The Predictability of Option Intraday Information On Index Returns

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Abstract

The Intraday IVS contains certain imformation about intraday stock return.

1 Introduction

In recent year, the information of derivatives market plays an increasingly crucial role in financial markets. There are multiple reasons why option market are vital for investors. One, informed traders may choose to trade in derivative markets since they can camouflage with noise traders by trading different option contracts on one specific security (Easley, O'hara, and Srinivas 1998). Another, authors such as Black and Scholes (1973), Mayhew, Sarin, and Shastri (1995), Fleming, Ostdiek, and Whaley (1996), among others, argue that widened financial leverage and narrowed transaction costs may encourage informed traders to trade in the option market instead of the equity market, Third, unlike stock market, there are no short selling constraints in option market. Therefore, the characteristics of an option contract are informational and worthy to investigate. However, To what extent has it been supported by empirical works?

It has been a fierce debate that the trading information from derivative markets lead the underlying markets. Prior studies hold different arguments toward this topic. Relevant papers, like Manaster and Rendleman Jr (1982), Anthony (1988), Chakravarty, Gulen, and Mayhew (2004), Cremers and Weinbaum (2010), Xing, X. Zhang, and Zhao (2010) have found that the information from option market take the lead of the information from stock market. When informed traders recieved private information, they prefer to trade in option market since there are several advatanges we mentioned in the first paragraph. Furthermore, voluminious literatures address that the informed trading in option market elucidate the process of price discovery, and the information contained in option price and volume would eventually get incoperated into the underlying prices. While, other studies like Chan, Chung, and Johnson (1993), Stephan and Whaley (1990) find no evidence that option prices can lead stock prices.

In this paper, we provide a comprehensive analysis on the examination of the interrelation between option and index markets. In other words, this paper contributes to the literature in several ways. First, rather than investigating on stock market, we focus mainly on the index, S&P 500. Since we would like to research on which interval in a single trading day carries the trading information the most rather than study imbalance orders behind an option volume, index are harder for traders to acquire private information than others. Most prior literature discuss informational linkage between option and stock markets, few of them had mentioned about index market.

Based on the call and put implied volatilty spread(CPIV) propsed by Cremers and Weinbaum (2010), we refine this approach and derive an intraday version which tells the predictability power toward future index returns within a single trading day. Within a single day, we would like to see whether the predictability power is stronger in open period, middle period or close period. Therefore, we partition a single day to 14 intervals, and each interval we only include 5 minutes long in case the Put-Call parity would be unbalanced due to major difference between the underlying prices in call and put options. Apart from the above reason, there are several causes that are responsible for the deviation of put-call parity, short sell constraints, the early exercise value of American options, transaction costs, taxes, to name a few.

The remainder of paper is organized as follows. In Section 2 we describe our research hypothesis, In Section 3, we describe our methedology and data. Section 4 presents the main empirical results on quote data on predicting index returns. Section 5 provides the results are robust to trade data given the identical sample period. Section 6 concludes.

2 Hypothesis Development

Pan and Poteshman (2006) considers that there is no evidence to prove the informed trading in the index market via performing an regression of the next-day index returns on open-buy put-call ratios. It is a common believe that informed traders tend to hold private information in firm-specific level rather than market-wide level. Therefore, we first exclude the possibility that the predictability of index market may comes from informed-trading.

In our research, we articulate the intraday CPIV may comes from yesterday trading information and the news beyond market close. Hence, we would like to see in which interval may also contain information toward the contemporaneous index prices and next-day index prices. Apart from prior studies, which possess the best-bid and best-offer of call and put option price within 5 minutes before market close. On top of that, we apply prior approaches to establish CPIV of every interval in a single trading day. We assume that yesterday trading information and news would also reflect in other intervals. In fact, we discuss whether it is appropriate to use the last 5-minutes best bid and best offer to represent the option information in daily frequency. Would it be another chance that other intervals may also be crucial roles in price discovery?

Hypothesis 1: The open and mid intervals may also contain important information toward index returns

Bergsma et al. (2018) spans the results from Easley, O'hara, and Srinivas (1998) that intraday signed option to stock ratios (O/S) have strong stock return predictability especially in the first 30 minutes of market open. They make a statemtent that the first half hour of trading has predictive power for the remainder of the trading day. In line with this study, we believe CPIV also reflect the market sentiment like O/S. Consequently, we suggest S&P 500 index option carry information toward the index market, and the information would get incorporated into the index market as time flows.

Hypothesis 2: The first 5-minutes CPIV has predictability on intra-day index return during the rest of the trading day

3 Data and Empirical Methodology

3.1 Deviation From Put-Call Parity

The put-call parity relations derived from Stoll (1969) is a classical options pricing concepts in finance. It characterized the relationship that must exist between European put and call options with the identical underlying asset, expiration and strike prices. The equation must hold for European options on no-dividends paying underlying in a perfect market.

$$C - P = S - PV(K) \tag{1}$$

Where C and P represent call prices and put prices, and S is Stock price. With same maturity and exercise price K, the arbitrage opportunity would exist if the equation is not hold. The Black and Scholes (1973) formula satisfies the put-call parity for any assumed value of the volatility parameter σ, therefore,

$$C^{BS}(\sigma) + PV(K) = P^{BS}(\sigma) + S \tag{2}$$

where $C^{BS}(\sigma)$ and $P^{BS}(\sigma)$ indicate Black-Scholes call and put prices, respectively. Combine the above equation, we can derive the equation

$$C^{BS}(\sigma) - C = P^{BS}(\sigma) - P \tag{3}$$

which implies that the implied volatility of call option and put option should be the same if all equation holds.

$$IV^{call} = IV^{put} \tag{4}$$

Of course the equation may not be hold once the option is American-style. However, our primary studies on SPX option is European style. Therefore, we do not need to consider the dividend payment or early exercise case in our further research.

Clearly, the larger implied volatilities are the higher the call or put option prices claim. Following Amin, Coval, and Seyhun (2004), we refer to the difference between call and put implied volatilities as the call-put implied volatility spread(CPIV). It is suggested that a positive(negative) CPIV could be viewed as a bullish (bearish) signal regarding the underlying stock.

The aggregate Intraday CPIV are construced as following steps:

1. We first divided a single day into 14 of 5-minutes interval. Each interval contains the tick data from 2.5 minutes ahead and behind. For example, the 9 a.m. invertal, we collect valid data from 08:47:30 to 09:32:30 to represent this interval. As for open (close) interval, we choose to accumulate the full 5 minutes data behind (ahead)[1]

2. Similar to Xing, X. Zhang, and Zhao (2010), in each interval, we eliminate an option from the sample if its time to expiration is less than 10 days or more than a year, if its open interest is negative, if its moneyness[2] is smaller than 0.9 or more than 1.1. Furthermore, the option quotes must not violate basic no-arbitrage relations.

3. Then, in each time interval, there must be several valid option pairs with

[1]We collect the whole transaction data in 5 minutes for trade data. However, the size of quote data is extremely unbalanced in different intervals, we restricted 1000 to 2000 quotes as maximum for call and put in collecting quote data.

[2]Moneyness is defined as the ratio of the strike price to the stock price.

identical maturity(T) and exercise price(K). For each option pair we choose only one pair to be the representitive. For quote data, we choose the mean of best bid(β^*) best offer(α^*) as the chosen call and put price. For trade data, we capture the transaction that is closet to the centering time.

4. After collecting several time interval valid option pairs. we calculated the CPIV by applying,

$$CPIV_t = IV_t^{call} - IV_t^{put} = \sum_{j=1}^{N_t} \theta_{j,t}(IV_{j,t}^{call} - IV_{j,t}^{put}) \tag{5}$$

$CPIV_t$ denotes the implied volatility spread on interval t; $IV_{j,t}$ describe the B-S implied volatility, where the j refers to valid pairs of put and call options; $\theta_{j,t}$ are weights, there are N_t valid pairs of option on interval t.

Follow by Holowczak, Hu, and Wu (2013), the aggregation of option information could be adjusted by the level of moneyness and maturity.

$$CPIV_t = IV_t^{call} - IV_t^{put} = \sum_{j=1}^{N_t} w_{j,t}(IV_{j,t}^{call} - IV_{j,t}^{put}) \tag{6}$$

The equation is identical except for the weight expression. $w_{j,t}$ is actually $exp(-(m_j^2)/2-(M_j-1)^2)*\theta_j$ where m_j^2 measures the moneyness of the option contract. $m_j = (\frac{K_i}{S_i} - 1)$ and K_i represents exercise prices and S_i represents underlying prices; the M_j evaluates the maturity of option contract. $M_j = max(1, T_i * 12)$ and T_i represents the maturity in month unit.

3.2 Data

In our analysis, the primary quote and trade intraday data for SPX option originates from CBOE MDR. The sample period studied is from January 2007 to December 2017. The option data includes trade date, trade time, expiration date, put-call code, exercise price, maturities, bid price, ask price, underlying price. The daily price of S& P 500 index is obtained from Bloomberg. The zero-coupon bond (ZCB) rate represent risk-free rate in B-S formula are collected from WRDS with different duration. The size of the sample data is about 1-TB around and the amount is about 1 billion. After we exclude the tick data fall outside the 5-minutes intervals, it remains about 40 million. Furthermore, we follow the approach from Ofek, Richardson, and Whitelaw (2004) to exclude the invalid option pairs. Finally, we have 1,692,542 valid volatility spreads for SPX option from January 2007 to December 2017.

Following the prior studiesBollerslev, Tauchen, and Zhou (2009), several macro-economic variable are suggested to be crucial and informative with regard to future returns. Specifically, we collect data of the default spread(between Moody's BAA and AAA corporate bond spreads), the term spread(between the 10-year T-Bond and 3-month T-bill yields) [3] as control variables in our regression analysis. The set of macro-economics controls used in regressions changes as the measurement window of the expected market returns changes.

In our study, the amount of intraday CPIV should be 38,668 (14 Intervals * 2,762 Days). However, most of option quote data are short date contract (less than 10 days) in the middle of month so that we have mutiple missing values by this

[3] The daily data are collected from the public website of the Federal Reserve Bank of St. Louis.

approach. Meanwhile, our research also winsorized the outliers of intraday CPIV on 1% at the front and end. The final valid interval CPIV of trade data is 36,959, as for quote data is 27,554.

Table 1 presents the descriptive statistics of intraday CPIV. In panel A, we demonstrate the descriptive statistics on CPIV of intervals. The mean (median) CPIV vary from -2.45 % to -3.65 % (-3.32 % to -3.72%), indicating that, on average, S&P 500 index put option have about three percent higher implied volatilty than index call option during our sample period. In fact, the results are similar to Atilgan, Bali, and Demirtas (2015), they put forth the obeservations that in average there are nine percent higher during their sample period. In index market, the implied volatitily to moneyness graph mostly shows a reverse skew, which prior studies (J. E. Zhang and Xiang 2008) claimed volatility smirk. Our observations also express this phenomenon. In addition, in panel A, we could tell that the CPIV of open interval (08:30) is completely different from other CPIV. The mean of CPIV in 08:30 is about 1% higher than other intervals, and the standard deviation of CPIV in 08:30 is 0.4% higher than others. Furthermore, the amount of positive CPIV are way larger than other intervals. We suggests during the open interval, numerous news and trading information flow in and cause the open-interval CPIV more volatile. Futhermore, the call options are more likely to be relatively expensive than put options in first interval. We suggests that if investors exposure to good news before market open, they prefer to reflect on option price in first 5-minutes.

In panel B, we test the population mean among the intervals CPIV.

$$H0 : \mu_i = \mu_j \tag{7}$$

The p-value of pairs are shown in corresponding rows and columns. From the results, we declare that the population mean of open interval CPIV is significantly different from other intervals, so does the close interval CPIV. In other words, we claim that the population mean of mid interval CPIV is not significantly different from other mid intervals. The mid intervals may gather similar information.

3.3 Empirical Methodology

Our research devide into two parts. The first part we analysis certain option pair characteristics that cause the deviation of put call parity. The second part we discuss the relationship between CPIV and index returns in different aspects.

Firstly, we regress CPIV on moneyness, time non-synchronization, maturity, and controlling on intervals. The CPIV term and moneyness term are in absolute form due to the opposite sign of deviation may eliminate the effect of each other.

$$|CPIV_i| = \alpha + \beta_1 TimeDiff_i + \beta_2 \left|Moneyness_i\right| + \beta_3 Maturity_i + \beta_j \sum_{j=1}^{13} IntDummy_j + \varepsilon_i \quad (8)$$

$TimeDiff_i$ represents time non-synchronization in option pair i. $Moneyness_i$ stands for the level of divergence between the underlying price and the excersie price of option pair i. $Maturity_i$ symbolizes the maturity date in option pair i. As for $IntDummy_j$, we control the intervals effect where j denote as each interval, for instance, $IntDummy_1$ stands for 09:00. All the t statistics are Newey and West statistics adjusted.

Secondly, we regress contemporaneous index returns, one day ahead index returns, certain intervals ahead index returns on CPIV and other macro economic variables respectively.

$$SPX\_Return_t = \alpha + \beta_1 CPIV_t + \beta_2 DEF_t + \beta_3 TERM_t + \varepsilon_t \tag{9}$$

In above equation, SPX_Return_t elucidates the SPX index returns in day t, where $CPIV_t$ could be any interval CPIV within day t. DEF_t explicates the change in the difference between the yeilds on BAA- and AAA-rated coporate bonds in day t, and $TERM_t$ expounds the difference between the yeilds on the 10-year Treasury bond and one-month Treasury bill in day t. All the t statistics are Newey and West statistics adjusted.

$$SPX\_Return_{t+1} = \alpha + \beta_1 CPIV_t + \beta_2 DEF_t + \beta_3 TERM_t + \varepsilon_t \tag{10}$$

In equation (9), the only term change is SPX_Return_{t+1}. We now regress a day forward returns on depedent variables rather than contemporaneous index returns.

$$Intra\_Return_{t,k} = \alpha + \beta_1 CPIV_t + \beta_2 DEF_t + \beta_3 TERM_t + \varepsilon_t, \forall k = 1, 2...13 - n \tag{11}$$

In this part, we would like to discuss the predictability in intra-day index returns, where $Intra\_Return_{t,k}$ means k of half-hour ahead cumulative returns. For example, when we'd like to do research on the intra-day return to the open interval CPIV(08:30), $k = 1$ means the cumulative returns from 08:30 to 09:00, and $k = 2$ means the cumulative returns from 08:30 to 09:30, and so on and so forth. n is which interval the CPIV represents.

4 Empirical Results

The main results are based on SPX option quote data. We take both Equation 5 (non-adjusted weights) and Equation 6 (adjusted weights) to build intraday CPIV. The results are quite similar, so we only present the results of Equation 6. The non-adjusted version is upon requsted.

4.1 Relationships Between CPIV and Option Characteristic

Before we explore the relationship between the index returns and CPIV, we need to survey on the option characteristics. From Equation 8, We expect the coefficient of time non-synchronization, moneyness. and maturity to be positive. There should be no deviation in put-call parity given that the underlying price is also identical in theroy. In other words, the larger the time gap between the pair option, the larger the divergence may occur and cause higher CPIV in absolute form. Furthermore, the level of moneyness and time to expiration are crucial to CPIV as well. According to Hentschel (2003), implied volatilities from options away from the money are especially sensitive to measurement errors in option prices and uderlying asset price. Therefore, we estimates that with greater level of moneyness and time to maturities, the measurement errors in implied volatilities would increase.

The results in Table 5 confirm our earlier statements based on regreesion of CPIV. Column (1) reports the regression of CPIV on time non-synchronization. All the coefficients are highly significant; they imply a positive effect on deviation of put-call parity. Column (2) of table 5 shows that regression of CPIV on moneyness. The coefficient of moneyness term is also highly siginficant (0.3833, t-statistic

434.96). Column (3) signifies of CPIV on maturity. The coefficient of maturity term is highly siginficant (0.0348, t-statistic 296.27) as well. Clearly, the regression results are aligned with previous literatures, which indicate the moneyness and maturity have positive effect on CPIV. Finally, in column (4), we regress CPIV on all option pair characteristics. The outcome is similar to previous regressions. Noticeably, the adjusted R^2 of moneyness term is almost 34%, which stands for the most influential factor.

4.2 Relationships Between Index Return and CPIV

In this subsection, we discuss the relationship between CPIV and index returns in different aspects. The Panel A in Table 6 depict the results of contemporaneous index return regressions, while Panel B acts for the results of one-day ahead index return regressions. The header of columns describes the interval of CPIV, and all th variables are in percentage format.

In panel A, the CPIV coefficients are all positive and this outcome is aligned with Cremers and Weinbaum (2010) which proves the evidence for a significant positive link between implied volatility spread and expected returns. To be more specific, $CPIV_{08:30}$ and $CPIV_{12:00}$ are siginificant in 1% and 10% level respectively. However, other intervals are not significant enough under 10% level. The result validate our first hypothesis: The open and mid intervals may also contain important information toward index returns. Apart from that, $CPIV_{08:30}$ has the largest coeffecient 8.33[4] (t-statistic 17.84), we believe that most trading information is incoporated into the first interval.

[4]The value is shown in percentage format.

In panel B, we test the next day index return on CPIV and other control variables to see whether the information spillover from the option market to the next-day index market. Surprisingly, none of them are significant enough and not all of them are positive. According to Atilgan, Bali, and Demirtas (2015), they assert the volatilty skewness of S&P index option may cause spillover effect to index market. We find out the implied volatility spread has no predictability on aggregate index returns in one-day horizon.

On intra-day frequency, we also test the predictability on culumlated half hour index returns in different horizons. We only take $CPIV_{08:30}$ and $CPIV_{12:00}$ as independent variables since they are the only variables significant on contemporaneous frequency. However, the results are completely not the same way. From Table 8, the coefficients of $CPIV_{08:30}$ range from 5.63 to 6.57, implying myriad economic significance. The adjusted R^2 of $CPIV_{08:30}$ range from 50.19% to 19.17% as hours decay. The results is consistent with our Hypothesis 2: The first 5-minutes CPIV has predictability on intra-day index return during the rest of the trading day. On the contrary, we did not find prediction power on $CPIV_{12:30}$ for any k. In this paragraph, we demonstrate that the first 5-minutes interval keep considerable information compared to other intervals, and this information would be incorporated into index market by hours – not by days. Our emperical results are sligtly different from Cremers and Weinbaum (2010), but similar to Kumar, Sarin, and Shastri (1992).

4.3 Robustness

In this paragraph, we employ above regressions on SPX option trade data. The descriptive statistics of trade data are displyed in Table 3, we can also see that there is an U-shaped on CPIV mean term.

5 Information Explanation

5.1 Consumer Sentiment

In this section, we provide evidence for the intertemporal relationship between CPIV from option market and index future returns. According to Atilgan, Bali, and Demirtas (2015), the periods of extremely high or low consumer sentiment index are crucial becuase these are the periods where asset prices are vulnerable to deviate from the fundamental values the most. Therefore, one would expect, during periods of extreme consumer sentiment, the intertemporal relation between CPIV and index returns to be stronger.

$$SPX\_Return_t = \alpha + \beta_1 VSPLUS_t + \beta_2 VSMINUS_t + \beta_3 DEF_t + \beta_4 TERM_t + \varepsilon_t \tag{12}$$

We follow the method (Atilgan, Bali, and Demirtas 2015) to define a dummy variable that is equal to one for a given trading day if the consumer sentiment index is greater than its 90^{th} percentile or less than its 10^{th} percentile over the sample period, and 0 otherwise. Hence, follow prior studies, VSPLUS is denoted as CPIV if dummy variable is equal to one and 0 otherwise, while VSMINUS is denoted as CPIV of dummy variable is equal to zero and 0 otherwise. If the information in

CPIV to consumer sentiment is essential in the predictive power of the CPIV on index returns, then β_1 is expected to be positive and larger than β_2.

Panel A in Table 9 focuses on Baker and Wurgler (BW) sentiment index [5], while panel B centers around University of Michigan Consumer (UOM) Sentiment Index[6].

[5]The data can be found in Jeffrey Wurgler personal website

[6]The data are availble on the University of Michigan Website

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List of Tables

Table 1: Descriptive Statistics of Intraday CPIV of Quote Data

This table shows descriptive statistics for call-put implied volatility (CPIV) of each interval. Panel A presents the summary statsitics for CPIV. Panel B presents the population mean test among CPIV of each interval. In panel A, the first row represents all intervals. # Pos. CPIV is the amount of CPIV above zero, where # Neg. CPIV is the amount of CPIV below zero. Nan Value Rate refers to the rate that CPIV of interval is blank due to the reasons like the option prices are out of boundary, or the maturity are not satisfied with the rules, etc. In Panel B, the first row and column represent all intervals. The values in the table convey the p-value of population mean test between each interval.

(a) Panel A: The Descriptive Statistics of CPIV on Quote Data

	08:30	09:00	09:30	10:00	10:30	11:00	11:30	12:00	12:30	13:00	13:30	14:00	14:30	15:00
Mean(%)	-2.45	-3.73	-3.65	-3.59	-3.57	-3.57	-3.62	-3.61	-3.60	-3.62	-3.62	-3.58	-3.51	-3.41
Std(%)	1.11	0.71	0.77	0.80	0.79	0.76	0.78	0.82	0.82	0.78	0.77	0.77	0.71	0.80
Min(%)	-51.17	-14.81	-11.38	-14.24	-10.65	-10.65	-11.86	-11.64	-13.95	-11.60	-10.09	-14.39	-11.22	-15.84
Max(%)	43.20	11.69	20.39	3.49	8.91	7.09	6.52	4.38	5.21	4.92	3.51	4.22	5.62	4.67
Median(%)	-3.36	-3.72	-3.59	-3.55	-3.47	-3.49	-3.50	-3.47	-3.46	-3.51	-3.43	-3.41	-3.33	-3.20
# Pos. CPIV	647	47	24	25	19	22	18	20	19	22	14	19	19	32
# Neg. CPIV	1916	2366	2183	2099	2048	1982	1943	1901	1847	1802	1758	1710	1649	1399
Nan Value Rate(%)	3.8	9.1	16.8	19.9	22.1	24.5	26.1	27.6	29.7	31.2	33.2	34.8	37.1	46.0

(b) Panel B: The Population Mean Test Among CPIV of Intervals

	08:30	09:00	09:30	10:00	10:30	11:00	11:30	12:00	12:30	13:00	13:30	14:00	14:30	15:00
08:30	1													
09:00	0.00***	1												
09:30	0.00***	0.08*	1											
10:00	0.00***	0.09*	0.91	1										
10:30	0.00***	0.00***	0.10	0.07*	1									
11:00	0.00***	0.00***	0.05**	0.03**	0.77	1								
11:30	0.00***	0.00***	0.22	0.17	0.66	0.46	1							
12:00	0.00***	0.00***	0.13	0.10	0.89	0.67	0.76	1						
12:30	0.00***	0.00***	0.06*	0.04**	0.80	0.96	0.50	0.71	1					
13:00	0.00***	0.00***	0.01***	0.06*	0.93	0.84	0.61	0.83	0.87	1				
13:30	0.00***	0.00***	0.00***	0.01**	0.42	0.62	0.22	0.36	0.59	0.49	1			
14:00	0.00***	0.00***	0.00***	0.00***	0.09*	0.16	0.04**	0.07*	0.16	0.12	0.37	1		
14:30	0.00***	0.00***	0.00***	0.00***	0.00***	0.00***	0.00***	0.00***	0.00***	0.00***	0.00***	0.04**	1	
15:00	0.00***	0.00***	0.00***	0.00***	0.00***	0.00***	0.00***	0.00***	0.00***	0.00***	0.00***	0.00***	0.00***	1

*** Significant at the 1 percent level.
** Significant at the 5 percent level.
* Significant at the 10 percent level.

Table 3: Descriptive Statistics of Intraday CPIV of Trade Data

This table shows descriptive statistics for call-put implied volatility (CPIV) of each interval. Panel A presents the summary statsitics for CPIV. Panel B presents the population mean test among CPIV of each interval. In panel A, the first row represents all intervals. # Pos. CPIV is the amount of CPIV above zero, where # Neg. CPIV is the amount of CPIV below zero. Nan Value Rate refers to the rate that CPIV of interval is blank due to the reasons like the option prices are out of boundary, or the maturity are not satisfied with the rules, etc. In Panel B, the first row and column represent all intervals. the values in the table convey the p-value of population mean test between each interval.

(a) Panel A: The Descriptive Statistics of CPIV on Trade Data

	08:30	09:00	09:30	10:00	10:30	11:00	11:30	12:00	12:30	13:00	13:30	14:00	14:30	15:00
Mean(%)	-1.74	-1.84	-1.90	-1.86	-1.93	-1.98	-1.97	-1.94	-1.94	-1.98	-1.97	-1.94	-1.94	-1.78
Std(%)	4.33	1.48	1.34	1.90	2.39	1.63	1.69	1.49	2.84	1.64	1.90	2.30	1.86	3.30
Min(%)	-38.20	-32.80	-16.22	-29.52	-30.79	-28.91	-33.16	-19.60	-50.13	-22.20	-36.12	-41.78	-38.06	-22.06
Max(%)	29.45	7.62	6.26	37.88	81.43	11.01	7.80	6.96	102.54	8.99	13.56	38.66	19.13	139.27
Median(%)	-1.58	-1.77	-1.86	-1.83	-1.89	-1.93	-1.91	-1.94	-1.90	-1.90	-1.88	-1.91	-1.86	-1.76
# Pos. CPIV	586	107	105	120	92	100	97	99	88	101	98	102	96	96
# Neg. CPIV	2139	2647	2635	2601	2586	2540	2474	2453	2409	2412	2477	2495	2573	2631
Nan Value Rate(%)	1.52	0.47	0.98	1.66	3.22	4.59	7.08	7.77	9.76	9.18	6.94	6.14	3.54	1.45

(b) Panel B: The Population Mean Test Among CPIV of Intervals

	08:30	09:00	09:30	10:00	10:30	11:00	11:30	12:00	12:30	13:00	13:30	14:00	14:30	15:00
08:30	1													
09:00	0.26	1												
09:30	0.06*	0.11	1											
10:00	0.18	0.62	0.39	1										
10:30	0.04**	0.09*	0.56	0.24	1									
11:00	0.01***	0.00***	0.04**	0.01**	0.34	1								
11:30	0.01***	0.00***	0.08*	0.02**	0.44	0.84	1							
12:00	0.02**	0.01**	0.26	0.08	0.81	0.36	0.49	1						
12:30	0.04**	0.11	0.51	0.24	0.88	0.51	0.62	0.97	1					
13:00	0.01**	0.00***	0.05**	0.01**	0.35	0.99	0.85	0.37	0.52	1				
13:30	0.01**	0.01**	0.12	0.04**	0.50	0.79	0.94	0.58	0.67	0.80	1			
14:00	0.03**	0.05**	0.41	0.16	0.86	0.45	0.57	0.98	0.99	0.46	0.63	1		
14:30	0.02**	0.02**	0.32	0.11	0.82	0.40	0.53	1.00	0.97	0.42	0.61	0.98	1	
15:00	0.72	0.37	0.07**	0.25	0.05*	0.00***	0.01***	0.02**	0.05**	0.00***	0.01**	0.03**	0.02**	1

*** Significant at the 1 percent level.
** Significant at the 5 percent level.
* Significant at the 10 percent level.

Table 5: Regression Results: CPIV and Option Pair Characterisitcs

This table shows the regression results of call-put implied volatility (CPIV) on moneyness, time non-synchronization, maturity with intervals fixed effect.The CPIV term and moneyness term are in absolute form due to the opposite sign of deviation may eliminate the effect of each other. TimeDiff represents time non-synchronization. Moneyness stands for the level of divergence between the underlying price and the excersie price. Maturity symbolizes the maturity date. As for Interval F.E., we control the intervals effect. All the t statistics in parathesis are Newey-West t statistics adjusted.

	(1)	(2)	(3)	(4)
Intercept	0.05577***	0.03087***	0.05055***	0.03011***
	(263.91)	(170.91)	(229.42)	(162.73)
TimeDiff	0.0000***			0.0000***
	(89.32)			(7.40)
Moneyness		0.3833***		0.3710***
		(434.96)		(366.56)
Maturity			0.0348***	0.0103***
			(296.27)	(68.17)
Interval F.E.	Yes	Yes	Yes	Yes
No. Obs	1692542	1692542	1692542	1692542
Adj. R^2	0.0473	0.3368	0.0853	0.3402

*** Significant at the 1 percent level.
** Significant at the 5 percent level.
* Significant at the 10 percent level.

Table 6: Regression Results: Index Return and CPIV

This table reports from time-series predictive regressions of daily return of the S&P 500 index on call-put implied volatility (CPIV), and macroeconomic varibles. Panel A presents the summary statistics for contemporaneous index return regression. Panel B presents summary statistics for one-day ahead index return regression. CPIV elucidates the interval implied volatility spreads.DEF explicates the change in the difference between the yeilds on BAA- and AAA-rated coporate bonds. TERM expounds the difference between the yeilds on the 10-year Treasury bond and one-month Treasury bill. All the t statistics in parathesis are Newey-West t statistics adjusted. All variable values are in percentage format.

(a) Panel A: The Contemporaneous Index Return Regression

	08:30	09:00	09:30	10:00	10:30	11:00	11:30	12:00	12:30	13:00	13:30	14:00	14:30	15:00
Intercept	0.26***	0.15	0.17	0.16	0.14	0.21*	0.13	0.25**	0.17	0.18	0.14	0.16	0.27**	0.31*
	(2.84)	(1.47)	(1.62)	(1.52)	(1.32)	(1.82)	(1.18)	(2.07)	(1.36)	(1.38)	(1.02)	(1.11)	(1.90)	(2.04)
CPIV	8.33***	1.35	1.30	1.84	1.50	2.86	0.41	3.86*	2.24	2.13	1.03	2.57	4.91	-0.25
	(17.84)	(0.85)	(0.83)	(1.07)	(0.85)	(1.48)	(0.20)	(1.83)	(1.01)	(1.09)	(0.51)	(1.21)	(1.91)	(-0.09)
DEF	0.04	-0.06	-0.07	-0.06	-0.06	-0.09	-0.10	-0.07	-0.07	-0.09	-0.11	-0.09	-0.12	-0.28
	(0.52)	(-0.63)	(-0.70)	(-0.61)	(-0.60)	(-0.73)	(-0.81)	(-0.55)	(-0.54)	(-0.73)	(-0.83)	(-0.67)	(-0.83)	(-1.77)
TERM	-0.03	0.00	0.00	0.02	0.02	0.02	0.02	0.01	0.02	0.03	0.04	0.04*	0.03	0.00
	(-1.29)	(0.07)	(0.21)	(0.71)	(0.92)	(0.77)	(1.00)	(0.59)	(0.98)	(1.26)	(1.63)	(1.74)	(1.33)	(0.00)
Adj. R^2	24.33	0.12	0.15	0.17	0.16	0.33	0.20	0.43	0.24	0.32	0.30	0.43	0.84	1.27

*** Significant at the 1 percent level.
** Significant at the 5 percent level.
* Significant at the 10 percent level.

(b) Panel B: The One-Day ahead Index Return Regression

	08:30	09:00	09:30	10:00	10:30	11:00	11:30	12:00	12:30	13:00	13:30	14:00	14:30	15:00
Intercept	0.02	0.04	0.12	0.03	0.06	0.02	0.02	0.07	0.08	0.13	0.08	0.11	0.15	0.13
	(0.20)	(0.44)	(1.18)	(0.31)	(0.56)	(0.15)	(0.18)	(0.61)	(0.66)	(1.08)	(0.66)	(0.84)	(1.10)	(0.91)
CPIV	-0.74	-0.54	1.24	-1.65	0.15	0.75	-1.11	1.31	-0.10	0.81	-0.64	-0.18	-0.49	-2.00
	(-1.23)	(-0.36)	(0.80)	(-0.87)	(0.08)	(0.40)	(-0.57)	(0.70)	(-0.05)	(0.42)	(-0.31)	(-0.09)	(-0.22)	(-0.84)
DEF	-0.01	-0.04	-0.05	-0.07	-0.04	0.03	-0.05	0.00	-0.07	-0.09	-0.09	-0.10	-0.14	-0.15
	(-0.15)	(-0.39)	(-0.53)	(-0.67)	(-0.35)	(0.29)	(-0.48)	(0.01)	(-0.61)	(-0.75)	(-0.77)	(-0.83)	(-1.13)	(-1.07)
TERM	0.00	0.00	0.00	0.01	0.01	0.01	0.02	0.01	0.01	0.01	0.01	0.01	0.00	-0.01
	(0.14)	(0.11)	(-0.01)	(0.29)	(0.33)	(0.37)	(0.75)	(0.39)	(0.42)	(0.41)	(0.36)	(0.28)	(0.09)	(-0.19)
Adj. R^2	0.19	0.02	0.10	0.08	0.02	0.03	0.05	0.03	0.07	0.13	0.09	0.12	0.24	0.31

*** Significant at the 1 percent level.
** Significant at the 5 percent level.
* Significant at the 10 percent level.

Table 8: Regression Results: Intra-day Index Return and CPIV

This table records from time-series predictive regressions of intra-day half-hour return of the S&P 500 index on call-put implied volatility (CPIV), and macroeconomic varibles. The independent varible is $CPIV_{08:30}$. DEF explicates the change in the difference between the yeilds on BAA- and AAA-rated coporate bonds. TERM expounds the difference between the yeilds on the 10-year Treasury bond and one-month Treasury bill. K means k of half-hour ahead cumulative returns. For example, k = 1 means the cumulative returns from 08:30 to 09:00, k = 2 means the cumulative returns from 08:30 to 09:30, and so on and so forth. All the t statistics in parathesis are Newey-West t statistics adjusted. All variable values are in percentage format.

	K=1	K=2	K=3	K=4	K=5	K=6	K=7	K=8	K=9	K=10	K=11	K=12	K=13
Intercept	0.18***	0.16***	0.16***	0.19***	0.19***	0.20***	0.20***	0.21***	0.22***	0.22***	0.17***	0.20***	0.18***
	(5.77)	(4.11)	(3.52)	(3.79)	(3.58)	(3.74)	(3.53)	(3.44)	(3.40)	(3.24)	(2.27)	(2.61)	(2.16)
$CPIV_{08:30}$	5.63***	5.77***	5.79***	5.80***	5.75***	5.81***	5.83***	5.93***	5.87***	5.94***	5.96***	6.12***	6.57***
	(30.81)	(27.76)	(24.92)	(24.37)	(21.44)	(22.27)	(21.92)	(22.05)	(20.71)	(19.94)	(19.12)	(17.58)	(16.17)
DEF	0.00	0.02	0.03	0.00	0.01	0.00	0.00	-0.01	-0.03	-0.04	0.01	0.01	0.03
	(-0.13)	(0.67)	(0.64)	(0.06)	(0.23)	(-0.04)	(-0.05)	(-0.26)	(-0.60)	(-0.62)	(0.22)	(0.09)	(0.45)
TERM	-0.01	-0.01	-0.02	-0.02	-0.02	-0.02	-0.02	-0.02	-0.01	-0.01	-0.01	-0.01	-0.02
	(-1.58)	(-1.43)	(-1.39)	(-1.54)	(-1.81)	(-1.57)	(-1.45)	(-1.07)	(-0.73)	(-0.70)	(-0.43)	(-0.81)	(-0.83)
Adj.R^2	50.19	41.65	36.43	33.14	29.80	28.79	27.25	26.43	24.69	23.11	20.85	19.87	19.37

*** Significant at the 1 percent level.
** Significant at the 5 percent level.
* Significant at the 10 percent level.

Table 9: Regression Results: Index Return Predictability on the Effects of Investors Sentiment

This table reports from time-series predictive regressions of contemporaneous return of the S&P 500 index on call-put implied volatility (CPIU), and macroeconomic varibles. Panel A focuses on Baker and Wurgler (BW) sentiment index, while panel B centers around University of Michigan Consumer (UOM) Sentiment Index. We take the definition of VSPLUS and VSMINUS in Atilgan, Bali, and Demirtas (2015) as reference. A dummy variable is equal to one if the consumer sentiment index is greater than the 90th percentile or less than the 10th percentile among the observed consumer sentiment values over the sample period. Therefore, VSPLUS is equal to the CPIV if dummy variable is equal to one and 0 otherwise. VSMINUS is equal to the CPIV if dummy variable is equal to zero and 0 otherwise. DEF explicates the change in the difference between the yeilds on BAA- and AAA-rated coporate bonds. TERM expounds the difference between the yeilds on the 10-year Treasury bond and one-month Treasury bill. All the t statistics in parathesis are Newey-West t statistics adjusted. All variable values are in percentage format.

(a) Panel A: Baker and Wurgler Sentiment Index

	08:30	09:00	09:30	10:00	10:30	11:00	11:30	12:00	12:30	13:00	13:30	14:00	14:30	15:00
Intercept	0.26**	0.16	0.18*	0.17	0.15	0.23**	0.15	0.27**	0.19	0.19	0.16	0.17	0.28***	0.33***
	(2.91)	(1.55)	(1.71)	(1.58)	(1.42)	(2.00)	(1.33)	(2.26)	(1.52)	(1.51)	(1.16)	(1.18)	(1.98)	(2.15)
VSPLUS	7.83***	2.12	2.10	2.34	2.39	4.60*	1.83	5.89**	4.13	3.90	2.76	3.83	6.15**	0.56
	(18.16)	(1.19)	(1.14)	(1.08)	(1.08)	(1.89)	(0.73)	(2.27)	(1.49)	(1.59)	(1.04)	(1.44)	(1.99)	(0.18)
VSMINUS	10.62***	0.36	0.50	1.47	0.81	1.61	-0.66	2.28	0.88	0.71	-0.11	1.46	3.66	-1.75
	(7.23)	(0.22)	(0.32)	(0.89)	(0.48)	(0.90)	(-0.35)	(1.19)	(0.44)	(0.40)	(-0.06)	(0.76)	(1.59)	(-0.69)
DEF	0.07	-0.08	-0.08	-0.07	-0.07	-0.10	-0.12	-0.09	-0.08	-0.11	-0.12	-0.10	-0.13	-0.30
	(0.90)	(-0.79)	(-0.82)	(-0.67)	(-0.70)	(-0.89)	(-0.93)	(-0.70)	(-0.68)	(-0.85)	(-0.93)	(-0.75)	(-0.92)	(-1.91)
TERM	-0.04	0.01	0.01	0.02	0.03	0.03	0.03	0.03	0.04	0.04	0.05	0.05	0.04	0.01
	(-1.80)	(0.45)	(0.56)	(0.89)	(1.28)	(1.44)	(1.55)	(1.34)	(1.70)	(1.96)	(2.25)	(2.28)	(1.85)	(0.23)
Adj. R^2	24.79	0.18	0.21	0.19	0.21	0.53	0.34	0.73	0.49	0.57	0.50	0.56	0.97	1.35

*** Significant at the 1 percent level.
** Significant at the 5 percent level.
* Significant at the 10 percent level.

(b) Panel B: University of Michigan Consumer Sentiment Index

	08:30	09:00	09:30	10:00	10:30	11:00	11:30	12:00	12:30	13:00	13:30	14:00	14:30	15:00
Intercept	0.17**	0.09	0.13	0.13	0.10	0.16	0.11	0.20	0.14	0.12	0.08	0.10	0.19	0.25*
	(2.02)	(0.93)	(1.27)	(1.21)	(0.99)	(1.46)	(0.98)	(1.72)	(1.16)	(0.99)	(0.65)	(0.74)	(1.39)	(1.68)
VSPLUS	12.57***	4.56*	3.80	3.86	3.59	5.74**	1.98	6.38**	3.86	5.73*	3.96	5.79*	9.69***	4.26
	(8.77)	(1.80)	(1.50)	(1.54)	(1.35)	(2.01)	(0.67)	(2.22)	(1.34)	(1.82)	(1.26)	(1.68)	(2.52)	(0.95)
VSMINUS	7.05***	0.63	0.81	1.35	0.88	2.05	-0.01	3.03	1.81	1.26	0.14	1.65	3.50	-1.33
	(19.03)	(0.40)	(0.51)	(0.76)	(0.49)	(1.05)	(-0.01)	(1.41)	(0.77)	(0.64)	(0.07)	(0.79)	(1.39)	(-0.50)
DEF	0.10	-0.01	-0.04	-0.04	-0.04	-0.05	-0.08	-0.04	-0.05	-0.05	-0.08	-0.05	-0.06	-0.24
	(1.35)	(-0.13)	(-0.36)	(-0.35)	(-0.34)	(-0.43)	(-0.66)	(-0.31)	(-0.40)	(-0.41)	(-0.58)	(-0.38)	(-0.44)	(-1.47)
TERM	-0.02	0.00	0.00	0.02	0.02	0.02	0.02	0.01	0.02	0.03	0.04	0.04	0.04	0.00
	(-1.20)	(0.02)	(0.18)	(0.71)	(0.93)	(0.78)	(1.00)	(0.64)	(1.00)	(1.31)	(1.69)	(1.84)	(1.46)	(0.08)
Adj. R^2	26.39	0.32	0.27	0.26	0.26	0.53	0.25	0.60	0.30	0.63	0.53	0.68	1.38	1.69

*** Significant at the 1 percent level.
** Significant at the 5 percent level.
* Significant at the 10 percent level.

Table 11: Regression Results: Index Return Predictability on the Effects of Option Liquidity

This table reports from time-series predictive regressions of contemporaneous return of the S&P 500 index on call-put implied volatility (CPIU), and macroeconomic varibles. To estimate the option liquidity, we employ option volume as a proxy refering to Chang, Lin, and Wang (2018). Then, we take the definition of VSPLUS and VSMINUS in Atilgan, Bali, and Demirtas (2015) as reference. A dummy variable is equal to one if the option volume is greater than the 90th percentile among the observed option volume over the sample period. Therefore, VSPLUS is equal to the CPIV if dummy variable is equal to one and 0 otherwise. VSMINUS is equal to the CPIV if dummy variable is equal to zero and 0 otherwise. DEF explicates the change in the difference between the yeilds on BAA- and AAA-rated coporate bonds. TERM expounds the difference between the yeilds on the 10-year Treasury bond and one-month Treasury bill. All the t statistics in parathesis are Newey-West t statistics adjusted. All variable values are in percentage format.

	08:30	09:00	09:30	10:00	10:30	11:00	11:30	12:00	12:30	13:00	13:30	14:00	14:30	15:00
Intercept	0.27***	0.17	0.19*	0.19	0.16	0.24**	0.16	0.29**	0.21	0.20	0.15	0.17	0.28**	0.31**
	(3.03)	(1.59)	(1.72)	(1.64)	(1.42)	(1.97)	(1.36)	(2.29)	(1.55)	(1.51)	(1.12)	(1.18)	(1.94)	(2.04)
VSPLUS	9.75***	2.94	2.73	3.46	2.96	5.04**	2.44	6.89***	4.97*	4.25	2.83	4.34	6.79**	1.19
	(13.61)	(1.51)	(1.46)	(1.55)	(1.30)	(1.96)	(0.97)	(2.56)	(1.70)	(1.69)	(1.10)	(1.69)	(2.25)	(0.38)
VSMINUS	7.09***	0.65	0.49	1.22	0.86	2.04	-0.39	2.84	1.39	1.39	0.30	1.59	3.56	-1.60
	(12.99)	(0.39)	(0.29)	(0.70)	(0.48)	(1.08)	(-0.19)	(1.37)	(0.64)	(0.71)	(0.15)	(0.75)	(1.43)	(-0.60)
DEF	0.02	-0.07	-0.09	-0.07	-0.07	-0.10	-0.11	-0.09	-0.08	-0.10	-0.11	-0.10	-0.13	-0.29
	(0.30)	(-0.73)	(-0.79)	(-0.69)	(-0.67)	(-0.82)	(-0.89)	(-0.64)	(-0.61)	(-0.77)	(-0.85)	(-0.69)	(-0.87)	(-1.78)
TERM	-0.03	0.00	0.00	0.01	0.02	0.01	0.02	0.01	0.02	0.02	0.03	0.04	0.03	0.00
	(-1.37)	(-0.06)	(0.10)	(0.57)	(0.80)	(0.57)	(0.80)	(0.37)	(0.75)	(1.07)	(1.47)	(1.62)	(1.26)	(-0.01)
Adj R^2	26.39	0.32	0.27	0.26	0.26	0.53	0.25	0.60	0.30	0.63	0.53	0.68	1.38	1.69

*** Significant at the 1 percent level.
** Significant at the 5 percent level.
* Significant at the 10 percent level.