Return predictability and profitability of option volatility spread: Evidence from the Taiwan index option market

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Abstract

This research examines whether option price deviations related to put-call parity in the Taiwan index option market contain information regarding future price movements of the underlying asset and profitability from exploiting these deviations. After controlling for factors that usually prevent violations of put-call parity from being arbitraged away quickly and that usually lead to bias when measuring these violations, including non-simultaneity of prices, early exercise value of American options, short sale constraints on the underlying asset, and the non-tradable feature of the underlying spot index, the empirical results provide strong evidence supporting the predictability of deviations from the futures-version put-call parity on subsequent five-minute spot index returns. The futures-version put-call parity herein states the no-arbitrage relation between prices of index calls, index puts, and index futures contracts, where all three assets are tradable. Moreover, the excess return from a trading strategy that uses trading signals generated by these violations is positive and statistically significant across all the individual years in the sample period ranging from 2007 to 2015, and the cumulative profits from this simulated trading strategy are very satisfactory even after taking transactions costs into account.

Key words: Volatility Spread; Return Predictability; Profitability; Trading strategy; Arbitrage Opportunity

EFM Classification Codes: 360, 410, 420

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1 Introduction

As a famous no-arbitrage relation between option prices and the underlying asset price, the classical put-call parity is expected to hold for European options in perfect markets. In the real world, however, prices of calls and those of puts are not always in line with put-call parity. The literature investigating deviations from put-call parity shows that these violations may result from the presence of short sale restrictions on the underlying stocks, early exercise value of American options, non-synchronous problems in trading call options, put options, and their underlying stocks, and transaction costs, indicating that not all of violations represent tradable arbitrage opportunities in practice.

Easley et al. (1998) and Kang and Park (2008) demonstrate that informed trading is also an important factor leading to violations of put-call parity. Due to the well-known advantages in derivatives trading, including high financial leverage, low transaction costs, and few short sale restrictions, traders with information about future price movements prefer to take a position in options before trading in the options’ underlying stock market. In effect, trading on information concerning an impending upward/downward revision in stock prices raises call/put prices, depresses put/call prices, and results in temporary violations of put-call parity before the private information is disseminated from the option market to the stock market. Taken together, violations of put-call parity driven by informed trading, rather than those resulting from market imperfections, are matters of concern for directional traders, because these violations may contain important information about future price movements.

Finucane (1991), Cremers and Weinbaum (2010), and Atilgan (2014) provide empirical evidence about predictability from violations of put-call parity to the underlying asset prices. With a dataset comprising exchange listed options on U.S. equities, Cremers and Weinbaum (2010) point out several concerns about market features of the U.S. that may prohibit call and put prices from being held in alignment when put-call parity is violated, including the
feature that options on individual stocks are American-style, the non-synchronicity problem between end-of-day stock quotes and end-of-day option quotes, and the presence of short sale constraints on the underlying stocks. In this context, Cremers and Weinbaum (2010) conduct a comprehensive analysis for these possible concerns and conclude that deviations from put-call parity are driven by informed trading, rather than by short sale constraints or the non-synchronicity problem. Nevertheless, the potential bias in the measurement of deviations from put-call parity in the case of American-style options, where put-call parity takes the form of an inequality rather than a strict equality, cannot be resolved directly.

This research adopts an ideal dataset in which we are able to address the common concerns about the presence of short sale restrictions, non-simultaneity of prices, and early exercise value of American options as much as possible, instead of providing a complementary analysis for these concerns as the method used in Cremers and Weinbaum (2010), in order to investigate whether violations of put-call parity in the Taiwan Stock Exchange Capitalization Weighted Stock Index option (TAIEX option, therefore) market exhibit the ability to predict the subsequent returns on the underlying TAIEX index. Notably, we further examine trading profits from the exploitation of these violations after incorporating transaction costs into account. The TAIEX option, of which the underlying asset is the TAIEX index, is the most actively traded option contract in Taiwan Futures Exchange (TAIFEX). According to WFE/IOMA 2015 Derivatives Market Survey, TAIEX options rank as the top five most frequently traded equity index options in terms of trading volume in 2015 around the world.

The concern that disparity between an index option market and its underlying asset market cannot be arbitraged away first originates in the non-tradable feature of the underlying spot index. To the extent that the spot index is non-tradable, the classical put-call parity, which expresses the no-arbitrage relation between a European-style call price, put price, and their underlying asset price, cannot be applied to index options without modifications. In reality, as a result of the non-tradable feature of the underlying stock index, professional
arbitrageurs exploit price deviations of index options related to put-call parity in the corresponding index futures market, rather than in the underlying spot index market. Thus, this research develops a futures-version put-call parity, which states the no-arbitrage relation between prices of index calls, index puts, and index futures, and examines the index return predictability from violations of put-call parity based on this proposed equality. It is worthwhile noting that the short sale constraints as well as the non-tradable feature of the underlying spot index are less of concerns for arbitrage trading in the case of futures-version put-call parity, because few short sale constraints are imposed on the futures market. A few related studies, including Lamont and Thaler (2003), Ofek and Richardson (2003), and Ofek, Richardson, and Whitelaw (2004), demonstrate that the presence of short sale restrictions on the options’ underlying asset can lead to violations of put-call parity, while Battalio and Schultz (2006) propose the opposite opinion concerning the impact of short sale constraints. Whatever happens, the short sale restriction on the options’ underlying asset is no longer a factor preventing arbitrageurs from exploiting violations of the proposed futures-version put-call parity.

The dataset adopted for this research, which includes all transaction records within the TAIEX option market, facilitates an investigation into option price deviations related to put-call parity in two other aspects. First, the TAIEX options are European-style and accordingly the proposed futures-version put-call parity is a strict equality, under which the no-arbitrage range within which prices can fluctuate is not influenced by the early exercise value of American options any longer. As a result, the common concern pointed out in related studies that bias in measurement of deviations arising from the early exercise value of American options is also less of concern in this research. Second, with the time-stamp TAIEX option transaction data and intraday data of the TAIEX spot index, the options’ implied volatility and volatility spread, which measures magnitude of deviations from the proposed futures-version put-call parity, can be estimated by synchronous data. As Battalio and Schultz (2006) document,
non-synchronicity may induce a biased measurement in implied volatility and lead to violations of put-call parity where none exist. We address the concern about the non-simultaneity of prices through the use of intraday option data, rather than end-of-date quotes.

Our empirical evidence supporting the return predictability of option price deviations related to the proposed futures-version put-call parity has two parts. First, by assessing the time-series relation between the volatility spread of TAIEX options and the subsequent TAIEX index return, we find that volatility spread is positively related to this subsequent index return, indicating that violations of the futures-version put-call parity possess predictive power with regard to TAIEX index return over the next five-minute interval. Second, we simulate the abnormal return of a volatility-spread strategy that trades TAIEX futures by using the volatility spread as a trading signal so as to exploit violations of the futures-version put-call parity. We find that the excess returns of this simulated volatility-spread strategy are positive and statistically significant across each year in the sample period ranging from 2007 to 2015. Remarkably, applying this volatility-spread trading strategy over the period ranging from 2007 through 2015 generates a cumulative return of 765% in total even after imposing the transactions costs. These results not only coincide with the findings about the return predictability of volatility spread, but also relate this predictive ability to trading activities of informed investors, who prefer to exploit their private information in an option market before doing so in its underlying asset market.

The remaining parts of this paper are arranged as follows. Section 2 develops the no-arbitrage relation between prices of index calls, index puts, and index futures and introduces the way to measure the magnitude of option price deviations related to the proposed futures-version put-call parity. Section 3 describes the sample data used in this paper. Section 4 provides regression specifications that assess the predictability from violations of the futures-version put-call parity to the subsequent TAIEX index returns and explains regression results. Section 5 presents trading performances of exploiting these option price deviations. Conclud-
ing remarks are given in the last section.

2 Measuring violations of the futures-version put-call parity

Due to the non-tradable feature of a stock index, arbitrageurs exploit the disparity between an index option market and its underlying asset market by taking a position in index futures contracts in practice, rather than taking a position in the underlying stock index. Thus, we develop the futures-version put-call parity in the following, which states the no-arbitrage price relation between a pair of call and put index options and index futures, whereby the expiration date is identical to that of the option pair. Herein, an index call and an index put are classified into a pair of call and put options, provided they have the same strike price and the same expiration date. The futures-version put-call parity can be easily developed by considering the following two portfolios.

**Portfolio A:** One TAIEX call option and an amount of \( 50 \times Ke^{-r(T-t)} \) invested in the risk-free asset.

**Portfolio B:** One TAIEX put option, one mini-TAIEX futures contract, and an amount of \( 50 \times F_{t}^{m}e^{-r(T-t)} \) invested in the risk-free asset.

Here, \( r \) displays the risk-free interest rate, \( K \) stands for the strike price of a pair of call and put options, \( T \) is the expiration date of the option pair, which is also the maturity date of the mini-TAIEX futures contract used to constitute Portfolio B, and \( F_{t}^{m} \) denotes the time \( t \) futures price of this mini-TAIEX futures contract. Among these financial products, both the TAIEX options and mini-TAIEX futures are traded on the TAIFEX. The TAIEX options are European-style and thus cannot be exercised early.
In addition to the underlying asset, the TAIEX options and mini-TAIEX futures are similar in terms of contract size, expiration date, and final settlement price. The multiplier of TAIEX options is NTD 50 per index point, and the contract size of mini-TAIEX futures is NTD 50 times per index point as well. Moreover, both the TAIEX options and mini-TAIEX futures expire on the third Wednesday of the delivery month. Most important of all, the final settlement price of TAIEX options as well as mini-TAIEX futures is the average price of the underlying index disclosed within the last 30 minutes prior to the close of trading on the final settlement day, which we denote as $F_m^T$. According to the above-mentioned specifications of TAIEX options and mini-TAIEX futures, quite intuitively, both Portfolio A and Portfolio B are worth $\max(50F_m^T, 50K)$ at the final settlement on the expiration date $T$.

The two portfolios that have identical values on the expiration date $T$ must be worth identically today in the absence of arbitrage opportunities. It follows that:

$$C_t + 50Ke^{-r(T-t)} = P_t + 50F_m^Te^{-r(T-t)}, \quad (1)$$

where $C_t$ and $P_t$ are the time $t$ prices of TAIEX call and put options, respectively, and $F_m^T$ denotes the final settlement price applied to TAIEX options as well as to mini-TAIEX futures, which is set on the basis of the simple average price of the underlying index during the last 30 minutes of trading before market close of the Taiwan Stock Exchange (TWSE) on the final settlement day. We name the relation between the prices of index call and put options and the index futures price, displayed in Equation (1), as the futures-version put-call parity.

Please also note that the proposed futures-version put-call parity for index options takes a form similar to the classical put-call parity relationship for futures options. Nevertheless, the former states the no-arbitrage relation between the prices of index options and index futures, whereas the latter specifies the no-arbitrage relation between the prices of futures options and the options’ underlying futures contract.

Deviations from the classical put-call parity for stock options are typically measured as volatility spread in the literature, such as by Amin, Coval, and Seyhun (2004), Figlewski and
Webb (1993), and Cremers and Weinbaum (2010). The violation of the futures-version put-call parity displayed in Equation (1) can be measured with volatility spread as well - that is, the difference in implied volatility between call and put options on the same underlying asset and with the same strike price and the same maturity date. The following justification is similar to that in Amin, Coval, and Seyhun (2004), Figlewski and Webb (1993), and Cremers and Weinbaum (2010).

Similar to the classical put-call parity for stock options, the futures-version put-call parity requires neither assumptions about the probabilistic behavior of the underlying asset prices nor specific option pricing models, implying that the Black-Scholes (1973) option pricing formula satisfies the futures-version put-call parity for any given positive value of the volatility parameter, \( \sigma \), i.e.:

\[
C_t^{BS}(\sigma) + 50Ke^{-r(T-t)} = P_t^{BS}(\sigma) + 50F_t^m e^{-r(T-t)}, \quad \forall \sigma > 0. \tag{2}
\]

Here, \( C_t^{BS}(\sigma) \) and \( P_t^{BS}(\sigma) \) represent the Black-Scholes call and put prices, respectively, on options in pairs, of which the volatility is set to be the value of \( \sigma \). Combining Equation (2) with Equation (1), we have:

\[
C_t^{BS}(\sigma) - C_t = P_t^{BS}(\sigma) - P_t, \quad \forall \sigma > 0. \tag{3}
\]

The implied volatility of an option, by definition, is a specific volatility value that makes the Black-Scholes price equal the market price of this option, indicating that implied volatility of a call option, \( IV_t^{\text{call}} \), satisfies the following equality:

\[
C_t^{BS}(IV_t^{\text{call}}) = C_t. \tag{4}
\]

Similarly, the implied volatility of a put option, \( IV_t^{\text{put}} \), must make the following equality hold:

\[
P_t^{BS}(IV_t^{\text{put}}) = P_t. \tag{5}
\]

By combining Equation (3) with Equation (4), we then have:

\[
P_t^{BS}(IV_t^{\text{call}}) = P_t, \tag{6}
\]
which in virtue of Equation (5) implies:

\[ IV_t^{\text{call}} = IV_t^{\text{put}}. \]  

(7)

The equality of the futures-version put-call parity is consequently equivalent to the condition that the Black-Scholes implied volatilities of calls and puts within the same option pair are equal, indicating that a violation of the futures-version put-call parity can be measured as the difference in implied volatilities between pairs of call and put options, i.e., the volatility spread. Moreover, the early exercise premium no longer biases measurements in violation of the futures-version put-call parity, because TAIEX options are European-style and thus cannot be exercised before expiration.

3 Sample description

This section describes the data utilized in this research and the methods adopted to generate option implied volatility and volatility spread. Empirical properties and summary statistics of volatility spread are analyzed in this section as well.

3.1 Data

This research explores the predictability from violations of the futures-version put-call parity in the TAIEX option market and profitability from exploiting these violations. The TAIEX option dataset, drawn from the database of CMoney, records all trades of TAIEX options traded on the TAIFEX over the period 2007 through 2015. As we mentioned above, TAIEX options are European-style, of which the underlying asset is the TAIEX index, and regularly expire on the third Wednesday of the delivery month. The expiration months of TAIEX options include the spot month, the next two calendar months, and the next two quarterly months. An exception is the weekly option. As very short-term options, weekly options,
the initial trading day of which is a given Wednesday and the last trading day is the next Wednesday, are added on Wednesday of each week excluding the second week of each month. Because a weekly option cannot be matched with a TAIEX futures that expires at the same date, we do not include weekly option data in our dataset. Overall, the TAIEX options are the most popular products in terms of trading volume on the TAIFEX, an order-driven market characterized by high individual participation. According to the statistics on the TAIFEX website, the trading volume of TAIEX options hits 191 million contracts in 2015, with the individual participation in derivatives trading well beyond 47% during that year.

Estimating implied volatility still requires the dividend yield, risk-free interest rate, and intraday quotations for the underlying TAIEX index. The minute-by-minute index quotations contained in our dataset are drawn from the database of CMoney as well, whereas the dividend yields on the TAIEX index are obtained from the TWSE website. Finally, we adopt the average of the 1-year time deposit interest rates of five major banks in Taiwan, expressed in continuously compounded rates, as a proxy for the risk-free interest rate, \( r \), where all of these interest rates are collected from the website of the Central Bank of the Republic of China.

To estimate the implied volatility behind each option trade, we merge each time-stamp TAIEX option trade with its synchronous TAIEX index - that is, the index quote at the closest time prior to this option transaction. To ensure all options’ implied volatilities are estimated by synchronous data, option trades executed before 9:00 a.m. or after 1:30 p.m., where the TWSE is either in the pre-open session or the post-close session, are excluded from our dataset. TAIEX option trades executed after 1:26 p.m. are removed from the dataset as well, because orders made are only accepted, but not matched, during the last five minutes until the close of the TWSE.

Following the method of Bollen and Whaley (2004), we adopt the realized return volatility of the underlying TAIEX index over the most recent sixty trading days as the proxy for the
volatility rate when estimating the Black-Scholes implied volatility of each option trade. An
option’s time to maturity is measured by the number of calendar days between the trading
date and the last settlement date. Finally, transactions for an option with a time to maturity
of less than 3 days are excluded so as to avoid the expiration day effect. We also remove
option trades with trading prices outside options’ theoretical price bounds from our dataset
in order to reasonably estimate options’ implied volatility.

3.2 Volatility spread computation

To focus more on the information effect of the volatility spread in the TAIEX option market
on the subsequent TAIEX return, this research investigates the predictability and profitabil-
ity of the volatility spread by utilizing 5-minute intraday data. The Black-Scholes implied
volatilities behind all option trades in a given option series are thereby averaged within each
5 minutes by using trading volume as weights. With this data in hand, we then estimate
volatility spread.

As we mentioned above, volatility spread is defined as the difference in implied volatilities
between pairs of call and put options. The difference is first calculated for each option pair
each 5 minutes and then weighted by average across option pairs for each 5-minute time
interval. Specifically, following Cremers and Weinbaum (2010), volatility spread at time $t$,$VS_t$, is measured by:

$$VS_t = IV_{t}^{\text{call}} - IV_{t}^{\text{put}} = \sum_{i=1}^{N_t} w_{i,t} \left( IV_{i,t}^{\text{call}} - IV_{i,t}^{\text{put}} \right), \quad (8)$$

where $i$ indexes pairs of put and call options with the same strike price and maturity date,$N_t$ is the number of valid option pairs during the time interval $t$, $w_{i,t}$ denotes the weight of
option pair $i$ at a 5-minute time interval $t$, and $IV_{i,t}^{\text{call}}$ and $IV_{i,t}^{\text{put}}$ represent the Black-Scholes
implied volatility of call and put options that are classed as a given option pair $i$.

An arbitrage trading strategy applied at the time when the futures-version put-call parity
is violated involves trading the same number of call and put option contracts. Accordingly, this research uses the minimum trading volume between pairs of call and put options as weights, i.e.:

\[ w_{i,t} = \frac{\text{Min}\{Q_{\text{call}}^{i,t}, Q_{\text{put}}^{i,t}\}}{Q_t}, \]

where

\[ Q_t = \sum_{i=1}^{N_t} \text{Min}\{Q_{\text{call}}^{i,t}, Q_{\text{put}}^{i,t}\}. \]

Herein, \( Q_{\text{call}}^{i,t} \) and \( Q_{\text{put}}^{i,t} \) denote the trading volumes of call and put options of pair \( i \) during a 5-minute time interval \( t \), respectively, and \( Q_t \) stands for the summed volume of option contracts available for arbitrage trading strategies across option pairs over the time interval \( t \). As a result, an option pair is not a valid pair in calculating the time \( t \) volatility spread, if one of the call and put options within this pair is not traded over this time period.

Instead of using the end-of-day option price quotes, this research measures implied volatility based on the TAIEX option transaction data and its synchronic index price and accordingly computes volatility spread using synchronic implied volatility of call and put options. This allows us to address the potential problem concerning non-simultaneity of prices as best as possible, thereby enabling us to get rid of any measurement error arising from this problem in the measurement of volatility spread.

### 3.3 Empirical properties of volatility spread

Table 1 contains descriptive statistics on volatility spread for both the full sample period and each individual year, respectively. As expected, the mean of volatility spread is negative, which is consistent with the fact that put options are usually more expensive than their corresponding call options, because of the need for hedging. It is also interesting to observe that volatility spread is more volatile in 2008 and 2009, while the market went through the worst recession in the 2008 global financial crisis and rebounded from the bottom in 2009.
Based on the similar reason, the minimum volatility spread happens in 2008, whereas the maximum volatility spread is observed in 2009.

4 Empirical analysis

This section examines whether the extent to which the futures-version put-call parity is violated in the TAIEX option market can predict the leading index returns. Regression specifications and regression results are provided in this section.

4.1 Regression specifications

To gauge the predictability from violations of the futures-version put-call parity to the subsequent TAIEX return, the predictive regression model is set as follows:

\[ R_{t+\tau} = \beta_0 + \beta_1 V S_t + \beta_2 Vol_t + \beta_3 CR_{t-5} + \epsilon_{t+\tau}, \quad \text{where } \tau = 1, 2, \cdots, \]  

where \( R_{t+\tau} \) denotes the \( \tau \)-period-ahead return on the TAIEX spot index at a 5-minute time interval \( t \), which in effect is the subsequent return of the TAIEX index over the time interval \( t+\tau \), \( V S_t \) represents the volatility spread at the time interval \( t \), \( Vol_t \) is the sum of the trading volume of the TAIEX index during the time-\( t \) interval, expressed in ten billions of New Taiwan dollars, and \( CR_{t-5} \) indicates the past five-period cumulative return on the TAIEX index. Both of the final two variables are control variables that may influence future movements of the TAIEX index, where, in particular, the latter is a reversal control variable. To avoid an impact of overnight returns on the past five-period cumulative return of the TAIEX index, \( CR_{t-5} \), the first 6 observations on each trading day are removed to facilitate the following regression analysis.

Investors with expectations concerning upward movements in the TAIEX spot index prefer in reality to buy call options and short put options before trading in the underlying stock
market. These trades raise the implied volatility of call options, but lower the implied volatility of put options, thereby resulting in violations of the futures-version put-call parity and a larger volatility spread. In the same way, trading by exploiting expectations about downward movements of the TAIEX index lessens volatility spreads and usually brings about a negative volatility spread. Taken together, the hypothesis associated with the predictive power of volatility spreads is summarized as follows.

**Hypothesis:** The volatility spread between pairs of call and put options, as a measurement of deviations from the futures-version put-call parity, possesses predictive power on the leading underlying asset returns, indicating that the coefficient of the volatility spread, $\beta_1$ in Equation (9), is expected to be positive and significant at least for some $\tau$.

In addition to the information content contained in option trading, the speed at which this information is disseminated to the underlying asset market is also a common interest among related studies. Cremers and Weinbaum (2010) show that volatility spreads in the U.S. option market have predictive power to one-week-ahead and four-week-ahead returns by using weekly frequency data. Chang, Hsieh, and Lai (2009) find that the put-call ratio of foreign institutional investors, constructed by open-buy volume of TAIEX options, predicts the next-day TAIEX spot index returns by utilizing daily frequency data. Kang and Park (2008) adopt 5-minute frequency data and provide evidence for the KOSPI 200 index option market, in which the information content behind put-call parity violation is disseminated to the underlying asset market 5 minutes later. This present research also investigates how the return predictability of volatility spreads, if any, declines over time by adopting the predictive regression model displayed in Equation (9). The extent to which the predictability of volatility spreads declines over time is critically important for directional traders who adopt volatility spreads as trading signals, since it is relevant to the timing at which their positions should be reversed.
4.2 Empirical results

Table 2 exhibits the regression results of Equation (9) for TAIEX options. In the regression of 1-period-ahead TAIEX index returns, as expected, the coefficient on the volatility spread, $\beta_1$, is positive and statistically significant at a significance level of 1%, strongly suggesting the predictive power of volatility spreads to the next-5-minute index returns. Table 2 also reports that the volatility spread has predictability at the leading 3-5 periods in terms of magnitude and significance. More precisely, the return predictability of the extent to which the futures-version put-call parity is violated persists within the following 35 periods, or equivalently the subsequent 175 minutes. Though results for regressions of $\tau$-period-ahead index returns with a $\tau$ greater than 5 are not reported in Table 2 under consideration of space, they are available upon request. Interestingly, the only exception appears in the regression of 2-period-ahead index returns, in which the coefficient of the volatility spread is insignificant, with a coefficient estimate of -0.002 and a $t$-statistic of -0.312. To some degree, the findings are not surprising. As market makers rebalance their positions immediately, the volatility spread is expected to lose its predictability to $R_{t+2}$, or at least exhibit some loss in part. Thus, these findings can be regarded as a result of market makers rebalancing their portfolios.

As Easley, O’Hara, and Srinivas (1998) point out, investors with expectations regarding upward movements in the underlying asset price buy call options and/or short put options, and the reverse is true, linking violations of put-call parity with future movements of these options’ underlying asset prices. Cremers and Weinbaum (2010) provide evidence supporting the return predictability of the volatility spread based on quintile portfolio returns. The time-series regression results displayed in Table 2 corroborate these findings of past studies.

In terms of the impact of the two control variables, as shown in Table 2, the coefficient on the trading volume of the TAIEX index $Vol_t$ and that of the past five-period cumulative TAIEX return $CR_{t-5}$ are both negative and statistically significant at the 1% significance level in the regression of 1-period-ahead index returns. The former can be viewed as evidence
against the lead-lag relationship between trading volume and stock returns, whereas the latter suggests a reversal of the TAIEX index. Table 2 also shows that the signs of these two coefficients, i.e., \( \beta_2 \) and \( \beta_3 \), change in the case of multi-period-ahead predictions, where \( \tau \geq 2 \).

5 The profitability of exploiting volatility spread

According to the findings in Table 2, where volatility spreads of TAIEX options provide the predictive power to the next-5-minute index returns, a straightforward strategy for direction traders is to exploit the information content behind violations of the futures-version put-call parity by trading TAIEX futures contracts, of which the underlying asset is also the TAIEX index. This section addresses the profitability of this volatility-spread strategy by taking transaction costs into consideration. Before doing so, we specify the details concerning how the trading simulation is conducted.

5.1 Trading simulation design

The volatility-spread trading strategy simply involves buying/selling the nearest-month TAIEX futures at the time when a bullish/bearish signal generated by five-minute intraday volatility spreads of TAIEX options shows itself for trading and then closing out this position five minutes later. The information embedded in a volatility spread is classified as a bullish signal, provided that this volatility spread is greater than \( \text{Mean}_t^{VS} + 2\sigma_t^{VS} \). On the contrary, a volatility spread less than \( \text{Mean}_t^{VS} - 2\sigma_t^{VS} \) is termed as a bearish signal. Herein, \( \text{Mean}_t^{VS} \) and \( \sigma_t^{VS} \) respectively denote the moving-window average and moving-window standard deviation of volatility spreads over the past 24 periods, or equivalently over the past 2 hours prior to time \( t \). As shown in Table 2, where volatility spreads of index options have no predictive power on the 2-period-ahead index return, i.e., \( R_{t+2} \), we thereby reverse the position of this
simulated trading strategy 5 minutes later than the time at which this position is created.

The time at which a bullish/bearish signal is alerted in reality does not always indicate a good timing to take a position in TAIEX futures, especially when the TAIEX futures market has already reflected the information content embedded in violation of the futures-version put-call parity. More precisely, in addition to the bullish/bearish signal generated by volatility spreads, we add the extent to which the nearest-month TAIEX futures price leads the spot TAIEX index as another trading signal. Taken together, traders can utilize this volatility-spread trading strategy to buy/sell nearest-month TAIEX futures contracts only when a bullish/bearish signal arises and when the difference between changes in the TAIEX futures price and changes in the spot TAIEX index is less/greater than 5/-5 points over the past 5 minutes. Moreover, both the futures and option markets are generally observed to be more volatile at the beginning of the TWSE trading session. Under this concern, no trade is executed within the first 30 minutes of the TWSE trading hours on each trading day in our trading strategy simulation, which is consistent with the sample data adopted in the regression analysis of Section 4. To ensure all trading is closed out before the closing session of the TWSE, where orders made are only accepted but not matched during the last 5 minutes of the TWSE trading hours, no position is created within the last 10 minutes of the TWSE trading hours. Due to the liquidity concern for long-term options, all bullish/bearish trading signals are generated from volatility spreads of options with a time to maturity of less than 60 days. Please note that the abnormal return and trading performance of this simulated trading strategy exhibited in the subsequent subsection are very similar to the results that use volatility spreads of TAIEX options across all kinds of time-to-maturity to generate bullish/bearish trading signals.

By adopting this volatility-spread trading strategy, the holding period return of futures
trading over a time interval \( t + 1 \), i.e., \( HPR_{t+1} \), is calculated as follows:

\[
HPR_{t+1} = \begin{cases} 
\frac{(F_{t+1} - F_t) \times 200}{83000}, & \text{if } VS_t > \text{Mean}_{t}^{VS} + 2\sigma_{t}^{VS} \text{ and } \text{leading}_t \leq 5; \\
\frac{(F_t - F_{t+1}) \times 200}{83000}, & \text{if } VS_t < \text{Mean}_{t}^{VS} - 2\sigma_{t}^{VS} \text{ and } \text{leading}_t \geq -5,
\end{cases}
\]

(10)

where \( F_t \) is the time \( t \) price of the nearest-month TAIEX futures contract, in which the contract multiplier is NTD 200 per index point. The subscripts \( t \) and \( t + 1 \) in Equation (10) also represent the time at which this futures position is opened and closed in the volatility-spread trading strategy, respectively. Finally, \( \text{leading}_t \) denotes the extent to which the change in the TAIEX futures price leads the movement of the spot TAIEX index, measured by:

\[
\text{leading}_t = \Delta F_t - \Delta I_t,
\]

(11)

where \( \Delta F_t \) stands for the change in the nearest-month TAIEX futures price from time \( t - 1 \) to time \( t \), and \( \Delta I_t \) is the analogous quantity for the TAIEX index. Consistent with the practices of TAIEX futures trading, the return is calculated based on the initial margin requirement of NTD 83,000 for each TAIEX futures contract trading.

We measure excess return, expressed in percentages, from applying this volatility-spread trading strategy to the nearest-month TAIEX futures contract by the intercept coefficient \( \alpha \) of the following one-factor CAPM model:

\[
HPR_t - r_t = \alpha + \beta_m (R_{m,t} - r_t) + \epsilon_t,
\]

(12)

where \( r_t \) stands for the risk-free return over the five-minute interval \( t \), and \( R_{m,t} \) represents the five-minute return on the TAIEX spot index, acting as a proxy for the return of the market portfolio during the time interval \( t \).

5.2 Results of volatility-spread trading strategy

Table 3 displays the abnormal returns from applying the volatility-spread trading strategy to the nearest-month TAIEX futures contracts during the whole sample period ranging from
2007 through 2015 and for each individual year. Remarkably, the average five-minute abnormal returns of the futures position formed on the volatility-spread-based trading signals are positive and statistically significant at a significance level of no more than 5% for the whole sample period and for all individual years, thus strongly suggesting the profitability of this volatility-spread trading strategy. Interestingly, these average five-minute abnormal returns range from 0.115% to 0.424% across years, among which superior performances appear especially in 2007-2009 and 2011. Indeed, these two periods are the time periods during which the 2007 global financial crisis and 2011 U.S. debt-ceiling crisis break out, respectively, and the influences of these financial crises upon the market are longer lasting. Taken together, these findings lead people to associate the profitability of this volatility-spread trading strategy with the extent of market variations.

Table 4 exhibits the summary statistics of five-minute holding period returns on futures trading executed according to the simulated trading strategy after taking trading costs into account. Herein, transaction costs, including the futures transaction tax rate of 0.002% and a commission of usually no more than NTD 70 per contract charged by futures commission merchants (FCM), are deducted from futures trading profits when calculating the after-trading-cost holding period return over the time interval $t+1$, $HPR_{t+1}^{AC}$. Specifically, $HPR_{t+1}^{AC}$ is calculated as follows:

$$HPR_{t+1}^{AC} = \begin{cases} (F_{t+1} - F_t) \times 200 - 70 - 0.002\%(F_{t+1} + F_t) / 83000, \\ & \text{if} \ VS_t > Mean_t^{VS} + 2\sigma_t^{VS} \text{ and } leading_t \leq 5; \\ (F_t - F_{t+1}) \times 200 - 70 - 0.002\%(F_{t+1} + F_t) / 83000, \\ & \text{if} \ VS_t < Mean_t^{VS} - 2\sigma_t^{VS} \text{ and } leading_t \geq -5. \end{cases}$$ (13)

As mentioned above, the initial margin requirement for each TAIEX futures contract trading is NTD 83,000, and the contract multiplier of TAIEX futures is NTD 200 per index point.

As shown in Table 4, the average returns on each TAIEX futures trading executed according to our volatility-spread-based trading signals are positive across all individual years even
after taking trading costs into consideration. Better performances still appear in 2007-2009 and 2011. The standard deviation of returns seems to provide a possible explanation for these findings, where the standard deviation of returns to the futures position formed on this trading strategy is higher in 2007-2009 and 2011 versus times other than these years. The evidence supports the important principle of financial markets that high returns compensate for high risks. This evidence is also consistent with the notion previously mentioned, in which we conjecture about the positive relationship between the profitability of the proposed volatility-spread trading strategy and the degree of market variations.

Table 4 also shows that applying this volatility-spread trading strategy over the period ranging from 2007 through 2015 generates a cumulative return of 765% in total. This outstanding performance again strongly suggests the profitability of this trading strategy. The cumulative return across years ranges from 17.78% to 151.45%. It is worthwhile noting that the poorest cumulative return that takes place in 2014 still exceeds 17%, even after taking trading costs into account.

6 Summary and conclusions

The information content behind violations of put-call parity in an option market, especially in an index option market, and the resulting predictability on the options' underlying asset prices have attracted the interest of related empirical studies. As the underlying asset of index options is non-tradable, however, disparity between an index option market and its underlying asset market cannot be arbitraged away quickly. The classical put-call parity that expresses the no-arbitrage relation between prices of European-type options and their underlying asset thus cannot be applied to index options without modifications. In order to explore whether deviations from put-call parity possess predictive power on the subsequent TAIEX index returns and profitability from exploiting these deviations, this research fills the
gap in the literature by developing the futures-version put-call parity, which corresponds to
the no-arbitrage relation among prices of three tradable assets: index calls, index puts, and
index futures.

Based on the futures-version put-call parity and time-stamped TAIEX option transaction
data, this study is able to appropriately address concerns about the existence of factors
that may prevent violations of the futures-version put-call parity from being arbitrated away
quickly and that may bring about bias in measurement of these violations, including non-
simultaneity of prices, early exercise value of American options, short sale constraints on
the underlying assets, and the non-tradable feature of the underlying spot index. This is
another feature distinguishable from related studies. After addressing common concerns in
the literature that we mentioned above, the empirical evidence strongly suggests that the
volatility spread of TAIEX options, which is a measurement of deviations from the futures-
version put-call parity in the TAIEX option market, possesses predictive power with regard
to the next five-minute TAIEX spot index returns.

We also find that exploiting these volatility spreads generates outstanding trading per-
formances. The average abnormal returns of the TAIEX futures position formed on the
volatility-spread-based trading signals are positive and statistically significant for all individ-
ual years ranging from 2007 to 2015, strongly supporting the profitability of the simulated
volatility-spread trading strategy. Furthermore, applying this volatility-spread trading strat-
egy over the period ranging from 2007 through 2015 creates a cumulative return of 765% in
total even after taking transaction costs into account. Overall, our findings are consistent
with the results of Easley et al. (1998), in which prices do not present full-information effi-
ciency and can convey information regarding future price movements. The findings of this
research, especially that concerning the outstanding profitability of the simulated volatility-
spread trading strategy, should help benefit direction traders.
References


### Table 1 Summary statistics of volatility spread

<table>
<thead>
<tr>
<th></th>
<th>2007</th>
<th>2008</th>
<th>2009</th>
<th>2010</th>
<th>2011</th>
<th>2012</th>
<th>2013</th>
<th>2014</th>
<th>2015</th>
<th>Whole sample period</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>-0.020</td>
<td>-0.075</td>
<td>-0.048</td>
<td>-0.034</td>
<td>-0.015</td>
<td>-0.022</td>
<td>-0.021</td>
<td>-0.005</td>
<td>-0.014</td>
<td>-0.028</td>
</tr>
<tr>
<td>Standard deviation</td>
<td>0.065</td>
<td>0.130</td>
<td>0.096</td>
<td>0.062</td>
<td>0.060</td>
<td>0.079</td>
<td>0.053</td>
<td>0.039</td>
<td>0.064</td>
<td>0.079</td>
</tr>
<tr>
<td>Maximum</td>
<td>0.494</td>
<td>0.689</td>
<td>1.061</td>
<td>0.359</td>
<td>0.141</td>
<td>0.102</td>
<td>0.100</td>
<td>0.103</td>
<td>0.100</td>
<td>1.061</td>
</tr>
<tr>
<td>Minimum</td>
<td>-0.804</td>
<td>-1.346</td>
<td>-1.175</td>
<td>-0.550</td>
<td>-0.384</td>
<td>-0.357</td>
<td>-0.279</td>
<td>-0.137</td>
<td>-0.310</td>
<td>-1.346</td>
</tr>
</tbody>
</table>

Notes: (1) The whole sample period ranges from January 2, 2007 to December 31, 2015. (2) Violations of the futures-version put-call parity are measured by volatility spread, calculated as:

\[ VS_t = IV_t^{\text{call}} - IV_t^{\text{put}} = \sum_{i=1}^{N_t} w_{i,t} \left( IV_{i,t}^{\text{call}} - IV_{i,t}^{\text{put}} \right), \]  

(8)

where \( i \) indexes pairs of put and call options with the same strike price and maturity date, \( N_t \) is the number of valid option pairs during the time interval \( t \), \( w_{i,t} \) denotes the weight of option pair \( i \) at a 5-minute time interval \( t \), and \( IV_{i,t}^{\text{call}} \) and \( IV_{i,t}^{\text{put}} \) represent the Black-Scholes implied volatility of call and put options that are classed as a given option pair \( i \).
Table 2 Predictability of volatility spread

<table>
<thead>
<tr>
<th>+τ periods ahead</th>
<th>β₀ (×10)</th>
<th>β₁</th>
<th>β₂</th>
<th>β₃</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.024***</td>
<td>0.061***</td>
<td>-0.015***</td>
<td>-0.010***</td>
</tr>
<tr>
<td></td>
<td>(3.275)</td>
<td>(14.953)</td>
<td>(-3.821)</td>
<td>(-8.634)</td>
</tr>
<tr>
<td>2</td>
<td>-0.007</td>
<td>-0.002</td>
<td>0.004</td>
<td>0.003**</td>
</tr>
<tr>
<td></td>
<td>(-0.844)</td>
<td>(-0.312)</td>
<td>(0.783)</td>
<td>(2.042)</td>
</tr>
<tr>
<td>3</td>
<td>-0.041***</td>
<td>0.031***</td>
<td>0.036***</td>
<td>0.005***</td>
</tr>
<tr>
<td></td>
<td>(-3.511)</td>
<td>(4.610)</td>
<td>(5.512)</td>
<td>(2.712)</td>
</tr>
<tr>
<td>4</td>
<td>0.004</td>
<td>0.039***</td>
<td>0.007</td>
<td>0.011***</td>
</tr>
<tr>
<td></td>
<td>(0.309)</td>
<td>(5.773)</td>
<td>(1.030)</td>
<td>(5.618)</td>
</tr>
<tr>
<td>5</td>
<td>0.003</td>
<td>0.034***</td>
<td>0.009</td>
<td>0.009***</td>
</tr>
<tr>
<td></td>
<td>(0.225)</td>
<td>(4.938)</td>
<td>(1.378)</td>
<td>(4.859)</td>
</tr>
</tbody>
</table>

Notes: (1) The regression model is:

\[ R_{t+\tau} = \beta_0 + \beta_1 VS_t + \beta_2 Vol_t + \beta_3 CR_{t-5} + \epsilon_{t+\tau}, \quad \text{where } \tau = 1, 2, \ldots, \quad (9) \]

where \( R_{t+\tau} \) denotes the \( \tau \)-period-ahead return of the TAIEX spot index over a 5-minute time interval \( t \), which in effect is the subsequent return of the TAIEX index over the time interval \( t+\tau \). \( VS_t \) represents the volatility spread at the time interval \( t \), \( Vol_t \) is the sum of the trading volume of the TAIEX index during the time-\( t \) interval, expressed in ten billions of New Taiwan dollars, and \( CR_{t-5} \) indicates the past five-period cumulative return on the TAIEX index. The regression model displayed in Equation (9) is utilized with 5-minute intraday data. (2) The sample period ranges from January 2, 2007 to December 31, 2015. (3) The values reported in parentheses are \( t \)-statistics. (4) One, two, and three asterisks indicate the 10%, 5%, and 1% significant levels, respectively. (5) Though results for regressions of \( \tau \)-period-ahead index returns with a \( \tau \) greater than 5 are not reported in this table under consideration of space, they are available upon request.
Table 3 Abnormal return from applying a volatility-spread strategy to the nearest-month TAIEX futures contracts

<table>
<thead>
<tr>
<th></th>
<th>2007</th>
<th>2008</th>
<th>2009</th>
<th>2010</th>
<th>2011</th>
<th>2012</th>
<th>2013</th>
<th>2014</th>
<th>2015</th>
<th>Whole sample period</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \alpha )</td>
<td>0.424***</td>
<td>0.372**</td>
<td>0.375***</td>
<td>0.278***</td>
<td>0.402***</td>
<td>0.220***</td>
<td>0.184***</td>
<td>0.115**</td>
<td>0.227**</td>
<td>0.288***</td>
</tr>
<tr>
<td></td>
<td>(2.722)</td>
<td>(2.288)</td>
<td>(2.913)</td>
<td>(2.816)</td>
<td>(3.389)</td>
<td>(2.797)</td>
<td>(2.828)</td>
<td>(1.972)</td>
<td>(2.015)</td>
<td>(7.945)</td>
</tr>
<tr>
<td>Number of observations</td>
<td>402</td>
<td>334</td>
<td>330</td>
<td>375</td>
<td>428</td>
<td>499</td>
<td>502</td>
<td>518</td>
<td>389</td>
<td>3,777</td>
</tr>
</tbody>
</table>

Notes: (1) The volatility-spread trading strategy involves buying/selling the nearest-month TAIEX futures at the time when a bullish/bearish signal generated by five-minute intraday volatility spreads of TAIEX options shows itself for trading and then closing out this position five minutes later. The information embedded in a volatility spread is classified as a bullish signal, provided that this volatility spread is greater than \( \text{Mean}_{t}^{\text{VS}} + 2\text{\sigma}_{t}^{\text{VS}} \). On the contrary, a volatility spread less than \( \text{Mean}_{t}^{\text{VS}} - 2\text{\sigma}_{t}^{\text{VS}} \) is termed as a bearish signal. Herein, \( \text{Mean}_{t}^{\text{VS}} \) and \( \text{\sigma}_{t}^{\text{VS}} \) respectively denote the moving-window average and moving-window standard deviation of volatility spreads over the past 24 periods, or equivalently over the past 2 hours prior to time \( t \). Excess return, expressed in percentages, from applying this volatility-spread trading strategy to the nearest-month TAIEX futures contract is measured by the intercept coefficient \( \alpha \) of the following one-factor CAPM model:

\[
HPR_i - r_i = \alpha + \beta_{m} (R_{m,t} - r_t) + \varepsilon_i, \tag{12}
\]

where \( HPR_i \) denotes the five-minute holding period return of this volatility-spread strategy over the time interval \( t \), \( r_i \) stands for the risk-free return at the five-minute interval \( t \), and \( R_{m,t} \) represents the five-minute return on the TAIEX spot index, acting as a proxy for the return of the market portfolio during the time interval \( t \). (2) The values reported in parentheses are the resulting \( t \)-statistics. (3) One, two, and three asterisks indicate the 10%, 5%, and 1% significant levels, respectively.
Table 4 Summary statistics of after-trading-cost returns on each futures trading executed according to the simulated trading strategy

<table>
<thead>
<tr>
<th>For each 5-minute trading</th>
<th>2007</th>
<th>2008</th>
<th>2009</th>
<th>2010</th>
<th>2011</th>
<th>2012</th>
<th>2013</th>
<th>2014</th>
<th>2015</th>
<th>Whole sample period</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of trading</td>
<td>402</td>
<td>334</td>
<td>330</td>
<td>375</td>
<td>428</td>
<td>499</td>
<td>502</td>
<td>518</td>
<td>389</td>
<td>3,777</td>
</tr>
<tr>
<td>Average return (%)</td>
<td>0.337</td>
<td>0.313</td>
<td>0.292</td>
<td>0.193</td>
<td>0.354</td>
<td>0.183</td>
<td>0.098</td>
<td>0.034</td>
<td>0.120</td>
<td>0.203</td>
</tr>
<tr>
<td>Standard deviation</td>
<td>3.150</td>
<td>3.015</td>
<td>2.335</td>
<td>1.912</td>
<td>2.609</td>
<td>1.834</td>
<td>1.522</td>
<td>1.333</td>
<td>2.243</td>
<td>2.233</td>
</tr>
<tr>
<td>Cumulated return (%)</td>
<td>135.571</td>
<td>104.494</td>
<td>96.405</td>
<td>72.326</td>
<td>151.446</td>
<td>91.230</td>
<td>49.033</td>
<td>17.776</td>
<td>46.783</td>
<td>765.063</td>
</tr>
</tbody>
</table>

Notes: The volatility-spread trading strategy involves buying/selling the nearest-month TAIEX futures at the time when a bullish/bearish signal generated by five-minute intraday volatility spreads of TAIEX options shows itself for trading and then closing out this position five minutes later. The information embedded in a volatility spread is classified as a bullish signal, provided that this volatility spread is greater than \( \text{Mean}_{t}^{VS} + 2\sigma_{t}^{VS} \). On the contrary, a volatility spread less than \( \text{Mean}_{t}^{VS} - 2\sigma_{t}^{VS} \) is termed as a bearish signal. Herein, \( \text{Mean}_{t}^{VS} \) and \( \sigma_{t}^{VS} \) respectively denote the moving-window average and moving-window standard deviation of volatility spreads over the past 24 periods, or equivalently over the past 2 hours prior to time \( t \). After taking transactions costs into account, the holding period return from the futures position formed on the volatility-spread trading strategy over a five-minute time interval \( t+1 \), \( HPR_{t+1}^{AC} \), can be calculated as follows:

\[
HPR_{t+1}^{AC} = \begin{cases} 
\frac{(F_{t+1} - F_t) \times 200 - 70 - 0.002\% \times (F_{t+1} + F_t)}{83000}, & \text{if } VS_{t} > \text{Mean}_{t}^{VS} + 2\sigma_{t}^{VS} \text{ and leading}_{t} \leq 5; \\
\frac{(F_{t} - F_{t+1}) \times 200 - 70 - 0.002\% \times (F_{t} + F_{t+1})}{83000}, & \text{if } VS_{t} < \text{Mean}_{t}^{VS} - 2\sigma_{t}^{VS} \text{ and leading}_{t} \geq -5,
\end{cases}
\]

where \( \text{leading}_{t} \) denotes the extent to which the change in the TAIEX futures price leads the movement of the spot TAIEX index. Consistent with the practices of TAIEX futures trading, we deduct transaction costs, including the futures transaction tax rate of 0.002% and a commission of usually no more than NTD 70 per contract charged by futures commission merchants (FCM), from futures trading profits when calculating \( HPR_{t+1}^{AC} \).