	46.28%	-6.66	-0.91%
	Low K	1,066	71.65% †††	4.56	25.87% **	62.73% †††	5.27	1.16% **
	Med-Low K	675	65.54% †††	8.56 ***	24.70% *	65.34% †††	11.76 **	1.02% *
All	Med K	606	63.53% †††	15.85 **	31.76% *	66.65% †††	10.05 *	0.77%
	Med-High K	675	69.91% ††	-1.15	10.72%	65.11% ††	9.77	0.84%
	High K	1,066	74.05% †††	4.17	15.75%	61.46% ††	0.4	0.93%
1-month								
	DOTM	840	92.89% †††	22.91 ***	48.62% **	75.89% †††	21.69 ***	1.99% ***
	OTM	579	80.60% †††	16.83 *	47.34% *	74.91% †††	34.87 *	1.86% *
Put	ATM	529	67.30% †††	15.11 **	27.40%	69.19% †††	26.77 *	0.75%
	ITM	562	58.38% †††	-2.08	-9.57%	60.97% ††	5.57	0.43% *
	DITM	788	53.10% †	-7.15	-13.71%	53.93%	6.59 *	0.40%
	DOTM	788	93.93% †††	18.82	54.43% *	76.79% †††	19.34 **	1.74% **
	OTM	562	78.58% †††	14.5 **	49.13%	73.92% †††	21.33 *	1.35%
Call	ATM	529	63.33% ††	11.02 *	33.28%	65.97% †††	10.95	1.04% *
	ITM	579	52.31% ††	9.74	21.77%	53.20%	-10.88	-0.67%
	DITM	840	45.56%	-4.48	-6.85%	44.42%	-7.73	-0.71%
	Low K	1,628	68.51% †††	9.36 **	29.74%	65.36% ††	13.56 *	1.25% **
	Med-Low K	1,411	66.48% †††	12.67 ***	47.56% *	67.58% †††	12.87	1.48% *
All	Med K	1,058	65.31% †††	11.56 *	28.34%	67.44% ††	13.86	0.87%
	Med-High K	1,141	68.46% ††	6.83	5.78%	64.06% †	13.05	0.80%
	High K	1,628	68.23% ††	5.33 *	6.36%	60.15% ††	12.23 *	1.15% *
2-month								
	DOTM	2189	93.60% †††	29.03 ***	64.08% ***	81.55% †††	38.36 **	1.98% ***
	OTM	2166	80.36% †††	22.76 ***	55.86% ***	76.92% †††	27.58 **	1.95% ***
Put	ATM	2076	66.86% †††	11.83 **	26.25% *	71.63% †††	28.43 ***	1.81% *
	ITM	2006	58.03% †	4.42	4.06%	62.74% †	15.52	0.22%
	DITM	1843	53.36% †	-13.19	-6.12%	54.04%	14.2	0.25%
	DOTM	1843	92.92% †††	20.24 **	40.28% *	73.87% †††	32.32 **	1.86% *
	OTM	2006	78.39% †††	17.98 *	57.44%	70.82% †††	31.17 **	1.94% **
Call	ATM	2076	63.63% †††	-4.37	-1.60%	62.28% ††	16.17	0.63%
	ITM	2166	50.45%	-12.07	-12.27%	50.35%	10.53 **	0.46% *
	DITM	2189	45.79%	-19.81	-32.92%	44.38%	25.27 *	0.55%
	Low K	4,032	73.14% †††	13.42 **	43.50% ***	66.78% †††	30.96 **	1.68% **
	Med-Low K	4,172	68.21% †††	12.91 *	44.06% *	66.96% †††	23.97 **	1.52% *
All	Med K	4,152	65.25% †††	8.1 *	15.32%	63.96% †††	17.37	1.44% *
	Med-High K	4,172	65.40% ††	6.22	16.69%	62.97% †††	22.68	1.57% *
	High K	4,032	69.70% ††	-3.22	18.20% **	63.63% †††	20.44 **	1.37% **

Note: [1]The †, ††, and ††† for profit probability indicate whether the probability of positive profit is significantly greater than 50% at the 10%, 5% and 1% level, respectively. The *, **, and *** for profit in index and profit ratio show whether the number is significantly greater than zero at the 1%, 5%, and 10% level, respectively. The test rules are based on Johnson's modified t-test.

The simulation results find that shorting put options generate higher profit probability, profit in index, and profit ratio than call options with profit probability reaching 79.34%. The results of trading simulations by moneyness and maturities are illustrated in Tables 9. As shown, OTM options, in particular DOTM put options have higher profit probability, profit and profit ratio than ATM and ITM options, suggesting options with lower exercise price are more likely to generate profit. Those results again demonstrate that OTM put premiums are driven by net buying pressure. Moreover, we compare the effect of net buying pressure on put options across different maturities and find that the effect of net buying pressure increases along with maturity from one week to three weeks but becomes inconsistent with maturity longer than three weeks. For example, the difference between the profit percentage of DOTM puts and OTM puts with one week is 21.25%. The difference grows to 77.11% when the maturity increases to three weeks, indicating the significant influence of net buying pressure for options with three weeks to maturity. These findings are consistent with previous empirical results on implied volatility in this paper.

Comparing the profitability of naked and delta-hedge trading, naked trading results in higher profit probability and profit ratio in put options, indicating a trade-off relation between return and risk, while such consistency is not observed in call options. We also find that the profitability of call options is similar to the performance of put options. That is, profitability and exercise price are inversely related. But DOTM calls generate the highest profit, which does not coincide with the net buying pressure hypothesis. In the discussion of similar empirical results, Chan, Cheng, and Lung (2004) suggest that the representing of higher implied volatilities of OTM put options cannot be fully translated to call options by put-call parity, and the higher implied volatilities of OTM call options might be driven by their own net buying pressure. We also concur that the higher profit generated by OTM call options is attributed to higher implied volatility in Taiwan’s options market, which in turn is caused by the net buying pressure of call options. This result is similar to the empirical results of implied volatilities in this paper.

Next we simulate the trading profits by combining call and put options according to their exercise price level to observe the impact of net buying pressure on the premium of TXO. From Table 9, we find that the net buying pressure hypothesis performs better in shorter term options. For example, the profit ratio in naked trading of all options with one week drops from 12.32% in low exercise price options to 8.53% in high exercise price options. The percentage of profit in delta-hedging trading of options with the same maturity fall from 1.65% to 0.97%, as exercise price increases, suggesting that there is an inverse relationship between exercise price and profitability in short-term options and that the option premium is driven by net buying pressure. By comparing the profits from naked trading and hedge trading, the trade-off between risk and return is also found to exist. While the inverse relation of exercise price and profitability is not obvious in options with longer maturities, we can still conclude that the low exercise price options generate the highest profit.

6. Summary

This study examines net buying pressure hypothesis in Taiwan's options market by observing the pattern of implied volatilities and conducting trading simulations. Grouping the options by type, moneyness, and maturity, we use high frequency data to test our hypotheses, and we further examine the net buying pressure hypothesis with trading simulations. Empirical results find that the shape of implied volatility of TXO is negatively skewed, caused by net buying pressure. After controlling the factors of information flow effect and leverage effect, empirical evidence shows that net buying pressure affects option premium due to the presence of limits to arbitrage in the market and that net buying pressure hypothesis exists in Taiwan's options market.

Consistent with the greater hedging demand of institutional investors for OTM put options, we also conclude that net buying pressure affects this moneyness category the most. The results of our trading simulations also support the net buying pressure hypothesis. We find a positive relationship between maturity and implied volatility, and implied volatility is the highest in options with three weeks to maturity. We further find that option investors are volatility traders in Taiwan, suggesting volatility is the primary basis for making trading decision. Finally, our testing by performing trading simulations supports the presence of net buying pressure in Taiwan's options market.

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