

# Net buying pressure and option informed trading

Chao-Chun Chen\* Shih-Hua Wang†

## Abstract

To differentiate the impacts of volatility trading and direction trading on an option market, this study develops a method to decompose net buying pressure into the volatility-motivated component and direction-motivated component. Unlike the totally net buying pressure adopted in the literature, in that a cancel-out effect may occur between volatility trading and direction trading and thus bring about a consequential mutually-exclusive result when inspecting the two trading effects by entire net buying pressure, the proposed decompositions in net buying pressure enable us to examine which kind of informed trading activities drive option price changes by independently testing the volatility-learning hypothesis and direction-learning hypothesis. Empirical evidences show that the change in implied volatility of TAIEX OTM put options can be accounted for by both of the two net-buying-pressure hypotheses. It indicates that trades on OTM put options may contain information regarding both future volatility and future price movements of the underlying asset, which is very different from the findings of the jointly test methodology adopted in the related literature.

*Key words:* Learning hypotheses; Net buying pressure; Volatility-motivated trading; Direction-motivated trading; Independent test

EFM Classification Codes: 410, 360

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\*All correspondence to Chao-Chun Chen. Associate Professor. Department of Finance, Tunghai University, Taichung, Taiwan, R.O.C. E-mail: [jawjiun@thu.edu.tw](mailto:jawjiun@thu.edu.tw)

†Department of Finance, Tunghai University, Taichung, Taiwan, R.O.C.

# 1 Introduction

The information content of trading activities, especially from informed traders, is a subject of widespread interest no matter in stock markets or in derivative markets. According to the preferred habitat of informed investors, the properties of high financial leverage, low transaction costs, and few short-selling restrictions in derivative markets are attractive for informed investors to exploit their private information in the option market before in the underlying asset market. According to the assertions in Black (1975), Easley, O'Hara, and Srinivas (1998), Bollen and Whalley (2004), and Kang and Park (2008), as long as markets are incomplete and there are informed traders taking advantage of private information in option markets before having a position in the underlying security markets, option trades are capable of carrying information concerning the subsequent price behavior of the underlying asset.

Indeed, there are at least two types of informed traders participating in an option market; those are volatility traders and direction traders. The former takes a position in options when shocks on volatility of the future underlying asset prices occur, while the latter engages in option trading provided expectations regarding the future price movements of the underlying asset change. The information content behind option demands is thus expected to differ across different types of informed trading, as long as the two types of informed trading relies on different news. A rich body of literature has emerged investigating the information content behind option trades, although few documents differentiate the volatility trading effect and direction trading effect from option demands.

In the literature, Bollen and Whaley (2004) propose a hypothesis to demonstrate the volatility trading effects in an option market and examine whether option price changes result from volatility trading by exploring the information content of net buying pressure. Herein,

net buying pressure is defined by the difference between the number of buyer-motivated contracts and seller-motivated contracts multiplied by the absolute value of the options' delta. According to the assertion of this hypothesis, volatility informed traders buy/sell both call and put options in case of positive/negative volatility shocks arriving. The consequential order imbalance in options reflects the change in market expectations about future volatility, and thus signals to market makers for updating option implied volatility. It eventually results in net buying pressure having positive influences on implied volatility of both call and put options. As suggested in Kang and Park (2008), we name the hypothesis proposed in Bollen and Whaley (2004) that concerns the volatility trading effect as the volatility-learning hypothesis. By adopting the daily data in the U.S. option market, Bollen and Whaley (2004) provide evidences that net buying pressure does matter to the shape of the implied volatility smile, although it cannot be concluded to result from volatility informed trading.

Kang and Park (2008) argue that option traders can be direction traders as well and extend the learning hypothesis to examine the direction trading effect in option price changes. They document that traders with optimistic/pessimistic expectations about future security price movements buy call/put options but sell put/call options before taking a position in the underlying security, provided that option markets possess higher financial leverage and lower transaction costs. Consequently, net buying pressure of call/put options induced by direction trading is observed to raise implied volatility of call/put options but lessen that of put/call options, before information is disseminated to the stock market. This is the content of the direction-learning hypothesis. By extending the empirical test methodology of Bollen and Whaley (2004), Kang and Park (2008) provide evidences supporting that price changes in KOSPI 200 options mainly result from direction trading and net buying pressure contains information about the future movements of the KISPI 200 index.

A common feature sharing with Bollen and Whaley (2004) and Kang and Park (2008) in inspecting the volatility trading effect and direction trading effect is to examine the way how the entire net buying pressure influences options' implied volatility. Simply speaking, Bollen and Whaley (2004) examine the volatility trading effect by looking at whether net buying pressure of call and that of put options has equally positive influences on an option's implied volatility, whereas Kang and Park (2008) demonstrate that a finding regarding net buying pressure of call and that of put options having opposite influences on an option's implied volatility can be attributed to direction trading. However, as net buying pressure is an aggregation of excess option demands across all option traders, including volatility traders and direction traders, a potential concern behind the usage of entire net buying pressure is parts of the volatility trading effect and direction trading effect may cancel each other out, if option trades conducted by the two kinds of informed trading are in the opposite positions. Indeed, this always happens while volatility shocks and direction shocks occur at the same time, in which put options may be bought by volatility traders but sold by direction traders, provided that both the two kinds of shocks are positive. As a result, under the empirical test methodology adopted in Bollen and Whaley (2004) and Kang and Park (2008), in that the volatility trading effect is examined by looking at whether net buying pressure of call and put options has equal and positive impacts on an option's implied volatility, little volatility trading effect can be found out while a large direction shock goes with a small volatility shock. Similarly, entire net buying pressure cannot be found to carry any information concerning the direction trading effect if a weak direction shock accompanies with a large volatility shock. The cancel-out effect behind entire net buying pressure in case of both volatility shocks and direction shocks happening simultaneously is also the reason why the volatility-learning and direction-learning hypotheses are always mutual exclusive when adopting entire net buying pressure, as the way in the empirical test of Kang and Park's (2008), to examine the two

hypotheses.

In reality, both direction traders and volatility traders are active in most of option markets, and direction shocks usually accompany volatility shocks as well. To avoid the cancel-out effect in entire net buying pressure and address the mutual-exclusive puzzle between the volatility-learning and direction-learning hypotheses, unlike the way of Kang and Park's (2008) that stands at an aggregative perspective to explore the impact of primarily informed trading activities on option price changes, this research proposes a method to decompose the overall net buying pressure into the volatility-motivated component and direction-motivated component, and examines the two types informed trading effects in an option market individually based on the proposed method. With the decompositions of net buying pressure, the volatility-learning hypothesis and direction-learning hypothesis are able to be tested independently, and, as a result, the changes in options' implied volatility are allowed to be accounted for by both the two hypotheses, which is very different from the jointly test methodology adopted in the literature.

We apply the proposed approach to investigate the impacts of the two types informed trading on prices of the Taiwan Stock Exchange Capitalization Weighted Stock Index options (TAIEX options, hereafter), and explore whether the information content behind the decomposed net buying pressure changes after the onset of the U.S. debt-ceiling crisis in 2011. The TAIEX option, in which the underlying asset is the Taiwan Capitalization Weighted Stock Index (TAIEX), is in a market with high individual participation and is one of the most liquid index options in the world. As the statistics in WFE/IOMA Derivatives Market Survey 2013, the number of TAIEX option contracts traded accrued in 2013 reach to 109 million contracts, ranking it sixth among the most actively traded index option in the world. Based on the empirical evidences, the change in implied volatility of TAIEX options is accounted for

by the direction-learning hypothesis across all models, regardless of moneyness and sample periods, while the volatility trading effect is only found in OTM put options. These empirical evidences are very different from that of Kang and Park (2008), in which the two learning effects are restricts to be mutually exclusive under the adoption of entire net buying pressure.

The remaining parts of this paper are arranged as follows. Section 2 proposes a method to decompose net buying pressure. Section 3 describes our data. The empirical specifications in investigating the relationship between the decomposed net buying pressure and options' implied volatility are provided in Section 4. Section 5 is empirically results. Concluding remarks are given in the last section.

## 2 Decompositions of net buying pressure

The classical net buying pressure adopted in Bollen and Whaley (2004) and Kang and Park (2008) is defined by the difference between the number of buyer-motivated contracts and seller-motivated contracts multiplied by the absolute value of options' delta. Herein, the difference is computed on a series-by-series basis, and is multiplied by the absolute value of the option's delta to express demand in index equivalent units. As we mentioned above, net buying pressure is comprised of excess option demands from both direction traders and volatility traders.

As the entire net buying pressure includes net option demands from direction trading and volatility trading, it can be displayed as:

$$NBP_{C,t}^k = NBPD_{C,t}^k + NBPV_{C,t}^k, \quad (1)$$

and

$$NBP_{P,t}^k = NBPD_{P,t}^k + NBPV_{P,t}^k, \quad (2)$$

where  $k \in \{\text{DOTM}, \text{OTM}, \text{ATM}, \text{ITM}, \text{DITM}\}$  and  $i \in \{C, P\}$ . Moreover,  $NBP_{i,t}^k$  displays net buying pressure summed across the time interval  $t$  for call/put options categorized in the moneyness category  $k$ ,  $NBPD_{i,t}^k$  denotes the direction-motivated net buying pressure for the  $k$ -category call/put options, and  $NBPV_{i,t}^k$  represents the volatility-motivated net buying pressure for the  $k$ -category call/put options. We follow Bollen and Whaley (2004) and Kang and Park (2008) to measure moneyness of an option by options' delta and group options into five different moneyness categories, those are the DOTM-, OTM-, ATM-, ITM-, and DITM-category, based on delta, since delta can be interpreted as the likelihood of being in the money at expiration. The upper and lower bounds of each moneyness category are listed in Table 1. As in the prior studies, this research focuses on investigating the information content of net buying pressure in the OTM- and ATM-category options, because these options are more liquid and expected to convey abundant information concerning option informed trading.

The direction informed trading and volatility informed trading is sensitive to different types of news. Specifically, volatility informed traders enter into option positions while a volatility shock hits markets and induces the expectation about volatility changes, whereas the direction informed traders are known to be occupied in option trading while a direction shock occurs and leads to the expectation concerning the future asset price change. Thus, for an option within moneyness category  $k$ , the volatility-motivated net buying pressure and direction -motivated net buying pressure can be defined as:

$$NBPV_{i,t}^k = \frac{\partial NBP_{i,t}^k}{\partial \sigma} \Delta \sigma^E, \quad (3)$$

and

$$NBPD_{i,t}^k = \frac{\partial NBP_{i,t}^k}{\partial S} \Delta S^E, \quad (4)$$

where  $\partial NBP_{i,t}^k / \partial \sigma$  represents sensitivities of entire net buying pressure to changes in volatility,  $\partial NBP_{i,t}^k / \partial S$  displays sensitivities of entire net buying pressure to changes in the underlying asset price, and  $\Delta \sigma^E$  and  $\Delta S^E$  stand for changes in the expectation of asset volatility and asset prices, respectively. Without loss of generality, the excess option demand is set to be a function of the option's price. By applying Chain rule to Equations (3) and (4) and substituting the results into Equations (1) and (2), entire net buying pressure can be displayed as:

$$\begin{aligned}
NBP_{C,t}^k &= NBPD_{C,t}^k + NBPV_{C,t}^k \\
&= \frac{\partial NBP_{C,t}^k}{\partial C_t^k} \frac{\partial C_t^k}{\partial S} \Delta S^E + \frac{\partial NBP_{C,t}^k}{\partial C_t^k} \frac{\partial C_t^k}{\partial \sigma} \Delta \sigma^E \\
&= \frac{\partial NBP_{C,t}^k}{\partial C_t^k} \Delta_C^k \Delta S^E + \frac{\partial NBP_{C,t}^k}{\partial C_t^k} v_C^k \Delta \sigma^E,
\end{aligned} \tag{5}$$

and

$$\begin{aligned}
NBP_{P,t}^k &= NBPD_{P,t}^k + NBPV_{P,t}^k \\
&= \frac{\partial NBP_{P,t}^k}{\partial P_t^k} \frac{\partial P_t^k}{\partial S} \Delta S^E + \frac{\partial NBP_{P,t}^k}{\partial P_t^k} \frac{\partial P_t^k}{\partial \sigma} \Delta \sigma^E \\
&= f'(\Delta P_{k,t}^E) \Delta_P^k \Delta S^E + f'(\Delta P_{k,t}^E) v_P^k \Delta \sigma^E,
\end{aligned} \tag{6}$$

where  $C_t^k$  and  $P_t^k$  are the time  $t$  prices of call and put options classified in moneyness category  $k$ , respectively. Moreover, both  $\Delta_i^k$  and  $v_i^k$ , where  $i \in \{C, P\}$  and  $k \in \{\text{DOTM, OTM, ATM, ITM, DITM}\}$ , are the option's Greek letters defined as:  $\Delta_C^k = \partial C_t^k / \partial S$ ,  $\Delta_P^k = \partial P_t^k / \partial S$ ,  $v_C^k = \partial C_t^k / \partial \sigma$ , and  $v_P^k = \partial P_t^k / \partial \sigma$ .

The properties of vega,  $v_C$  and  $v_P$ , and delta,  $\Delta_C$  and  $\Delta_P$ , play important roles in refining the direction-motivated and volatility-motivated components from entire net buying pressure. According to the Black and Scholes option pricing model, variation of vega with



stock prices is identical to a symmetrically normal distribution, indicating that the vega of a  $k$ -category call option is identical to that of a  $k$ -category put option:

$$V_C^k = V_P^k. \quad (7)$$

On the other hand, according to the moneyness category definition listed in Table 1, a definitely property concerning delta that can be observed from Table 1 is:

$$\Delta_C^k = -\Delta_P^k, \quad (8)$$

where  $k \in \{\text{DOTM, OTM, ATM, ITM, DITM}\}$ . It indicates that delta for  $k$ -category call options and delta for  $k$ -category put options has equivalent values but in different signs.

Combining these important properties of Greek Letters displayed in Equations (7) and (8) with Equations (5)-(6), the direction-motivated net buying pressure of the  $k$ -category call options can be solved by:

$$NBPD_{C,t}^k = \frac{NBP_{C,t}^k - NBP_{P,t}^k}{2}, \quad (9)$$

while the volatility-motivated net buying pressure of call options can be sized by:

$$NBPV_{C,t}^k = \frac{NBP_{C,t}^k + NBP_{P,t}^k}{2}. \quad (10)$$

Similarly, net buying pressures of put options induced by direction trading and volatility trading are measured respectively by:

$$NBPD_{P,t}^k = \frac{NBP_{P,t}^k - NBP_{C,t}^k}{2}, \quad (11)$$

and

$$NBPV_{P,t}^k = \frac{NBP_{P,t}^k + NBP_{C,t}^k}{2}. \quad (12)$$

As shown in Equations (9) and (11), direction-motivated net buying pressure of  $k$ -category call options,  $NBPD_{C,t}^k$ , is symmetric to that of put options,  $NBPD_{P,t}^k$ , in that the two variables are identical in values but in different signs. This feature is convincing since the degree of

information content behind direction-motivated trading cannot change, no matter that is measured from a viewpoint of call options or from a put option's perspective. The only difference is the signal concerning the future price movements is opposite, where direction-motivated net buying pressure on call/put options is expected to result in a higher/lower asset price, because the option's delta is positive for call options but negative for put options.

Equations (10) and (12) also show that volatility-motivated net buying pressure of  $k$ -category call options,  $NBPV_{C,t}^k$ , is identical to that of the corresponding put options,  $NBPV_{P,t}^k$ , in terms of both the magnitude and sign. Similarly, it is convincing since the degree of information content embedded in volatility-motivated trading does not change, no matter it is measured from the call option's viewpoint or from the put option's perspective. Moreover, the two variables are in the same signs because both of call and put options have positive vega, indicating that an increase in net demands for volatility, regardless of option types, is expected to enlarge realized volatility.

### **3 Sample Description**

This section displays the data adopted in this research and the way to generate option's implied volatility and the classical net buying pressure. The sample statistics and empirical properties of implied volatility and net buying pressure are analyzed in the section as well.

#### **3.1 Data**

This research applies the proposed decompositions of net buying pressure to analyze the price changes of TAIEX options in 2011. The TAIEX option, traded on Taiwan Futures Exchange, is European-style and matures on the third Wednesday of the expiration month.

The asset underlying TAIEX options is the Taiwan Capitalization Weighted Stock Index (TAIEX), which is reported based on 1-min frequency in our data set. For TAIEX options, there are five expiration months listed in the exchange, including the spot month, the next two calendar months, and the next two quarterly months. As we mentioned above, the TAIEX options have been one of the most frequently traded and important index options in the world.

The TAIEX option transaction data that we adopt are drawn from the database of CMoney-Institutional Investor Investment Decision Support System and comprises the trading time, including the trading date, hour, minute, and second, bid price, ask price, trading price, strike price, expiration month, option type, and trading volume for each transaction of TAIEX options in 2011. As well known, the U.S. debt-ceiling crisis is one of the most impressively catastrophic event happened in 2011, in that the delay in raising the debt ceiling by Republicans in Congress almost causes the U.S. government shutdown in the beginning of August 2011. It also results in the first downgrade in the U.S. credit rating and a consequently sharp drop in the stock market. To analyze the impact of the U.S. sovereign debt crisis on the TAIEX option market, we adopt July 31, 2011 as the cutoff point and divide the whole sample period into two subperiods: Subperiod I and II, representing the subperiods before and after the onset of the U.S. sovereign debt crisis, individually. Summarily, subperiod I ranges from January 2011 to July 2011, while Subperiod II covers from August 2011 to December 2011.

In order to calculate options' implied volatility and theirs net buying pressure, we merge the time-stamp TAIEX option transaction data with the intraday TAIEX index data by trading time, and calculate implied volatility for each transaction based on its synchronic TAIEX index. Denote the trading prices of call and put options at time  $t$  are  $C_t$  and  $P_t$ , respectively. Implied volatility can be calculated by the following Black and Scholes model:

$$C_t = S_t e^{-q(T-t)} N(d_1) - K e^{-r(T-t)} N(d_2), \quad (13)$$

and

$$P_t = K e^{-r(T-t)} N(-d_2) - S_t e^{-q(T-t)} N(-d_1), \quad (14)$$

where

$$d_1 = \frac{\ln(S_t / K) + (r - q + 0.5\sigma^2)(T - t)}{\sigma\sqrt{(T - t)}}, \quad (15)$$

and

$$d_2 = d_1 - \sigma\sqrt{(T - t)}. \quad (16)$$

Herein,  $S_t$  denotes the index level at time  $t$ ,  $K$  is the option's strike price,  $T$  displays the time to expiration,  $r$  stands for the risk-free interest rate,  $q$  represents the dividend yield of the index,  $N(\cdot)$  is the normal cumulative density function, and  $\sigma$  denotes the volatility. We adopt the average of one-month time deposit interest rates of five major banks in Taiwan as the risk-free interest rate,  $r$ , which are collected from the website of the Central Bank of the Republic of China. Moreover, according to the statistics of Taiwan Stock Exchange, the TAIEX dividend yield,  $q$ , is equal to 5.83% in 2011.

Transactions with the non-synchronic problem and with possible price distortions are removed from our data set. The non-synchronic problem results from the design of the market mechanism, whereas the price distortions usually happen in very DITM or DOTM options. Specifically, Taiwan Stock Exchange, in which TAIEX index lists, operates from 9:00 to 13:30 each trading date, while the trading hour for TAIEX options list in Taiwan Futures Exchange is from 8:45 to 13:45 for each trading date. According to TWSE information disclosure mechanism during the closing session, orders made will not be matched but only be accepted from 13:25 to 13:30, and no information is disclosed during this last five minutes

until closing. It indicates that stock prices stay at 13:25 and will not update until 13:30. Although the TWSE launches a new order-matching simulation mechanism five minutes during the closing session from February 20, 2012, and release information on the highest bid price and the lowest ask price approximately every twenty seconds at the last five minutes during the closing session, there is no actual matched trade information available. Accordingly, it is impossible to match the synchronic underlying asset price after 13:25 on each trading day. For TAIEX option transactions executed before 9:00 and after 13:30, there exists even more serious nonsynchronic problem. To be without in the nonsynchronic problem, we delete transactions of TAIEX options traded before 9:00 and after 13:25 on each trading day.

Implied volatility executed in each transaction cannot be analyzed by the regression method yet. We follow Bollen and Whaley (2004) and Kang and Park (2008) to group options into five different moneyness categories and compute an average implied volatility for each of the option categories over a five-minute time interval. The moneyness categories are classified by option's delta,

$$\Delta_C = N \left[ \frac{\ln(S_t / K) + (r - q + 0.5\sigma^2)(T - t)}{\sigma\sqrt{(T - t)}} \right], \quad (17)$$

and

$$\Delta_P = N \left[ \frac{\ln(S_t / K) + (r - q + 0.5\sigma^2)(T - t)}{\sigma\sqrt{(T - t)}} \right] - 1, \quad (18)$$

in which option's delta,  $\Delta_C$  and  $\Delta_P$ , can be regarded as the probability of the option being in the money at maturity. Herein, the proxy for the volatility rate in calculating option's delta is realized return volatility of the underlying asset over the most recent sixty trading days, as

in the method of Bollen and Whaley (2004). Upper and lower bounds for each category are displayed in Table 1.

Finally, as in Bollen and Whaley (2004) and Kang and Park (2008), transactions of options with absolute deltas below 0.02 or above 0.98 are excluded because the value of DITM and DOTM options are extraordinarily insensitive to volatility changes and may have distortions due to price discreteness. The transactions with a trading price above its theoretically upper bound or below its theoretically lower bound are also excluded from our data set, since implied volatility cannot be estimated reasonably in these cases. Herein, the theoretically boundary of call prices is:

$$\text{Max}(S_t e^{-q(T-t)} - K e^{-r(T-t)}, 0) \leq C_t \leq S_t,$$

and that of put prices is:

$$\text{Max}(K e^{-r(T-t)} - S_t e^{-q(T-t)}, 0) \leq P_t \leq K e^{-r(T-t)}.$$

### 3.2 Empirical Properties of Implied Volatility

Figure 1 plots the time series properties of the TAIEX closing price and average implied volatility of TAIEX options over the whole sample period. A salient feature observed in Figure 1 is a significant jump in TAIEX implied volatility after the onset of the 2011 U.S. debt-ceiling crisis, indicating that trading activities on TAIEX options are substantially affected by this crisis. This is the reason why we chose July 31, 2011 as the cutoff point to divide the whole sample period into two sub-periods.

The implied volatility functions for the whole sample period and two sub-periods are plotted in Figure 2. As expected, the implied volatility curve for Subperiod II is not only higher but also steeper than that from the Subperiod I, indicating that the occurrence of the 2011 U.S. debt-ceiling crisis affects both the level and shape of implied volatility curve. This phenomenon is very similar to the findings in the literature, in which the shape of the implied

volatility curve are observed to change from a smile to smirk after October 1987 market crash.

### **3.3 Net Buying Pressure**

Table 2 reports the summary for the number of contracts traded and net purchases of contracts in TAIEX options, respectively. As shown in Panel A of Table 2, 55 percent of all contracts traded were call options, with only 45 percent being put options. There are similar results observed in Subperiod I and Subperiod II. It implies that TAIEX option traders prefer call options to put options. This phenomenon is different from the U.S. index option market reported in literature, where the percentage of put options traded was usually more than the proportion of call options. After taking the trading motivation into account, Panel B of Table 2 shows that the trading motivation for most TAIEX options belongs to seller-motivated.

Table 3 summarizes net buying pressure of call options and put options. The result is similar to what observed in the statistics of net-purchases contracts, because net buying pressure is generated by the number of net-purchases contracts multiplying the absolute value of the option's delta so as to express demand in index equivalent units. For the whole sample period, Table 3 reports that TAIEX option traders generally have net selling positions except for DOTM call options. To compare across the results in Subperiod I and Subperiod II, the net buying pressure of call options was 1.36 times that of puts during Subperiod I, while the proportion lessened to 1.13 in Subperiod II. This result suggests that the 2011 U.S. debt-ceiling crisis changed investors' trading behavior on TAIEX options again.

## **4 Empirical Specifications**

This study examines the two informed trading effects in the TAIEX option market with the proposed decompositions of net buying pressure, and explores whether the impacts of the

two informed trading on options' implied volatility alter after the onset of the 2011 U.S. sovereign debt crisis. The model specifications for the cases of call and put options across various moneyness categories are as follows:

$$\Delta\sigma_{i,t}^{ATM} = \beta_0 + \beta_1 RS_t + \beta_2 VS_t + \beta_3 NBPV_{i,t}^{ATM} + \beta_4 NBDP_{i,t}^{ATM} + \beta_5 \Delta\sigma_{i,t-1}^{ATM} + \varepsilon_t, \quad (19)$$

$$\Delta\sigma_{i,t}^{OTM} = \beta_0 + \beta_1 RS_t + \beta_2 VS_t + \beta_3 NBPV_{i,t}^{OTM} + \beta_4 NBDP_{i,t}^{OTM} + \beta_5 \Delta\sigma_{i,t-1}^{OTM} + \varepsilon_t, \quad (20)$$

where  $i \in \{C, P\}$ . Herein, as in Equations (9-12),

$$NBPV_{i,t}^k = (NBP_{C,t}^k + NBP_{P,t}^k)/2,$$

$$NBDP_{C,t}^k = (NBP_{C,t}^k - NBP_{P,t}^k)/2,$$

and

$$NBDP_{P,t}^k = (NBP_{P,t}^k - NBP_{C,t}^k)/2.$$

Moreover,  $\Delta\sigma_{i,t}^{ATM}$ , where  $i \in \{C, P\}$ , denotes the change in the average implied volatility of ATM call/put options, while  $\Delta\sigma_{i,t}^{OTM}$  represents the analogous quantity for OTM options.  $RS_t$  displays TAIEX returns during the time interval  $t$ , and  $VS_t$  stands for the summed trading volume of the TAIEX over the time interval  $t$ , expressed in millions of New Taiwan (NT) dollars. As mentioned above,  $NBPV_{i,t}^{ATM}$  and  $NBPV_{i,t}^{OTM}$ , where  $i \in \{C, P\}$ , are the volatility-motivated net buying pressure of ATM and OTM call/put options, whereas  $NBDP_{i,t}^{ATM}$  and  $NBDP_{i,t}^{OTM}$  denote the direction-motivated net buying pressure of ATM and OTM call/put options. All variables are calculated across five-minute time interval. Similar to the way adopted in Kang and Park (2008), we conduct the regression analysis with 5-min intraday data, in order to focus more on the information effect of net buying pressure on options' prices.



The regression specification in Equations (19) and (20) is identical to the ones adopted in the related literature, except for two adjustments in explanatory variables, in that we replace entire net buying pressure with the proposed decompositions of net buying pressure, as suggested in this research, and exclude the variable on ATM options' net buying pressure from the regression of OTM options' implied volatility. In the literature, ATM options' net buying pressure is included in the regressions of OTM options' implied volatility in order to differentiate the volatility-learning hypothesis from the limit of arbitrage hypothesis. Unlike the empirical test methodology adopted in Kang and Park (2008) that aims to examine three net-buying-pressure hypotheses, including the limit of arbitrage hypothesis, volatility-learning hypothesis, and direction-learning hypothesis, the proposed approach focuses on independently examining the two learning hypotheses. We do not include any variables about net buying pressure of ATM options in the regressions of changes in implied volatility of OTM call/put options, because examining the limit of arbitrage hypothesis is not a purpose of the proposed method and thus distinguishing this hypothesis from the volatility-learning hypothesis by comparing the coefficient of ATM options' net buying pressure and that of OTM options' net buying pressure, as done in the related literature, needs not to be taken into account in this study.

Similar to the setting in Bollen and Whalley (2004) and Kang and Park (2008), our regression model includes the contemporaneous index return  $RS_t$  and its trading volume  $VS_t$  as control variables for leverage and information flow effects. According to Black (1976) and Anderson (1996), stock return volatility is negatively associated with stock returns due to leverage effects, but is positively related to trading volume due to information flow effects. We thus expect the coefficient on TAIEX return,  $\beta_1$ , to be negative, whereas the coefficient on the trading volume of the TAIEX,  $\beta_2$ , is expected to be positive.

The volatility-learning hypothesis and direction-learning hypothesis for options within a particular moneyness category can be examined by the coefficients of the two decomposed net buying pressure, i.e.,  $\beta_3$  and  $\beta_4$ , respectively, in terms of the sign and significance. Under the volatility-learning hypothesis, new information about future volatility causes an order imbalance in option contracts and then signals market makers to change implied volatility. It indicates that volatility-motivated net buying pressure of a call/put option,  $NBPV_{i,t}^k$ , has a positive impact on changes in the option's own implied volatility, no matter what moneyness category the option is in. Contrarily, under the opinion of the direction-learning hypothesis, in that the option order imbalance induced by direction shocks changes the market expectations about the future price movements of the underlying asset and option prices correspondingly, the impact of direction-motivated net buying pressure of a call/put option,  $NBPD_{i,t}^k$ , on changes in the option itself implied volatility is expected to be positive, regardless of moneyness. Consequently, the volatility-learning hypothesis predicts the coefficient of volatility-motivated net buying pressure,  $\beta_3$ , in the regressions of changes in implied volatility to be significantly positive, whereas the direction-learning hypothesis argues that the coefficient on direction-motivated net buying pressure,  $\beta_4$ , should be significant and positive.

Among the coefficients of the two decomposed net buying pressure, the coefficient on  $NBPV_{i,t}^k$  is only related to the examination of the volatility-learning hypothesis and does not matter to the direction-learning hypothesis at all. Similarly, the direction-learning hypothesis cannot account for the coefficient on  $NBPV_{i,t}^k$  any more. The properties behind the proposed decompositions of net buying pressure enable us to independently inspect the volatility-learning hypothesis and direction-learning hypothesis by the estimates of  $\beta_3$  and

$\beta_4$ , respectively, and thus allows the possibility of both the two learning hypothesis being correct, which is very different from the jointly test methodology adopted in the literature.

The coefficient of lagged change in implied volatility,  $\beta_5$ , plays an assistant role in differentiating the two learning hypotheses as well. Specifically, the volatility-learning hypothesis predicts the coefficient of lagged change in implied volatility being not different from zero, because shifts in market expectations about volatility drives permanent changes in options' implied volatility and lead these unpredictable volatility shocks as well as the change in implied volatility to be serially uncorrelated. Contrarily, under the direction-learning hypothesis the lagged change in implied volatility is expected to be negatively correlated with the current one. Recall that direction informed traders prefer to exploit their private information about the future price movements in the option market before in the stock market, resulting in option prices leading their underlying asset price. The option's implied volatility changes at once when a direction shock hits the market and then reversely returns to its previous level as the price of the option's underlying asset reflects the new information, provided that market volatility does not change. To briefly summarize, the regression coefficient of the lagged change in implied volatility is expected to be insignificant under the volatility-learning hypothesis, whereas it is predicted to be significantly negative under the direction-learning hypothesis.

## **5 Empirical analysis**

This section displays empirical results in terms of the relationship between decomposed net buying pressure and changes in option's implied volatility and provides evidences for the two learning hypotheses in the TAIEX option market. Table 4 exhibits the regression results

for changes in implied volatility of ATM options across various sample periods, while the results for OTM options are displayed in Table 5. As expected, the coefficients on TAIEX returns are negative and statistically significant at the 1% level no matter what option category and sample period the model is specified, strongly suggesting the leverage effect of Black (1976). Being as the second controlled variable, the TAIEX trading volume is found to have positive impacts on changes in implied volatility regardless of moneyness, confirming the information flow effect proposed in Andersen (1996) that trading volume is driven by the identical factors generating return volatility. Interestingly, the information flow effect is not consistently found across the two subperiods.

The coefficients of  $NBPV_{i,t}^k$  and  $NBPD_{i,t}^k$  play important roles in exploring the two types informed trading effects in the TAIEX option market. Tables 4 and 5 show that the coefficient on  $NBPD_{i,t}^k$  is positive and statistically significant at 1% significance level across all cases, including cases for various option types, option moneyness, and sample periods, apparently supporting the direction-learning hypothesis. On the contrary, only the change in implied volatility of OTM put options is consistent with the volatility-learning hypothesis, as the coefficient on  $NBPV_{p,t}^{OTM}$  is positive and statistically significant at 1% significance level no matter whether the 2011 U.S. debt-ceiling crisis happens. Recognized that the OTM put option is the most popular tool for hedging the downside risk of the underlying asset, it may be the reason why trades on OTM put options carry more information regarding volatility shocks than those of other options. It is also observed that the coefficient on  $NBPV_{c,t}^{ATM}$  is negative, indicating that changes in implied volatility of ATM call options, which is rarely adopted in volatility informed trading in practices, cannot be accounted for by the volatility-learning hypothesis any more. Combined with these evidences, both the

volatility-learning hypothesis and direction-learning hypothesis are able to account for the change in implied volatility of OTM put options.

## **6 Conclusions**

One potential concern behind totally net buying pressure is parts of the demand from direction trading may offset the demand of the volatility trading, especially when the direction shock and volatility shock arrive simultaneously. To avoid this cancel-out effect, this study develops a method to decompose net buying pressure of options into the volatility-motivated component and direction-motivated component, and re-investigates the two informed trading effects in the TAIEX option market. The empirical evidences show that implied volatility of OTM put options is driven by both of the two decomposed net buying pressure, indicating that traders of OTM put options are both direction traders and volatility traders. We note that this empirical finding is very different from that in the literature, where the two learning effects are restricts to be mutually exclusive under the adoption of entire net buying pressure.

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**Table 1. Moneyness category definitions**

Category for calls	Delta range	Category for puts	Delta range
DITM	$0.875 < \Delta_C \leq 0.980$	DOTM	$-0.125 < \Delta_P \leq -0.020$
ITM	$0.625 < \Delta_C \leq 0.875$	OTM	$-0.375 < \Delta_P \leq -0.125$
ATM	$0.375 < \Delta_C \leq 0.625$	ATM	$-0.625 < \Delta_P \leq -0.375$
OTM	$0.125 < \Delta_C \leq 0.375$	ITM	$-0.875 < \Delta_P \leq -0.625$
DOTM	$0.020 < \Delta_C \leq 0.125$	DITM	$-0.980 < \Delta_P \leq -0.875$

Notes: (1). This paper measures moneyness of an option by using option's delta, since it can be regarded as the possibility of options being in the money at maturity. (2). Transactions for call options with delta below 0.02 and above 0.98 are excluded. Similarly, transactions for put options with delta below -0.98 and above -0.02 are excluded as well. (3). The moneyness category definition adopted in this research is the same as that used in Bollen and Whaley (2004) and Kang and Park (2008).



**Table 2. The number of TAIEX options traded in 2011**

Delta value category	Whole period				Subperiod I				Subperiod II			
	January 2011-December 2011				January 2011-July 2011				August 2011-December 2011			
	Call		Put		Call		Put		Call		Put	
	No. of contracts	Prop. of total	No. of contracts	Prop. of total	No. of contracts	Prop. of total	No. of contracts	Prop. of total	No. of contracts	Prop. of total	No. of contracts	Prop. of total
Panel A. Number of contracts traded												
DITM	214,501	0.29%	290,339	0.39%	162,521	0.36%	167,869	0.37%	4,045,143	13.44%	122,470	0.41%
ITM	1,974,878	2.64%	1,732,018	2.31%	1,482,408	3.31%	1,115,305	2.49%	8,530,511	28.35%	616,713	2.05%
ATM	9,290,363	12.41%	6,644,519	8.88%	6,025,131	13.46%	3,743,833	8.36%	3,265,232	10.85%	2,900,686	9.64%
OTM	20,584,453	27.50%	13,450,954	17.97%	12,053,942	26.92%	7,808,899	17.44%	492,470	1.64%	5,642,055	18.75%
DOTM	9,405,554	12.56%	11,278,510	15.06%	5,360,411	11.97%	6,857,514	15.31%	51,980	0.17%	4,420,996	14.69%
Totals	41,469,749	55.39%	33,396,340	44.61%	25,084,413	56.02%	19,693,420	43.98%	16,385,336	54.46%	13,702,920	45.54%
Panel B. net purchases of contracts												
DITM	-5,849		-23,475		-7,370		-7,931		1,521		-15,544	
ITM	-1,090		-11,861		-1,943		432		853		-12,293	
ATM	-280,033		-64,327		-178,892		-24,772		-101,141		-39,555	
OTM	-172,819		-403,142		57,149		-212,455		-229,968		-190,687	
DOTM	1,603		-8,139		125,155		96,582		-123,552		-104,721	
Totals	-458,188		-510,944		-5,901		-148,144		-452,287		-362,800	

Note: (1). The whole sample period that ranges from January 2011 to December 2011 is divided into two subperiods. Subperiod I is from January 2011 to July 2011, whereas Subperiod II starts from August 2011 and ends in December 2011. (2). The net purchases of contracts displayed in Panel B are calculated as the number of buyer-motivated contracts minus the number of seller-motivated contracts.

**Table 3. Net buying pressure**

Delta value category	Whole period		Subperiod I		Subperiod II	
	Call	Put	Call	Put	Call	Put
DITM	-5,467	-21,783	-6,839	-7,469	1,372	-14,314
ITM	-2,032	-10,941	-2,799	-1,430	767	-9,511
ATM	-127,213	-27,299	-82,959	-7,981	-44,254	-19,318
OTM	-58,849	-90,409	-5,400	-48,779	-53,449	-41,630
DOTM	2,346	-5,451	11,053	1,650	-8,708	-7,101
Totals	-191,215	-155,883	-86,944	-64,009	-104,271	-91,874

Note: (1). The whole sample period that ranges from January 2011 to December 2011 is divided into two subperiods. Subperiod I is from January 2011 to July 2011, whereas Subperiod II starts from August 2011 and ends in December 2011. (2). The net buying pressure is defined as the number of contracts traded above the prevailing bid/ask midpoint less the number of contracts traded below the prevailing bid/ask midpoint times the absolute value of the option's delta.

**Table 4. Regression results for the impact of the net buying pressure on the changes of ATM implied volatility**

$\Delta\sigma_{i,t}^{ATM}$	Parameter estimates					
	$\beta_0$	$\beta_1$	$\beta_2$ ( $\times 10^4$ )	$\beta_3$ ( $\times 10^3$ )	$\beta_4$ ( $\times 10^3$ )	$\beta_5$
Panel A. Whole Period: January 2011-December 2011						
Call	-0.0284 **	-0.8187 ***	0.1808 ***	-0.2498 ***	1.44 ***	-0.2133 ***
Put	-0.0445 ***	-1.5665 ***	0.1325 **	0.0767	1.04 ***	-0.2494 ***
Panel B. Subperiod I: January 2011-July 2011						
Call	0.0041	-0.8759 ***	0.0114	-0.1271	1.29 ***	-0.2412 ***
Put	-0.0860 ***	-0.2103 **	0.3357 ***	0.0754	1.42 ***	-0.2946 ***
Panel C. Subperiod II: August 2011-December 2011						
Call	-0.0598 ***	-0.8224 ***	0.3848 ***	-0.3728 **	1.82 ***	-0.2036 ***
Put	-0.0220	-2.2180 ***	-0.0160	-0.0442	1.12 ***	-0.2272 ***

Notes: The regression model is displayed as follows:

$$\Delta\sigma_{i,t}^{ATM} = \beta_0 + \beta_1 RS_t + \beta_2 VS_t + \beta_3 NBPV_{i,t}^{ATM} + \beta_4 NBPD_{i,t}^{ATM} + \beta_5 \Delta\sigma_{i,t-1}^{ATM} + \varepsilon_t, \quad i \in \{C, P\}, \quad (19)$$

where  $\Delta\sigma_{i,t}^{ATM}$ ,  $i \in \{C, P\}$ , denotes the change in the averaged implied volatility of ATM call/put options,  $RS_t$  indicates the index returns over the time interval  $t$ , and  $VS_t$  is the trading volume of the TAIEX index expressed in billions of New Taiwan Dollars for the time interval  $t$ . All variables are calculated at a five-minute time interval. Moreover, for ATM options, the volatility-motivated net buying pressure,  $NBPV_{i,t}^{ATM}$ , and the direction-motivated net buying pressure,  $NBPD_{i,t}^{ATM}$ , are measured by:

$$NBPV_{i,t}^{ATM} = (NBP_{C,t}^{ATM} + NBP_{P,t}^{ATM})/2, \quad \text{where } i \in \{C, P\}, \quad \text{and} \quad \begin{cases} NBPD_{C,t}^{ATM} = (NBP_{C,t}^{ATM} - NBP_{P,t}^{ATM})/2; \\ NBPD_{P,t}^{ATM} = (NBP_{P,t}^{ATM} - NBP_{C,t}^{ATM})/2. \end{cases}$$

Finally, one, two and three asterisks indicate the 10%, 5%, and 1% significant levels, respectively.

**Table 5. Regression results for the impact of the net buying pressure on the changes of OTM implied volatility**

$\Delta\sigma_{i,t}^{OTM}$	Parameter estimates					
	$\beta_0$	$\beta_1$	$\beta_2$ ( $\times 10^4$ )	$\beta_3$ ( $\times 10^3$ )	$\beta_4$ ( $\times 10^3$ )	$\beta_5$
Panel A. Whole Period: January 2011-December 2011						
Call	-0.0302 ***	-0.9201 ***	0.1399 ***	-0.0675	0.9326 ***	-0.1799 ***
Put	-0.0312 ***	-1.3954 ***	0.1234 **	0.5025 ***	0.6505 ***	-0.2185 ***
Panel B. Subperiod I: January 2011-July 2011						
Call	-0.0109	-0.8129 ***	0.0340	-0.0832	0.7946 ***	-0.2177 ***
Put	-0.0557 ***	-0.1853 ***	0.2566 ***	0.4132 ***	1.05 ***	-0.2808 ***
Panel C. Subperiod II: August 2011-December 2011						
Call	-0.0504 ***	-1.0198 ***	0.2846 ***	-0.0018	1.2 ***	-0.1689 ***
Put	-0.0209	-2.0502 ***	0.0651	0.7646 ***	0.5023 ***	-0.1999 ***

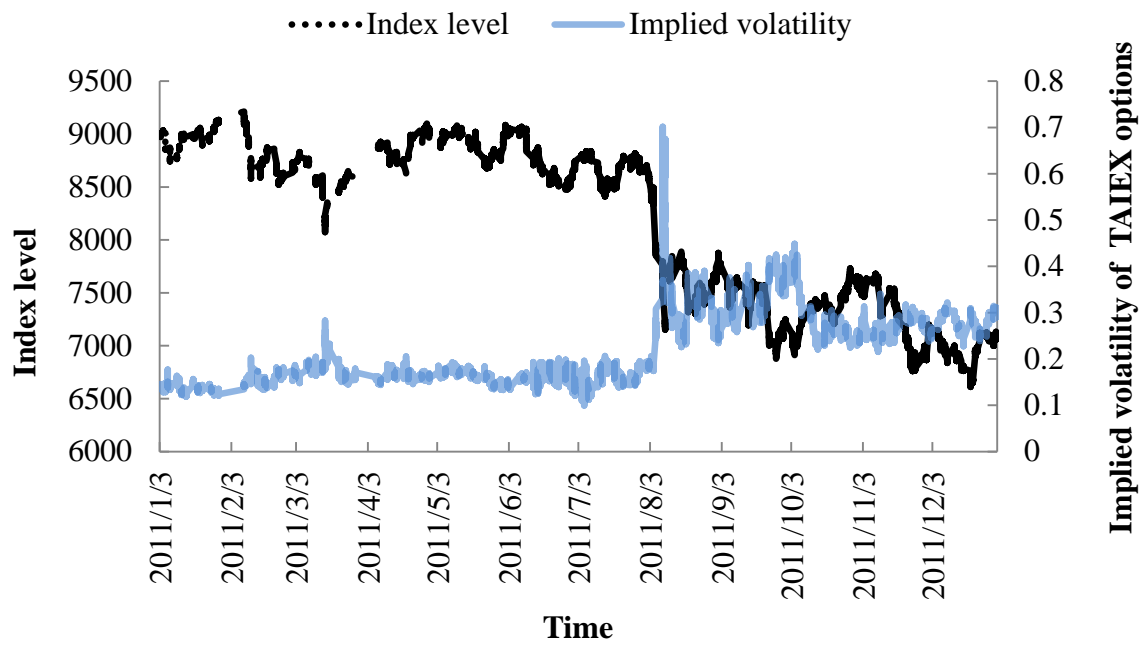
Notes: The regression model is displayed as follows:

$$\Delta\sigma_{i,t}^{OTM} = \beta_0 + \beta_1 RS_t + \beta_2 VS_t + \beta_3 NBPV_{i,t}^{OTM} + \beta_4 NBPD_{i,t}^{OTM} + \beta_5 \Delta\sigma_{i,t-1}^{OTM} + \varepsilon_t, \quad i \in \{C, P\}, \quad (20)$$

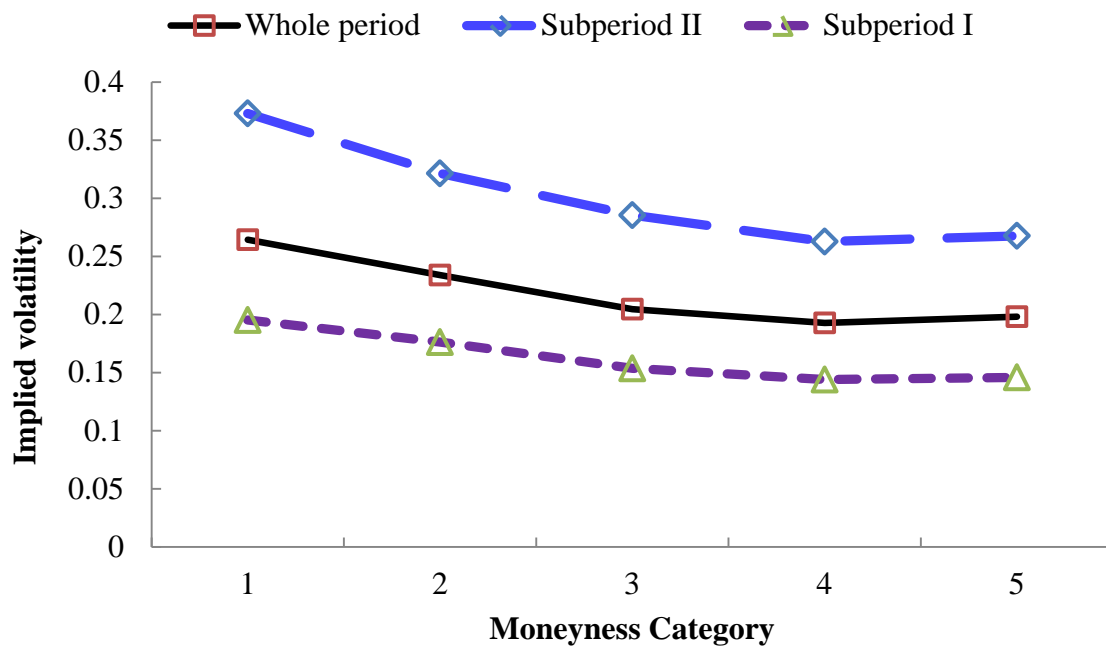
where  $\Delta\sigma_{i,t}^{OTM}$ ,  $i \in \{C, P\}$ , denotes the change in the average implied volatility for OTM call/put options,  $RS_t$  indicates the index returns over the time interval  $t$ , and  $VS_t$  is the trading volume of the TAIEX index expressed in billions of New Taiwan Dollars for the time interval  $t$ . All variables are calculated at a five-minute time interval. Moreover, for OTM options, the volatility-motivated net buying pressure,  $NBPV_{i,t}^{OTM}$ , and the direction-motivated net buying pressure,  $NBPD_{i,t}^{OTM}$ , are measured by:

$$NBPV_{i,t}^{OTM} = (NBP_{C,t}^{OTM} + NBP_{P,t}^{OTM})/2, \quad \text{where } i \in \{C, P\}, \quad \text{and} \quad \begin{cases} NBPD_{C,t}^{OTM} = (NBP_{C,t}^{OTM} - NBP_{P,t}^{OTM})/2; \\ NBPD_{P,t}^{OTM} = (NBP_{P,t}^{OTM} - NBP_{C,t}^{OTM})/2. \end{cases}$$

Finally, one, two and three asterisks indicate the 10%, 5%, and 1% significant levels, respectively.



**Figure 1. Implied volatility of TAIEX options and TAIEX closing prices in 2011**



**Figure 2. Estimated implied volatility functions of TAIEX options in 2011**

As in Bollen and Whaley (2004), category 1 comprises DITM calls and DOTM puts, category 2 contains ITM calls and OTM puts, category 3 are ATM calls and ATM puts, category 4 includes OTM calls and ITM puts, and category 5 consists of DOTM calls and DITM puts.