How Do Chinese Option-Traders “Smirk” on China: Evidence from SSE 50 ETF options

Tian Yue
Department of Accountancy and Finance
Otago Business School, University of Otago
Dunedin 9054, New Zealand
Email: tin.yue@otago.ac.nz

Sebastian Gehricke
Department of Accountancy and Finance
Otago Business School, University of Otago
Dunedin 9054, New Zealand
Email: sebastian.gehricke@otago.ac.nz

Jin E. Zhang
Department of Accountancy and Finance
Otago Business School, University of Otago
Dunedin 9054, New Zealand
Email: jin.zhang@otago.ac.nz

Zheyao Pan
Department of Applied Finance
Macquarie University
North Ryde, NSW, 2109, Australia
Email: terry.pan@mq.edu.au

First Version: March 2018
This Version: April 2019

Abstract

This paper analyzes the empirical dynamics of the implied volatility (IV) of SSE 50 ETF options, the only equity options market in China. We adopt Zhang and Xiang's (2008) methodology to quantify the IV curve and find it exhibits a right skewed smirk shape, which is different to the left skewed IV smirk shape commonly exhibited by US and international equity option markets. The IV curve becomes more right skewed during the 2015 Chinese stock market crash and calms to symmetry thereafter. We show that the variation in the shape of SSE 50 ETF option IV curves is explained by investor sentiment.

Keywords: ETF options, implied volatility, investor sentiment, China options

JEL Classification: G13, G14, G15.

1 Introduction

In this paper, we adopt the methodology of Zhang and Xiang (2008) to quantify and analyze the implied volatility (IV) curves of the newly established Shanghai Stock Exchange (SSE) 50 exchange-traded-fund (ETF) options market in China. This is the first paper documenting the IV curves of an options market in China. We find that the IV curve usually resembles a right skewed smirk, which is in contrast to the commonly observed left skewed shape in U.S. and other international equity options markets (e.g., Foresi and Wu, 2005). Further, we analyze the determinants of the changes in the IV shape and find that it is driven by investor sentiment.

Currently, the SSE 50 ETF options are the only equity options traded in mainland China. The underlying asset is the SSE 50 ETF fund, which tracks the SSE 50 index and was listed on the SSE on 23 February, 2005. The SSE 50 index includes the 50 largest blue-chip stocks traded on the SSE, which constitute 25% of the SSE's market capitalization. Since the launch of SSE 50 ETF options on 9 February, 2015, investors are able to access volatility trading in the world's largest emerging capital market. This option market has experienced significant and now has daily trading volume (value) close to 35% (15%) of SPY (SPDR S&P 500 ETF) options at the end of 2017 (see Figures 1).

We quantify all the SSE 50 ETF option IV curves following Zhang and Xiang's (2008) methodology and find that they usually exhibit a right skewed smirk shape. Furthermore, we report time series dynamics, the three factors are also proportional related to the risk neutral (RN) moments of SSE 50 ETF option returns (Zhang and Xiang, 2008), therefore our results provide an benchmark for the SSE 50 option pricing model.

We further investigate whether the IV smirk factors: level, slope and curvature, are driven by investor sentiment, we find a strong relationship between IV curve and liquidity/Put-to-Call (PCR) ratios. This could be expected as more positive investor sentiment should lead to more bullish option market, which is reflected by an increased slope of the IV curves.

The IV is volatility which matches the option's market price when input into the option pricing model (usually the Black and Scholes (1973) and Merton (1973), BSM from now on). It is therefore a forward-looking measure of expected volatility demand from market option prices. In the BSM model, all options across different strikes are assumed to have the same and constant volatility. If this assumption is true, using the market option data we would find a flat BSM IV curve across different strikes. However, Rubinstein (1985) constructs the IV curve from US equity options and finds a "smile" shaped IV curve instead.

Now option pricing models have been developed, which can reproduce option's IV shape through stochastic factors (e.g., Heston, 1993, Bakshi, Cao, and Chen, 1997, Pan, 2002, etc.). Papanicolaou and Sircar (2014) find the Heston (1993) model IV calculated with SPX (S&P 500) options still shows a non-linear pattern. The IV from the BSM model is widely used by industry practitioners and academics as a way of quoting options in a comparable manner, although it is understood that the BSM is not the best model for accurately pricing options.

Bates (1991) finds that price of (OTM) Out-of-The-Money put options become unusually expensive during the year after the 1987-financial crisis. After 1987, the S&P 500 IV curve shape changed from the symmetric "smile" shape changed to a left skewed "smirk" shape, which is usually heavily negatively skewed to the left (e.g., Rubinstein, 1994; Jackwerth and Rubinstein, 1996; Aït-Sahalia and Lo, 1998; Carr and Wu, 2003 and Foresi and Wu, 2005). The left skewed IV implies that OTM put options are more expensive than the corresponding OTM call options. There are several potential drivers of the asymmetric shape of the IV curve. Hentschel (2003) attributes the smirk shape to the measurement errors in options which violate the non-arbitrage principle. Bollen and Whaley (2004) find that the net buying pressure (defined as the difference of buyer initiated order and seller initiated orders) has an impact on the IV curve. Han (2007) finds the IV smile pattern is driven by investor sentiment.

Consistent with the findings in the US market, the left skewed IV smirk pattern has also been documented in the international option markets (Pena, Rubio, and Serna, 1999, Foresi and Wu, 2005, Shiu, Pan, Lin, and Wu, 2010, Nordén and Xu, 2012 Tanha and Dempsey, 2016). The only exception is Gemmill (1996), who shows that the IV smirk of the FTSE 100 index options in the UK skewed to the right rather than left from 1 July, 1985 to 31 Dec, 1990, indicating that option traders in the UK expected market recovery in the future. We find similar bullish option traders leading up to and during the 2015 stock market crash in China.

There is a vast literature showing that IV curve's shape has significant predictive power for the future return of underlying asset (e.g., Dumas, Fleming, and Whaley, 1998, Dennis and Mayhew, 2002 and Dennis, Mayhew, and Stivers, 2006). Xing, Zhang, and Zhao (2010) use the measure in difference of IV between OTM options and ATM call options to define IV smirk, they find that the shape of the IV smirk has significant cross-section predictive power for the future equity returns. Later literature adopt the same measure in IV smirk from Xing, Zhang, and Zhao (2010) and they find the IV smirk is negatively correlated to the underlying stock (Yan, 2011).

The literature on the option and derivatives market in China is scare, Chang, Luo, Shi, and Zhang (2013) analyze whether the Chinese warrants market shares some of properties of options, and find there are huge bubbles in the put warrants market. Wang, Chen, Tao, and Zhang (2017) develop a state price dynamic factor model to forecast the IVS (implied volatility surface) with SSE 50 ETF options. Huang, Liu, Zhang, and Zhu (2018) construct the VIX (Volatility Index) in China and analyze the variance risk premium (VRP) in China. Yue, Zhang, and Tan (2018) examine the SSE 50 ETF options with a one-dimensional diffusion model and delta-hedged gain in China. Li, Yao, Chen, and Lee (2018) examine the momentum effect of the SSE 50 ETF options. Li, Gehricke, and Zhang (2019) document the IV smirk from FXI (iShares China Large-Cap) ETF options, which are US traded. The slope of IV curves of SSE 50 ETF/FXI ETF are very different, highly different in expectations of US and Chinese traders on similar underlings.

To the best of our knowledge, this paper is the first paper to provide a comprehensive analysis for the IV curve of SSE 50 ETF options the first equity option market in China. We find that the SSE 50 ETF options IV curve is usually a right-skewed smirk, different to other equity options markets. Further we show this average shape is predominantly drive by the pre/post-2015 financial crisis periods after which it changes to an almost symmetric smile slope.Lastly, we analyze if investor sentiment drive the shape the IV curves.

The rest of this paper is organized as follows. Section 2, introduces the SSE 50 ETF and options markets. In Section 3, reports the data used in this study. Then Section 4, describes the methodology. In section 5, we present the documentation of the IV curves. Section 6, presents the sentiment proxies we constructed and relationship to the IV curve shape though time. The last section concludes the paper.

2 Background of SSE 50 index ETF and options market

On 2 January 2004, the SSE introduced the SSE 50 index, which is a capitalization-weighted index consisting of the 50 largest and most liquid stocks listed on the SSE. The SSE 50 index reflects the performance of the most influential blue chip stocks, which constitute more than 25% of the total market capitalization of the Chinese capital market. Hua Xia fund management company launched its first ETF fund, the SSE 50 ETF, which tracks the SSE 50 index on 30 December, 2004. With the growth in popularity of passive ETF fund index investments (Gastineau, 2001, Poterba and Shoven, 2002), there are now 141 ETF funds with total capitalization CNY 232 billion in China (at the end of 2017). The SSE 50 ETF fund is the largest ETF fund in China with capitalization CNY 38 billion (at the end of 2017). The Table 1 below presents a summary of leading ETF funds in China. As can be seen the SSE 50 ETF is the largest, most liquid, oldest and only ETF with an option market.

< Insert Table 1 about here >

The SSE introduced the first exchanged traded option in China, the SSE 50 ETF options on 9 February, 2015. Each SSE 50 ETF option contract is written on 10,000 shares of SSE 50 ETF fund. The SSE 50 ETF option has four different maturity terms, namely the current month, the next month and the first two following months out of the March-June-September-December cycle. The SSE 50 ETF options mature on the fourth Wednesday of its maturity month. For each option chain, a range of strikes are available on each trading day. On the initial trading day there are four OTM, one ATM (At-The-Money) and four ITM (In-The-Money) call (put) options.[1]

The SSE sets a high entry barrier to SSE option markets, which include capital requirement (at least CNY 500,000, approximately USD 71,000) and qualification tests include three levels.[2] This means that SSE 50 ETF option traders are sophisticated/experienced traders. Figure 1 presents the daily trading volume, value and open interest of SSE 50 ETF options in comparison with the most active ETF option market, the SPY (SPDR S&P 500 ETF) options market.[3] From Figure 1, we can see the liquidity of SSE 50 ETF option market increased significantly since its inception at Feb 2015 and its daily trading volume

[1]Before 2 January 2018, on the initial trading day, there were only two OTM/ITM and one ATM strike available in the option chain.

[2]There are three levels of trading privileges in SSE options: level 1 investors can implement covered call and protective put only, level 2 include privileges in level 1 and investor could open long positions in call/put, level 3 include privileges in level 2 and investor could open naked short selling options.

[3]SPY options' trading value are not available in Option Metrics, we using the mid of bid-ask times total trading volume to approximate the SPY options' daily trading value. We convert SPY's trading value in USD to CNY with the average exchange rate in 2017: USD/CNY = 6.7518.

is close to 35% of SPY option at the end of 2017.

< Insert Figure 1 about here >

3 Data

Our sample period is from 9 Feb 2015 to 31 Dec 2017, and the SSE 50 ETF option data are sourced from the WIND financial terminal ,while the SPY ETF option data from Ivy DB option metrics database.[4]

We follow the option data cleaning method used by Bakshi, Cao, and Chen (1997) and Zhang and Xiang (2008) to process our option dataset as follows:

(1) Options with less than seven days to maturity are discarded, since very short term options may introduce liquidity biases.

(2) Options with unsolvable implied volatility are discarded.[5]

(3) Option contracts with price quotes lower than CNY 2 (as the minimum commission fee charged by SSE is CNY 2 per contract) are excluded to mitigate the impact of price discreteness.[6]

(4) Options violate the non-arbitrage principle:

$$\begin{aligned} c_{t,T} &\leq max(0, F_{t,T}e^{-r(T-t)} - Ke^{-r(T-t)}), \\ p_{t,T} &\leq max(0, Ke^{-r(T-t)} - F_{t,T}e^{-r(T-t)}), \end{aligned} \tag{1}$$

[4]When we construct the forward-looking Volatility Index and sentiment proxies we need longer data sample to calculate the index (Whaley, 1993), the sentiment proxies' sample period extend to the 31 Dec, 2018.

[5]We set the maximum limit of IV to 1,000% and minimum limit to 0%, if the IV is higher than 1,000% or less than 0%, they are discarded from our sample.

[6]The SSE 50 ETF option's minimum commission fee was CNY 2 per contract (10,000 shares) before 11 November 2016, SSE adjusted the minimum commission fee to CNY 1.3 after 11 November 2016.

where K is the strike price, $F_{t,T}$ is the implied forward price at current time t with maturity T and r is the risk free rate are also left out.

Figure 2 presents the performance of the SSE 50 ETF fund, its benchmark index and the mean IV level from ATM call options.

< Insert Figure 2 about here >

In Table 2, we report the trading activity of the SSE 50 ETF options by maturity groups. It shows that the majority of options have time to maturity less than 180 days, and options' trading activities, such as trading volume, number of strikes and open interest, decreases with maturity.

< Insert Table 2 about here >

4 Methodology

With the IV calculated from the market option price data using the Black (1976) model, we document the IV curve from SSE 50 ETF option. We inspect whether the asymmetric IV pattern, known as the IV smirk (Pena, Rubio, and Serna, 1999, Foresi and Wu, 2005 and Shiu, Pan, Lin, and Wu, 2010) exist in the SSE 50 ETF option market. We first apply the methodology developed by Zhang and Xiang (2008) to quantify the IV curve, across all maturities in our sample. We further follow Li, Gehricke, and Zhang (2019)'s methodology to calculate the constant maturity quantified IV factors and investigate their time series.

4.1 The calculation of BSM implied volatility

The WIND financial dataset provides IV based on BSM model and use the closing price of SSE 50 ETF options. However, WIND assumes a zero dividend yield in their IV calculation, while in fact the SSE 50 ETF will pay discrete cash dividends.[7] Therefore, we use implied forward price from put-call parity, which contains the implied continuous dividend yield for IV calculation. We calculate the IV of SSE 50 ETF option by inverting market option price back to the Black (1976) formula with this implied forward price.

The ATM strike price K is selected with the smallest difference between the call and put option prices (with same strike and maturity). Based on the put-call parity, we can calculate the implied forward price from:

$$F_{t,T} = K_{t,T}^{ATM} + e^{r(T-t)} \times (c_{t,T}^{ATM} - p_{t,T}^{ATM}), \tag{2}$$

where $c_{t,T}^{ATM}$ and $p_{t,T}^{ATM}$ are ATM option prices. With the calculation of implied forward price we can get more precise IV than WIND database.

4.2 Quantifying the implied volatility

Zhang and Xiang (2008) developed an approach to quantifying the IV curve by fitting the second order polynomial function. They further showed that the coefficients of the polynomial are proportional to risk-neutral moments of the underlying asset's return.

Following Carr and Wu (2003), Zhang and Xiang (2008) and industry practice, we define moneyness as the logarithm of the strike price over the implied forward price, normalized by the volatility as follows:

$$\xi = \frac{\ln(K/F_{t,T})}{\bar{\sigma}\sqrt{T-t}}, \tag{3}$$

where ξ is the moneyness of the option, t is the current time, T is the maturity date, K is the strike price and $F_{t,T}$ is the implied forward price. We use the linearly interpolated IV of two ATM call options with maturities closest to 30 days as the measure of 30-day constant volatility $\bar{\sigma}$.

[7]We checked WIND's support documents and help desk, they confirmed that WIND use zero dividend yield and closing price for option's IV calculation.

With the definition of moneyness in Eq (3), we quantify the IV curve by fitting the second order polynomial function given by:

$$IV(\xi, t, T) = \alpha_0 + \alpha_1 \xi + \alpha_2 \xi^2. \tag{4}$$

We then convert the coefficients α_0, α_1 and α_2 to the dimensionless quantified IV factors through the following transformations:

$$\gamma_0 = \alpha_0, \quad \gamma_1 = \frac{\alpha_1}{\alpha_0}, \quad \gamma_2 = \frac{\alpha_2}{\alpha_0}.$$

Resulting in the following quantified IV function:

$$IV(\xi, t, T) = \gamma_0(1 + \gamma_1 \xi + \gamma_2 \xi^2). \tag{5}$$

The first factor γ_0 is the level, which is an estimate of the exact ATM IV. [8] The parameter γ_1 captures the slope of quantified IV curve and γ_2 captures its curvature. The polynomial in Eq (4) is estimated by minimizing the volume-weighted mean squared error:

$$VWMSE = \frac{\sum_{\xi_i} Volume(\xi_i) \times [IV_{market}(\xi_i) - IV(\xi_i)]^2}{\sum_{\xi_i} Volume(\xi_i)}, \tag{6}$$

where $Volume(\xi_i)$ is the trading volume, $IV_{market}(\xi_i)$ is the IV calculated from market price and $IV(\xi_i)$ is the model IV. We estimate the IV function with OTM options only.

The level, slope and curvature are approximately related to the risk-neutral volatility (σ), skewness (λ_1) and kurtosis (λ_2), respectively:

$$\gamma_0 \approx \left(1 - \frac{\lambda_2}{24}\right)\sigma, \quad \gamma_1 \approx \frac{1}{6}\lambda_1, \quad \gamma_2 \approx \frac{1}{24}\lambda_2, \tag{7}$$

as shown by Zhang and Xiang (2008).

[8] The ATM we discussed earlier is where the moneyness level ξ is approximately zero and the exact ATM here is where the moneyness level ξ is zero.

5 Empirical Results

5.1 The quantified IV curves

In this section we report and analyze the average shape of the quantified IV curves of the SSE 50 ETF options market. In Table 3, we report the summary of the implied forward price, fitted IV curve level (γ_0), slope (γ_1) and curvature (γ_2) factors, fitted statistics and mean trading volume by maturity grouping.

< Insert Table 3 about here >

From Table 3, we can see that the mean SSE 50 forward price in the full sample is 2.4193. The mean forward price decreases as maturity increases, from 2.4334 to 2.3849, for maturity less than 30 days and more than 180 days, respectively. The term structure of implied forward price is therefore downward sloping. The standard deviation of implied forward price is 0.3243 and it is increasing from 0.3104 to 0.3551.

The level factor ($\hat{\gamma}_0 = \hat{\alpha}_0$), which estimates the exact ATM IV, is 0.2413 on average. The average level factor monotonically increases from 0.2365 to 0.2493. Therefore the term structure of the level factor is upward sloping on average. The term structure of mean IV reveals that the SSE 50 option traders' long term forecast of SSE 50 volatility are higher than short and middle terms over sample. The level factor is significant for all of the fitted IV curves, except for only a few options with maturity greater than 180 days.

For the slope factor (γ_1), we can see that, on average, the IV curves are upward sloping for all maturity groups. The right skewed IV curve indicates that the OTM call options are more expensive than corresponding OTM put options. As maturity increases, the slope becomes steeper from 0.0158 to 0.0602. The slope coefficients are significant, at the 5% level, for 73% of IV curves. The proportion of significant slope coefficients is lowest in the shortest maturity group (58.80%), which may be due to the inclusion of the 2015 stock market crash in the sample..

For the curvature factor (γ_2), on average, it is positive across all maturity groups, which means that the SSE 50 ETF option's IV curves are convex on average. The overall average curvature factor is 0.0386. The curvature coefficients are significant for 73.98% of the IV curves, and the proportion of significant coefficients decreases with the increase of time to maturity.

It is also clear that the proportions of significant factors and R squared decrease with maturity, indicating that the option traders' views on long term options in SSE 50 maybe less consistent. This may be due to a vast drop of in liquidity as maturity increases, as revealed by the decrease in trading volume along maturities.

We have randomly selected three trading days to inspect the SSE 50 option's IV curve: 8 May 2015, 17 February 2016 and 2 May 2017, and present them in Figures 3, 4 and 5 respectively.

< Insert Figure 3 about here >

< Insert Figure 4 about here >

< Insert Figure 5 about here >

From these figures, we can see that the IV curves are usually upward sloping (except for some long maturity option groups) and slightly convex.[9] Consistent with the positive slope

[9]SSE will add new strikes to the option chain along with the movements of the underlying index to maintain at least four OTM/ITM options and one new ATM options, the option strikes are not symmetrically distributed.

factor identified above, the IV curves skewed to the right side. The right skewed SSE 50 ETF option IV curves indicate that with the same distance from the ATM level, OTM call options are more expensive than OTM put options. This pattern suggests that the SSE 50 ETF option traders are willing to pay more on call options because they are betting on the upward movement of the underling asset. This pattern is significantly different from other option traders worldwide, who are willing to pay more for put option as insurance (Bates, 1991, Rubinstein, 1994 and Foresi and Wu, 2005, etc.). To the best of our knowledge, only Gemmill (1996) finds similar right skewed IV curves in the FTSE 100 option market in UK from 1 July, 1985 to 31, December, 1990.

< *Insert Figure 6 about here* >

In Figure 6, we plot the mean IV curves across maturity groups. We can see that, the IV curves are skewed to the right side and with increase in maturity term, IV curves become more convex and steeper.

5.2 The interpolated constant maturity quantified IV curves

We have been examining the term structure of SSE 50 ETF option's IV curves across different maturity groups. For each trading day there are four IV curves with different maturity, these four maturity terms are not constant through time. To analyze the IV curves more accurately, we create constant 30 and 120 day factors through linear interpolation. The constant maturity factors will enable us to study the term structure, time series and evolution of the term structure of the factors for the same horizon of option traders' expectations.

In 2015, due to the deregulation in margin trading, investors have access to margin trading and high level products in the SSE and SZE (Shenzhen Stock Exchange), the SSE index increased from 3,258 to 5,178 points in less than six months. Due to liquidation of high leveraged margin position (leverage-induced fire sales), the market crashes and the SSE index plunged from 5,178 to 2,850 points in 52 trading days. Bian, He, Shue, and Zhou (2018) find that the leverage-induced fire sales lead to abnormal price declines and subsequent reversal in stock with greater margin level. Han and Pan (2017) test the relation between futures-cash basis and liquidity during the 2015 financial crisis in China. To compare option traders' expectation of market movements in different sample periods, following Han and Pan (2017), we split our sample into three sub-samples: pre-crisis, during crisis and post-crisis. Table 4 reports the summary statistics for the constant maturity factors of the full sample and three sub-samples. The overall findings in interpolated maturity terms are consisted with the finding in table 3: the IV of longer maturity term is higher than short maturity term and the slopes are positive.

< *Insert Table 4 about here* >

During the financial crisis period, the IV level almost doubled compared with full sample. The slope coefficients are still positive pre/during/post the financial crisis, indicating that option traders are willing to pay more on OTM call options compared with OTM put options during the sub sample of 2015 financial crisis. The slope factor is the highest in the 30 day maturity sub sample during the 2015 financial crisis, which reflects the option traders' greedy for short term recovery. We plot the mean IV curves in full sample and sub sample around the 2015 financial crisis using the constant maturity factors in Figure 7.

< *Insert Figure 7 about here* >

We would like to study the time series of the IV curve factors from the interpolated constant maturity term. We plot the time series of 30 and 120 days constant maturity IV curve in Figure 8. We can see that the ATM IV varies in a mean reverting manner, the difference between 30 and 120 days maturity in level varies in small magnitude around zero. During the period of financial crisis there are spikes in short term 30 day maturity IVs, which cause huge difference between 30 and 120 day maturity term. Referring to the violent index level during financial crisis, the option traders were willing to pay more for short term options.

$<$ *Insert Figure 8 about here* $>$

The slope factor, presented in Figure 8 c, also exhibits mean reversion. Both short term and long term option traders have negative slope during the 2015 financial crisis, however, there is a huge difference between short/long term investors. This difference indicates the short term option traders willing to pay more on insurance than long term investors.We have the similar finding in the curvature as well, though the mean reverting in curvature is very small compared with IV level and slope.

6 Determinants of IV smirk

The dynamics of the SSE 50 ETF option IV curves described above may be related to investor sentiments, as options provide a great vehicle for leveraged investment. We consider the following sentiment proxies from the literature. Firstly, Amihud (2002) find that the market turn over (The trading volume of underlying asset to total listed number of shares) and the ratio of absolute market return to turnover are good predictors of futures returns through a sentiment mechanism. Baker and Stein (2004) find higher turnover and increased liquidity predict lower future subsequent return, and this is the linked to investors' sentiment. Therefore we include the turnover ratio in to our analysis as a proxy for investor sentiment.

Whaley (2000) find that the CBOE VIX (Volatility Index), which is called the "investor fear gauge" fits the name as a sentiment indicator: high levels of VIX are accompanied with high market turmoil. However, VIX constructed by options listed in China is not publically available, therefore, we construct a simple VIX (CNVXO) in China by following the methodology from Whaley (1993), this is the methodology of first version of CBOE VIX , which has been renamed to VXO after 2003.[10]

Billingsley and Chance (1988), Pan and Poteshman (2006), Yang and Wu (2011) and Houlihan and Creamer (2018) find that PCR (Put-to-Call ratio) is good market sentiment proxy and can be used to forecast the direction of the market.[11] Deuskar, Gupta, and Subrahmanyam (2008) inspect the two sentiment indicators VIX and PCR, they find PCR is a better explanatory variable for investors sentiment. A higher PCR ratio indicates investors purchased more put option as insurance of expected market turmoil, which made the option become relatively expensive. Cremers and Weinbaum (2010) finds the deviation of put to call with strong liquidity indicates future abnormal negative returns.

Lamont and Stein (2004), Yang and Wu (2011) and Stambaugh, Yu, and Yuan (2012) find short selling and margin trade's volume/open interest are contrarian indicators, they reflect the investors sentiment in market. A higher the sentiment level contribute to stronger anomalies profit.[12]

[10] The SSE published China Volatility Index (iVIX Code: 000188) from SSE 50 ETF options on 5 Dec, 2016, however, they cancelled the iVIX since 22 Feb, 2018

[11] Three version of PCR ratios are calculated from daily total trading volume/value/open interest of put option to call option.

[12] We provide details of the calculation of sentiment proxies in China in appendix.

6.1 Stationary test of sentiment proxies

Before our analysis of the relationship between investors sentiment and IV factors, we plot the sentiment proxies in Figure 9 to inspect the existence of trends in the time series. Table 5 shows stationary test of all the sentiment proxies. We convert non-stationary proxies through the difference in log, we find that CNVXO, PCROI are not stationary, but their first difference log are stationary. Therefore, we use all stationary sentiment proxies in the following regression analysis.

< *Insert Figure 9 about here* >

< *Insert Table 5 about here* >

Some of the sentiment proxies might be correlated to each other, to investigate multicollinerity, we build the correlation matrix of all the sentiment proxies. From Table 6 we can find the PCR Volume and PCR Value ratios are highly correlated to each other, when we estimate the multivariate regression we use only one or the other. The Short and Margin Ratios are also highly correlated, therefore we exclude the margin ratio in the multivariate regressions and include only the short ratio in order to avoid multicollinerity in regression.

< *Insert Table 6 about here* >

6.2 Regressions

We first estimate the univarate regressions to analyze the determinants of the IV curve in China given by :

$$Y_i = \beta_0 + \beta_1 * X_j + \epsilon_i, \tag{8}$$

where X_j is one of the independent variables *LNCNVXO, PCRVOL, PCRVAL, LNPCROI, TurnOver, LagRet, ShortRatio* or *MarginRatio.*

We then combine all of the variables, except the highly correlated ones to examine their joint effect.

$$Y_i = \beta_0 + \sum_{j=1}^{n} \beta_j * X_j + \epsilon_i, \tag{9}$$

where the highly correlated independent variable are separated in two regression.

6.3 Results

We report the regression of investor sentiment with IV shape's level, slope and curvature:

< Insert Table 7 about here >

< Insert Table 8 about here >

From Tables 7 and 8 we can see that PCRVAL, TurnOver and ShortRatio significantly contribute to the higher IV level (exact ATM IV) in both 30 day and 120 day maturities. This is consistent with negative relationship between TurnOver/IV/PCR/ShortRatio and asset returns (Dechow, Hutton, Meulbroek, and Sloan, 2001, Amihud, 2002, Giot, 2005, Cremers and Weinbaum, 2010, etc).

< *Insert Table 9 about here* >

< *Insert Table 10 about here* >

Tables 9 and 10 show that PCRVAL and LNPCROI contribute to the decreasing slope in the IV smirk, which means investors purchase more put option as insurance during turmoil consistent with other option markets (Foresi and Wu, 2005). Turnover is positively related to the IV slope shown that as sentiment improves investors will pay more for bullish (OTM calls) positions. The table also shows that more short selling levels to a more positive IV slope, which is contrary to expectation (Lamont and Stein, 2004 and Stambaugh, Yu, and Yuan, 2012). However, the options market in China is restricted and so the sentiment of ETF traders many be different to option traders.

< *Insert Table 11 about here* >

< *Insert Table 12 about here* >

Tables 11 and 12 present the regression results on IV's curvature. We find that only the higher LNPCROI contribute to future lower IV curvature in 30-day maturity group, while only Lagged SSE 50 returns contributed higher IV curvature in the 120 day group.

7 Conclusion

In this paper we documented the implied volatility of the newly established SSE 50 ETF option market in China and quantified its IV curves by following the methodology developed by Zhang and Xiang (2008). We examine the time series and term structure of the quantified IV curve factor dynamics by maturity groups and by calculating constant maturity factors. Lastly, we examine investor sentiment as a determinant of the IV curve shape.

We find that, on average the IV curve for SSE 50 ETF options market reflects a smirk shape which is skewed to the right. This is different to the common finding of the left skewed IV curve in the US (Rubinstein, 1985; Bates, 1991) in major international option markets (Foresi and Wu, 2005) and for US traded China options (Li, Gehricke, and Zhang, 2019). However, a similar right skewed IV curve slope was found in the FTSE 100 options market during the 87 financial crisis in the UK by Gemmill (1996), which indicates that option traders have strong expectation of market recovery in the future.

Overall, the level (exact ATM IV) factor decreases with maturity and become less volatile with longer maturities, which shows that the option traders expect the SSE 50's volatility to be mean-reverting. The IV curves are on average upward sloping and become steeper as maturity increases. The IV curves have positive curvature on average and the IV curve become more convex as maturity increases.

We further analyze the quantified IV curve factors by splitting the sample into: before, during and after the 2015 financial crisis period (15 June 2015 to 31 August 2015). We find that the level (exact ATM IV) almost doubled from before the financial crisis to during the financial crisis. We observe the right skewed IV smirk before the crisis, which becomes even more skewed to the right during the crisis, indicating investors have strong confidence in the recovery of the SSE 50 index. However, after the crisis the IV curve become less skewed and forms a symmetric smile pattern. This story is very different to the IV curve of the US equity option markets, which has an even more left skewed IV smirk during the GFC in 2008 (Guo, Gehricke, and Zhang, 2018).

We further analyze the impact on IV factors of several investor sentiment proxies. We find that the turn-over, the PCR ratio and the short sell ratio of underlying asset is related to the slope of IV in China.

Our quantified SSE 50 ETF option IV curve could be used in developing and/or calibrating SSE 50 ETF option pricing models. Such a model must exhibit positive skewness and some kurtosis, on average. We could also use our quantified IV factors to predict future returns and realized volatility of the SSE 50 ETF, which we leave for future research.

A Appendices

A.1 Calculation of market sentiment proxies

The calculation of the market sentiment proxies are provided as follows:

China Volatility Index (CNVXO):

Our first proxy for sentiment is the volatility index, currently no official volatility index is available to investors in China. We construct the volatility index by following Whaley (1993), which also being adopted by CBOE (Chicago Board Options Exchange) as its first version of VIX (Volatility Index) in 1993.[13] The first version of VIX, which is based on the average Black (1976) model implied volatility of eight near-term and next term near the money SSE 50 ETF options. It is a model based approach, which can be constructed from

[13]CBOE changed its first version of VIX to VXO after new model-free VIX with SPX options lunched in 2003.

available options in limited strike range.[14] The near-term SSE 50 ETF options are selected with time to maturity at least seven calendar days.[15]

The eight options include four call options and four put options, four put (call) options are selected with near-term (the first maturity date with more than seven days). At time T_i options with strike K_H, which is higher than the spot price S_t, and with strike price K_L lower than the spot price. Then we use implied volatility from these eight options to calculate the following four average implied volatility in near/next term:

$$\begin{aligned}
\sigma_{T_1}^{K_L} &= (\sigma_{c,T_1}^{K_L} + \sigma_{p,T_1}^{K_L})/2,\\
\sigma_{T_1}^{K_H} &= (\sigma_{c,T_1}^{K_H} + \sigma_{p,T_1}^{K_H})/2,\\
\sigma_{T_2}^{K_L} &= (\sigma_{c,T_2}^{K_L} + \sigma_{p,T_2}^{K_L})/2,\\
\sigma_{T_2}^{K_H} &= (\sigma_{c,T_2}^{K_H} + \sigma_{p,T_2}^{K_H})/2,
\end{aligned} \tag{10}$$

where T_1 (T_2) indicate near-term (next term), subscript c (p) indicate implied volatility from call (put) option.

We use the four average implied volatility above (below) spot price to calculate the average implied in two terms:

$$\begin{aligned}
\sigma_{T_1} &= \sigma_{T_1}^{K_L}\frac{K_H - S}{K_H - K_L} + \sigma_{T_1}^{K_H}\frac{S - K_L}{K_H - K_L},\\
\sigma_{T_2} &= \sigma_{T_2}^{K_L}\frac{K_H - S}{K_H - K_L} + \sigma_{T_2}^{K_H}\frac{S - K_L}{K_H - K_L}.
\end{aligned} \tag{11}$$

Then we interpolate between the near term and next term implied volatility to create a 30 day (22 trading day) implied volatility index:

$$CNVXO = 100 \times \left[\sigma_{T_1}\left(\frac{N_{T_2} - 22}{N_{T_2} - N_{T_1}}\right) + \sigma_{T_2}\left(\frac{22 - N_{T_1}}{N_{T_2} - N_{T_1}}\right)\right]. \tag{12}$$

[14]The CBOE published new model free VIX in 2003, which using OTM option portfolio to replicate the variance. However, the SSE 50 ETF option only has limited number of OTM options available (mean/median number strikes on each day-maturity group: 13/11), direct implementation of CBOE VIX 2003 in SSE 50 ETF is inaccurate.

[15]Options with maturity less than seven days are discarded for our calculation

Put to Call ratio (PCR):

The PCR indicators are calculated from total trading volume/volume and open interest from put/call options:

$$PCRVOL = \frac{Total\ trading\ volume\ of\ put\ option}{Total\ trading\ volume\ of\ call\ option}, \tag{13}$$

$$PCRVAL = \frac{Total\ trading\ value\ of\ put\ option}{Total\ trading\ value\ of\ call\ option}, \tag{14}$$

$$PCROI = \frac{Total\ open\ interest\ of\ put\ option}{Total\ open\ interest\ of\ call\ option}. \tag{15}$$

Turnover ratio:

The turnover ratio of the underlying asset is calculated from:

$$Turnover = \frac{Daily\ trading\ volume}{Listed\ number\ of\ shares}. \tag{16}$$

Short-selling ratio:

The short selling ratio is calculated from:

$$ShortRatio = \frac{Daily\ short\ selling\ volume}{Daily\ trading\ volume}. \tag{17}$$

Margin trading ratio:

The margin trading ratio is calculated from:

$$MarginRatio = \frac{Daily\ margin\ trading\ value}{Daily\ trading\ value}. \tag{18}$$

References

Aït-Sahalia, Yacine, and Andrew W Lo, 1998, Nonparametric estimation of state-price densities implicit in financial asset prices, *Journal of Finance* 53, 499–547.

Amihud, Yakov, 2002, Illiquidity and stock returns: cross-section and time-series effects, *Journal of Financial Markets* 5, 31–56.

Baker, Malcolm, and Jeremy C Stein, 2004, Market liquidity as a sentiment indicator, *Journal of Financial Markets* 7, 271–299.

Bakshi, Gurdip, Charles Cao, and Zhiwu Chen, 1997, Empirical performance of alternative option pricing models, *Journal of Finance* 52, 2003–2049.

Bates, David S, 1991, The crash of 87: Was it expected? the evidence from options markets, *Journal of Finance* 46, 1009–1044.

Bian, Jiangze, Zhiguo He, Kelly Shue, and Hao Zhou, 2018, Leverage-induced fire sales and stock market crashes, Technical report, National Bureau of Economic Research.

Billingsley, Randall S, and Don M Chance, 1988, Put-call ratios and market timing effectiveness, *Journal of Portfolio Management* 15, 25.

Black, Fischer, 1976, The pricing of commodity contracts, *Journal of Financial Economics* 3, 167–179.

Black, Fischer, and Myron Scholes, 1973, The pricing of options and corporate liabilities, *Journal of Political Economy* 81, 637–654.

Bollen, Nicolas PB, and Robert E Whaley, 2004, Does net buying pressure affect the shape of implied volatility functions?, *Journal of Finance* 59, 711–753.

Carr, Peter, and Liuren Wu, 2003, The finite moment log stable process and option pricing, *Journal of Finance* 58, 753–777.

Chang, Eric C, Xingguo Luo, Lei Shi, and Jin E Zhang, 2013, Is warrant really a derivative? evidence from the chinese warrant market, *Journal of Financial Markets* 16, 165–193.

Cremers, Martijn, and David Weinbaum, 2010, Deviations from put-call parity and stock return predictability, *Journal of Financial and Quantitative Analysis* 45, 335–367.

Dechow, Patricia M, Amy P Hutton, Lisa Meulbroek, and Richard G Sloan, 2001, Short-sellers, fundamental analysis, and stock returns, *Journal of Financial Economics* 61, 77–106.

Dennis, Patrick, and Stewart Mayhew, 2002, Risk-neutral skewness: Evidence from stock options, *Journal of Financial and Quantitative Analysis* 37, 471–493.

Dennis, Patrick, Stewart Mayhew, and Chris Stivers, 2006, Stock returns, implied volatility innovations, and the asymmetric volatility phenomenon, *Journal of Financial and Quantitative Analysis* 41, 381–406.

Deuskar, Prachi, Anurag Gupta, and Marti G Subrahmanyam, 2008, The economic determinants of interest rate option smiles, *Journal of Banking and Finance* 32, 714–728.

Dumas, Bernard, Jeff Fleming, and Robert E Whaley, 1998, Implied volatility functions: Empirical tests, *Journal of Finance* 53, 2059–2106.

Foresi, Silverio, and Liuren Wu, 2005, Crash-o-phobia: a domestic fear or a worldwide concern?, *Journal of Derivatives* 13, 8.

Gastineau, Gary L, 2001, Exchange-traded funds: An introduction, *Journal of Portfolio Management* 27, 88–96.

Gemmill, Gordon, 1996, Did option traders anticipate the crash? evidence from volatility smiles in the UK with US comparisons, *Journal of Futures Markets* 16, 881–897.

Giot, Pierre, 2005, Relationships between implied volatility indices and stock index returns, *Journal of Portfolio Management* 31, 92–100.

Guo, Wei, Sebastian Gehricke, and Jin E Zhang, 2018, Do Brothers 'Smirk' Differently? Evidence from SPX and SPY options, University of Otago, Working paper.

Han, Bing, 2007, Investor sentiment and option prices, *Review of Financial Studies* 21, 387–414.

Han, Jianlei, and Zheyao Pan, 2017, On the relation between liquidity and the futures-cash basis: Evidence from a natural experiment, *Journal of Financial Markets* 36, 115–131.

Hentschel, Ludger, 2003, Errors in implied volatility estimation, *Journal of Financial and Quantitative Analysis* 38, 779–810.

Heston, Steven L, 1993, A closed-form solution for options with stochastic volatility with applications to bond and currency options, *Review of Financial Studies* 6, 327–343.

Houlihan, Patrick, and Germán G Creamer, 2018, Leveraging a call-put ratio as a trading signal, *Quantitative Finance* 1–15.

Huang, Xinming, Jie Liu, Xinjie Zhang, and Yinglun Zhu, 2018, Volatility premium and term structure of china blue-chip index options, *Emerging Markets Finance and Trade* .

Jackwerth, Jens Carsten, and Mark Rubinstein, 1996, Recovering probability distributions from option prices, *Journal of Finance* 51, 1611–1631.

Lamont, Owen A, and Jeremy C Stein, 2004, Aggregate short interest and market valuations, *American Economic Review* 94, 29–32.

Li, Jianhui, Sebastian Gehricke, and Jin E Zhang, 2019, How do US option trades "Smirk" on China: Evidence from FXI options, *Journal of Futures Markets* , *forthcoming.*

Li, Jianping, Yanzhen Yao, Yibing Chen, and ChengFew Lee, 2018, Option prices and stock market momentum: evidence from china, *Quantitative Finance* 1–13.

Merton, Robert C, 1973, Theory of rational option pricing, *Bell Journal of Economics and Management Science* 141–183.

Nordén, Lars, and Caihong Xu, 2012, Option happiness and liquidity: Is the dynamics of the volatility smirk affected by relative option liquidity?, *Journal of Futures Markets* 32, 47–74.

Pan, Jun, 2002, The jump-risk premia implicit in options: Evidence from an integrated time-series study, *Journal of Financial Economics* 63, 3–50.

Pan, Jun, and Allen M Poteshman, 2006, The information in option volume for future stock prices, *Review of Financial Studies* 19, 871–908.

Papanicolaou, Andrew, and Ronnie Sircar, 2014, A regime-switching heston model for VIX and S&P 500 implied volatilities, *Quantitative Finance* 14, 1811–1827.

Pena, Ignacio, Gonzalo Rubio, and Gregorio Serna, 1999, Why do we smile? on the determinants of the implied volatility function, *Journal of Banking and Finance* 23, 1151–1179.

Poterba, James M, and John B Shoven, 2002, Exchange-traded funds: A new investment option for taxable investors, *American Economic Review* 92, 422–427.

Rubinstein, Mark, 1985, Nonparametric tests of alternative option pricing models using all reported trades and quotes on the 30 most active cboe option classes from august 23, 1976 through august 31, 1978, *Journal of Finance* 40, 455–480.

Rubinstein, Mark, 1994, Implied binomial trees, *Journal of Finance* 49, 771–818.

Shiu, Yung-Ming, Ging-Ginq Pan, Shu-Hui Lin, and Tu-Cheng Wu, 2010, Impact of net buying pressure on changes in implied volatility: Before and after the onset of the subprime crisis, *Journal of Derivatives* 17, 54.

Stambaugh, Robert F, Jianfeng Yu, and Yu Yuan, 2012, The short of it: Investor sentiment and anomalies, *Journal of Financial Economics* 104, 288–302.

Tanha, Hassan, and Michael Dempsey, 2016, The impact of macroeconomic information releases on the smile shape: Evidence from the australian options market, *Review of Behavioral Finance* 8, 80–90.

Wang, Jinzhong, Shijiang Chen, Qizhi Tao, and Ting Zhang, 2017, Modelling the implied volatility surface based on shanghai 50 ETF options, *Economic Modelling* 64, 295–301.

Whaley, Robert E, 1993, Derivatives on market volatility: Hedging tools long overdue, *Journal of Derivatives* 1, 71–84.

Whaley, Robert E, 2000, The investor fear gauge, *Journal of Portfolio Management* 26, 12.

Xing, Yuhang, Xiaoyan Zhang, and Rui Zhao, 2010, What does the individual option volatility smirk tell us about future equity returns?, *Journal of Financial and Quantitative Analysis* 45, 641–662.

Yan, Shu, 2011, Jump risk, stock returns, and slope of implied volatility smile, *Journal of Financial Economics* 99, 216–233.

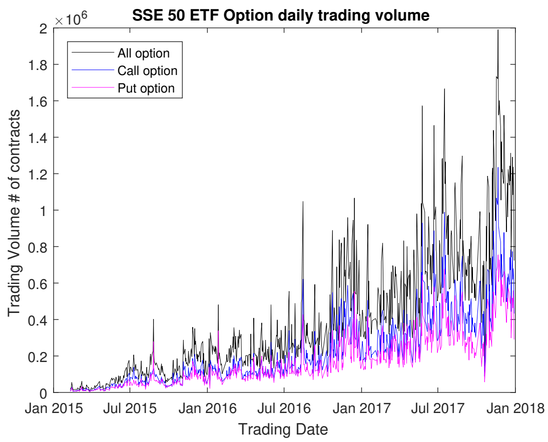
Yang, Ann Shawing, and Ming-Lung Wu, 2011, Exploring the relationship between investor sentiment and price volatility, *Quantitative Finance* 11, 955–965.

Yue, Tian, Jin E Zhang, and Eric Tan, 2018, Chinese equity index option market University of Otago, Working paper.

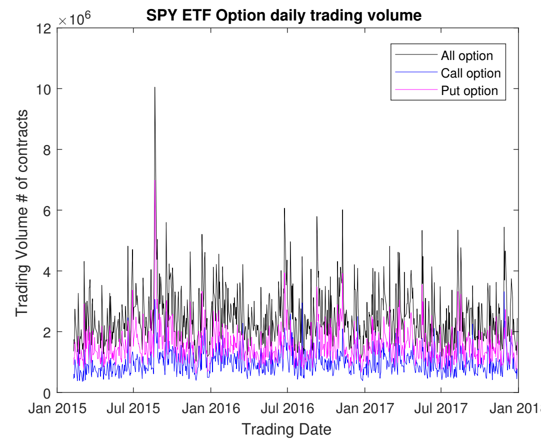
Zhang, Jin E, and Yi Xiang, 2008, The implied volatility smirk, *Quantitative Finance* 8, 263–284.

Figure 1: SSE 50/SPY ETF Option trading volume, value and open interest

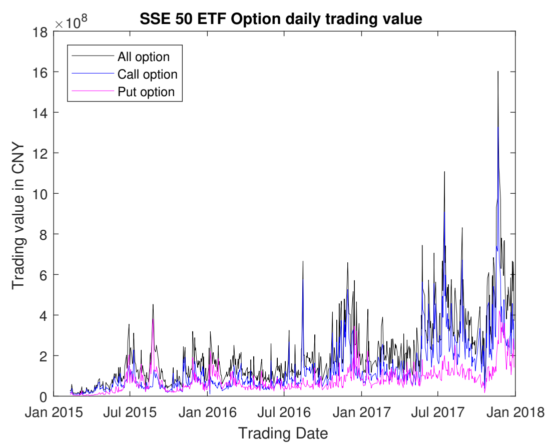
This figure reports the total daily trading volume, trading value and open interest in SSE 50/SPY ETF option. The trading value of SPY option is converted to CNY by the mean USD/CNY exchange rate (¥6.7821) in 2017.



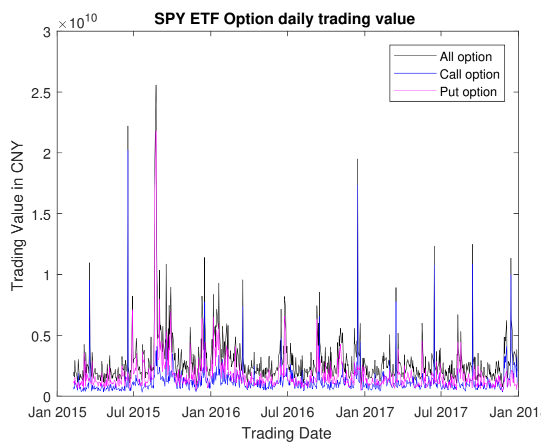
(a) Daily trading volume



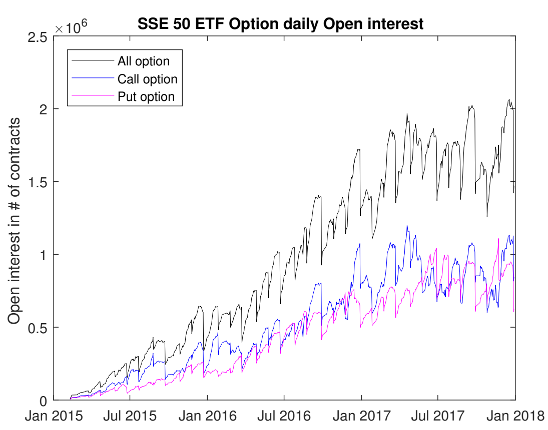
(b) Daily trading volume



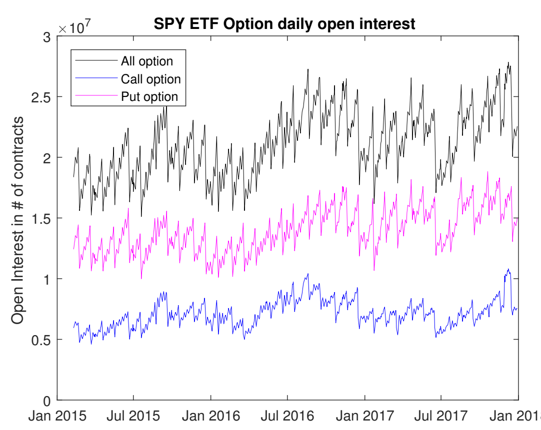
(c) Daily trading value



(d) Daily trading value



(e) Daily open interest



(f) Daily open interest

Figure 2: The SSE 50 index and SSE 50 ETF index tracking in our data sample

This figure reports the performance of SSE 50 index and SSE 50 ETF's index tracking during our sample (9 February, 2015 to 31 December, 2017). We also annotate the sub sample: the 2015 financial crisis from 15 June 2015 to 31 August according to the time window defined by (Han and Pan, 2017).

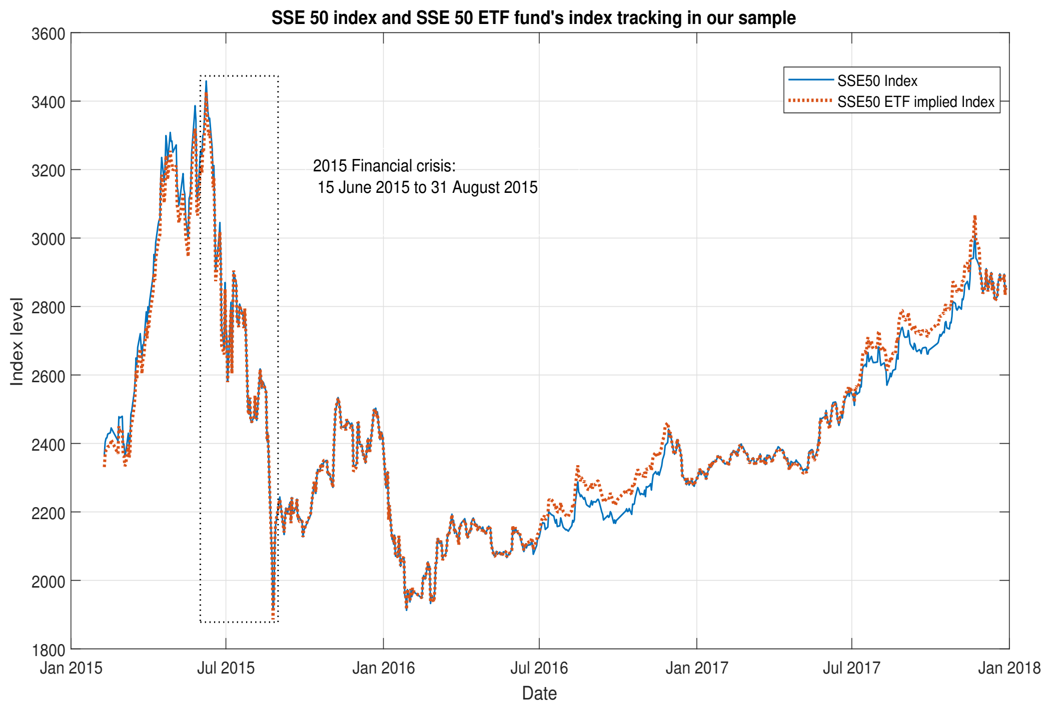
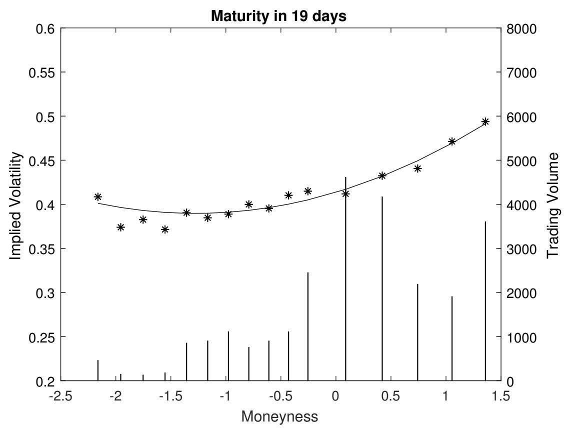
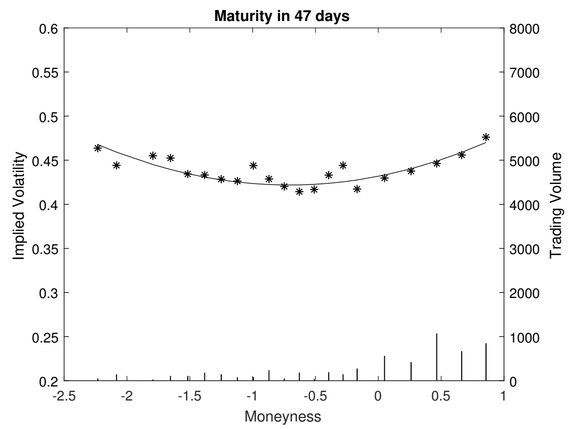


Figure 3: Fitted IV curves on 8 May 2015

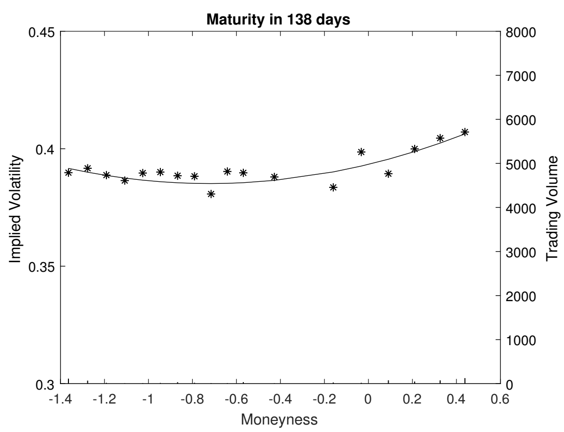
This figure illustrates the fitted IV curves for four different maturity terms (May, June, September and December) on 8 May 2015. The stars in each sub-figure are the market implied volatility, bars are their trading volume and the solid lines are fitted IV curves.



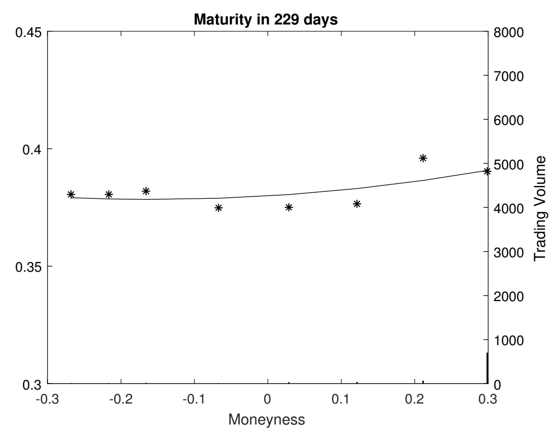
(a) Maturity in 19 days



(b) Maturity in 47 days



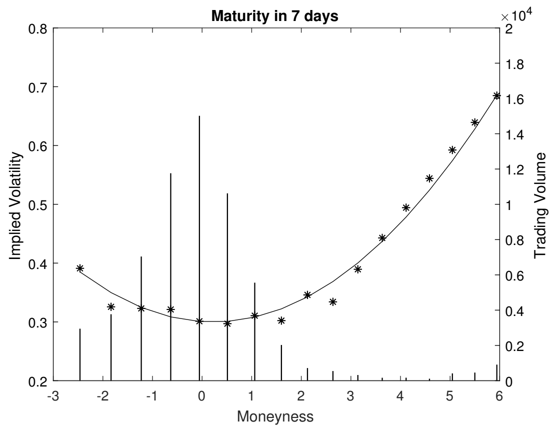
(c) Maturity in 138 days



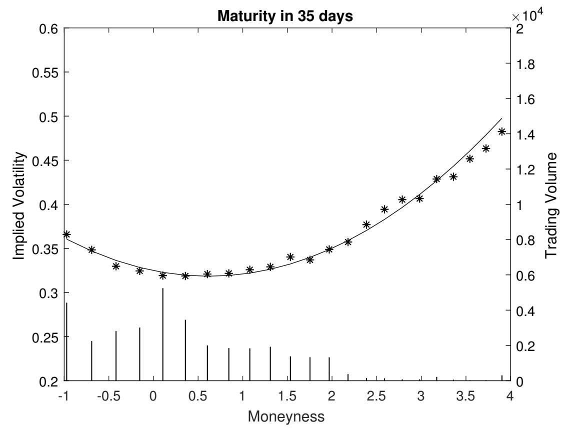
(d) Maturity in 229 days

Figure 4: Fitted IV curves on 17 Feb 2016

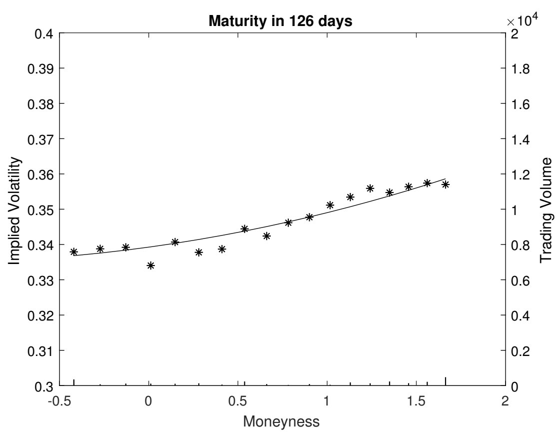
This figure illustrates the fitted IV curves for four different maturity terms (February, March, June and September) on 17 Feb 2016. The stars in each sub-figure are the market implied volatility, the bars are their trading volume and the solid lines are fitted IV curves.



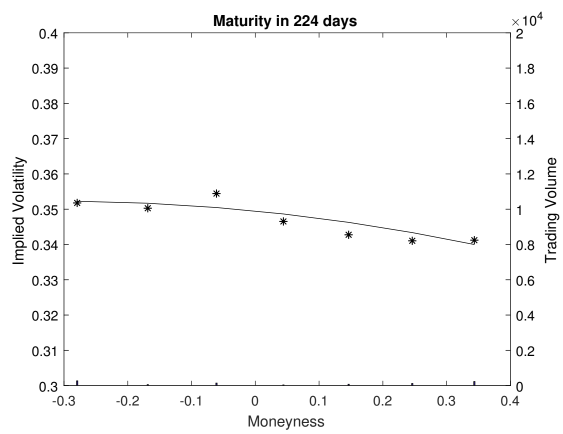
(a) Maturity in 7 days



(b) Maturity in 35 days



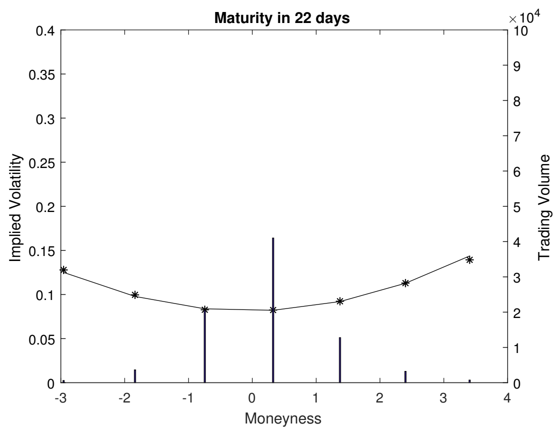
(c) Maturity in 126 days



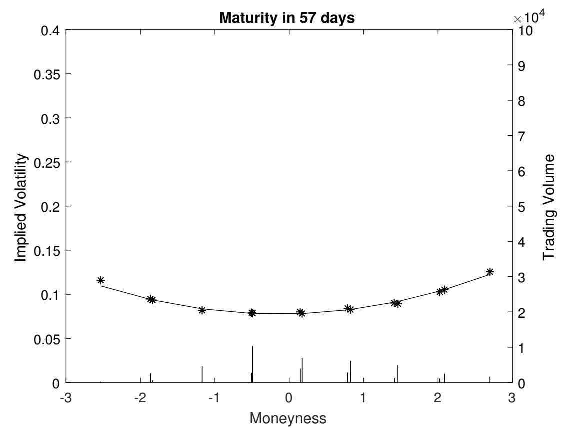
(d) Maturity in 224 days

Figure 5: Fitted IV curves on 2 May 2017

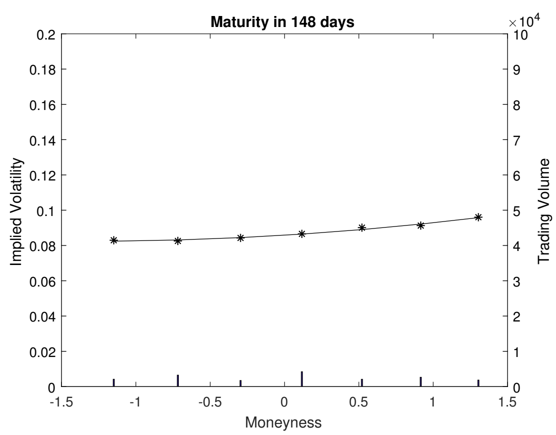
This figure illustrates the fitted IV curves for three different maturity terms (August, September and December) on 1 Aug 2017. The stars in each sub-figure are the market implied volatility, the bars are their trading volume and the solid lines are fitted IV curves.



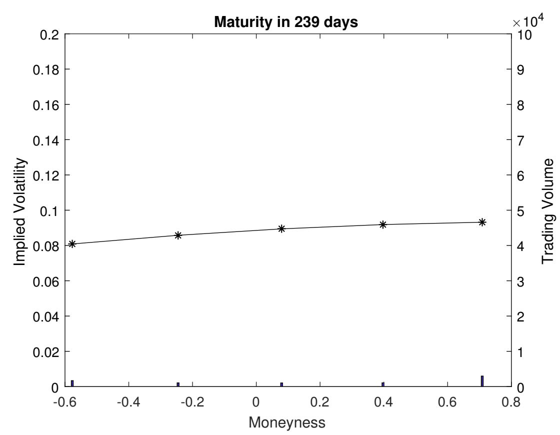
(a) Maturity in 22 days



(b) Maturity in 57 days



(c) Maturity in 148 days



(d) Maturity in 239 days

Figure 6: Mean IV curves

This figure reports the fitted IV curves from mean IV factors(level, slope and curvature) for the full sample and split by different maturity sub-groups.

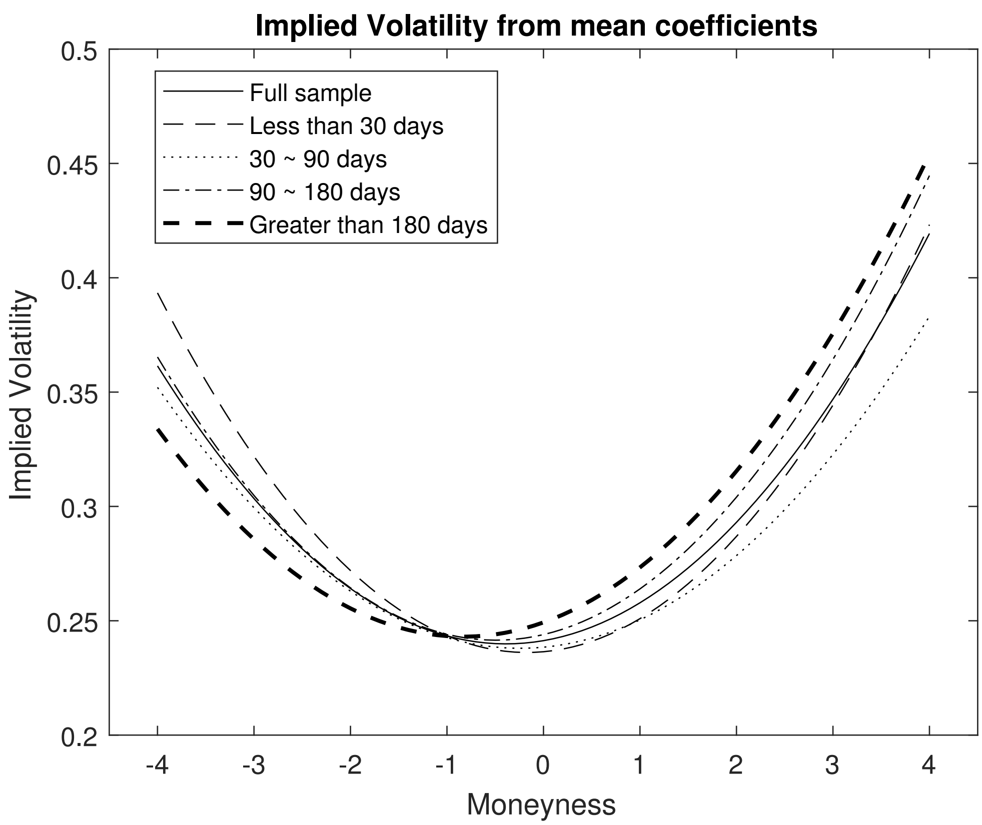
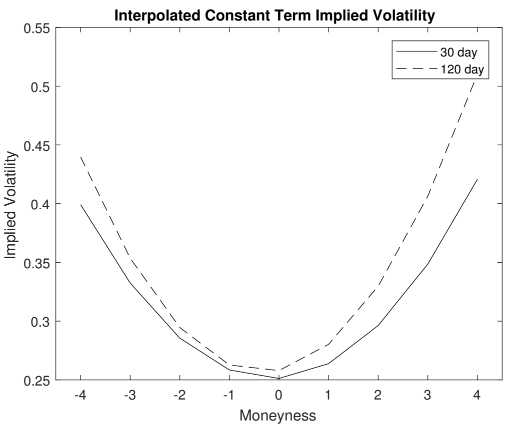
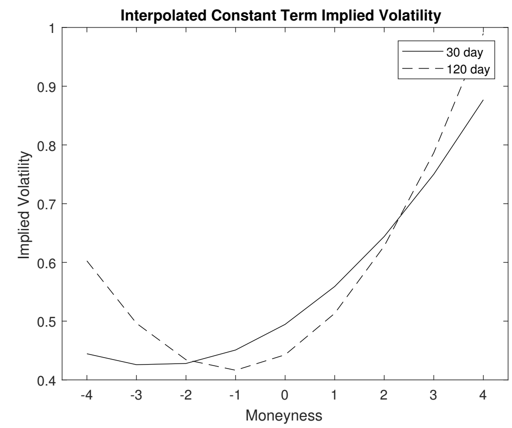


Figure 7: Constant maturity mean IV curves

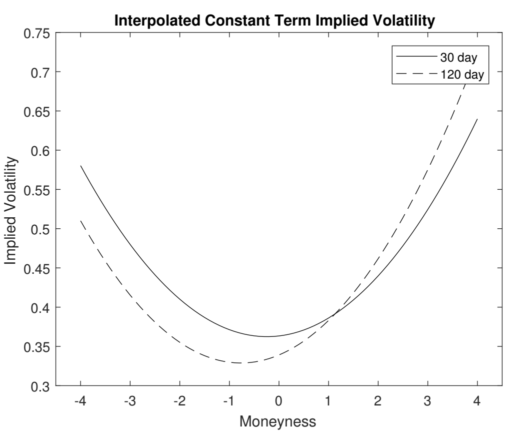
This figure shows the IV curve interpolated for two constant maturities 30 day and 120 day. The sub sample includes the trading days during financial crisis from 15 June 2015 to 31 August 2015. We follow Han and Pan (2017)'s definition of time period in analysis the pricing and efficiency of stock index futures during the 2015 financial crisis.



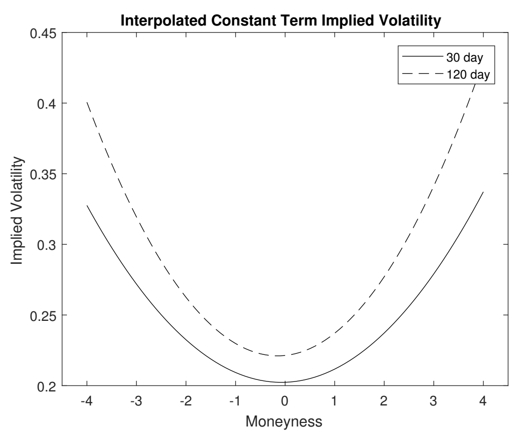
(a) Full Sample



(b) Sub Sample: Financial Crisis 2015



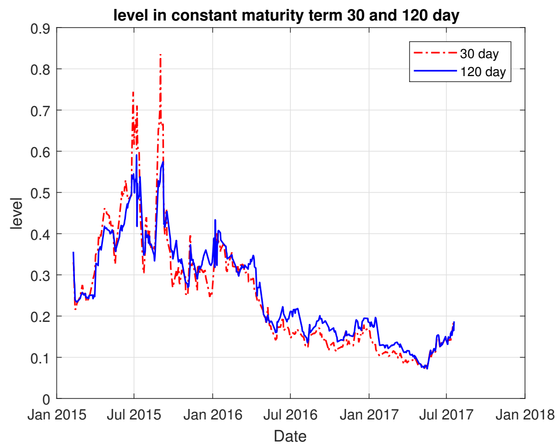
(c) Sub Sample before the Crisis



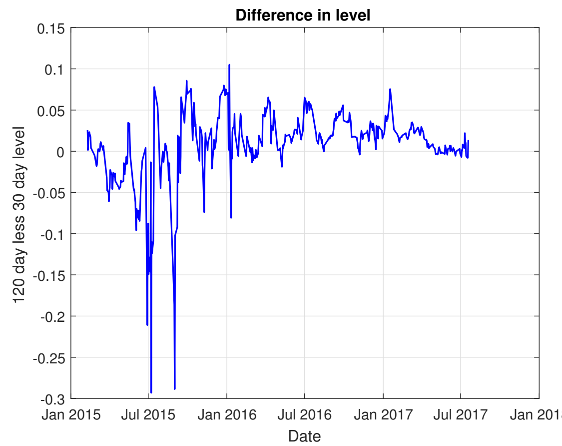
(d) Sub Sample after the Crisis

Figure 8: Time series of IV curves factors

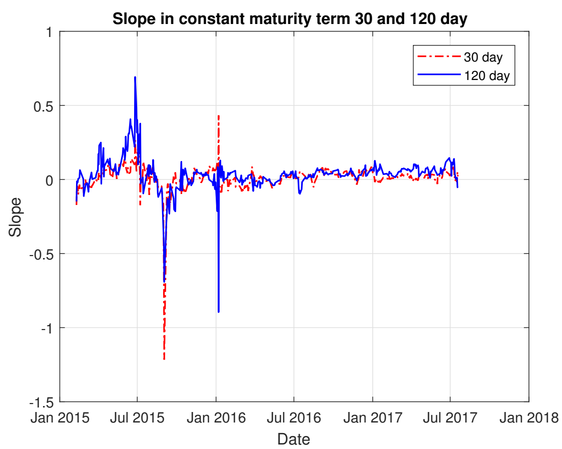
This figure reports the interpolated time series of ATM IV level, slope and curvature for 30 and 120 day maturity terms and their difference.



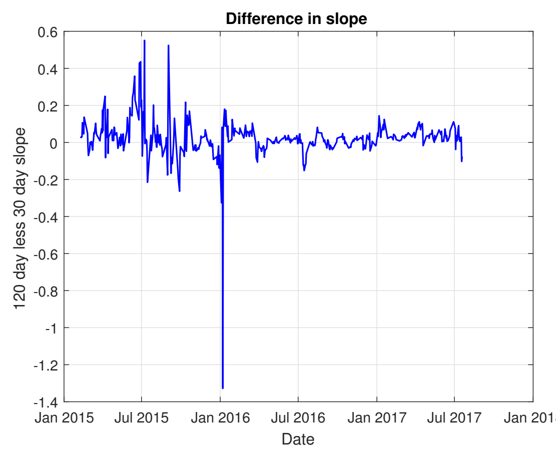
(a) IV level in two terms



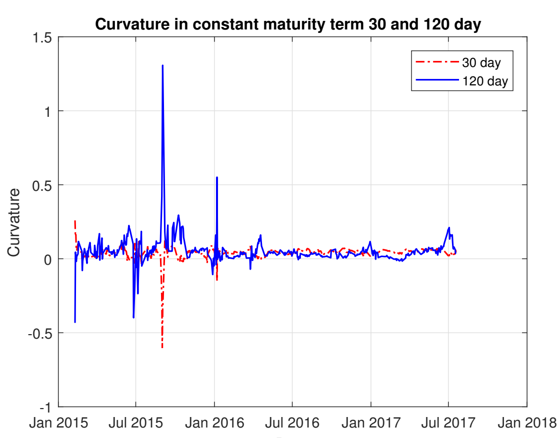
(b) Difference in IV level



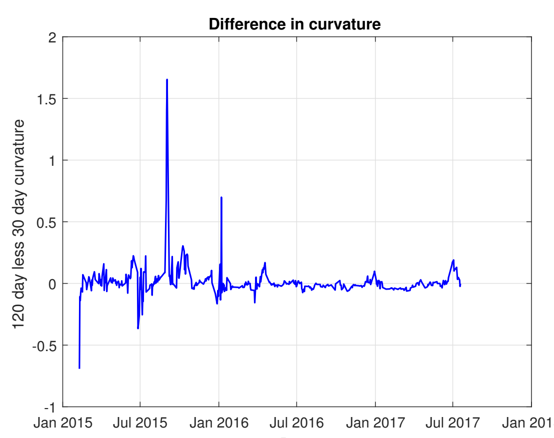
(c) IV slope in two terms



(d) Difference in IV slope



(e) IV Curvature in two terms



(f) Difference in IV curvature

Figure 9: Investor sentiment proxies in China

This figure reports the time series of investor sentiment proxies in our analysis: CNVXO (Volatility Index in China), PCR Volume (Put to Call ratio of trading volume of SSE 50 ETF option), PCR Value (Put to Call ratio of trading value of SSE 50 ETF option), PCR OI (Put to Call ratio of Open Interest of SSE 50 ETF option), SSE 50 ETF Turn-over ratio, SSE 50 Short ratio(Short selling volume/total trading volume), SSE 50 Margin ratio(Margin trading value/total trading value) and SSE 50 lagged return.

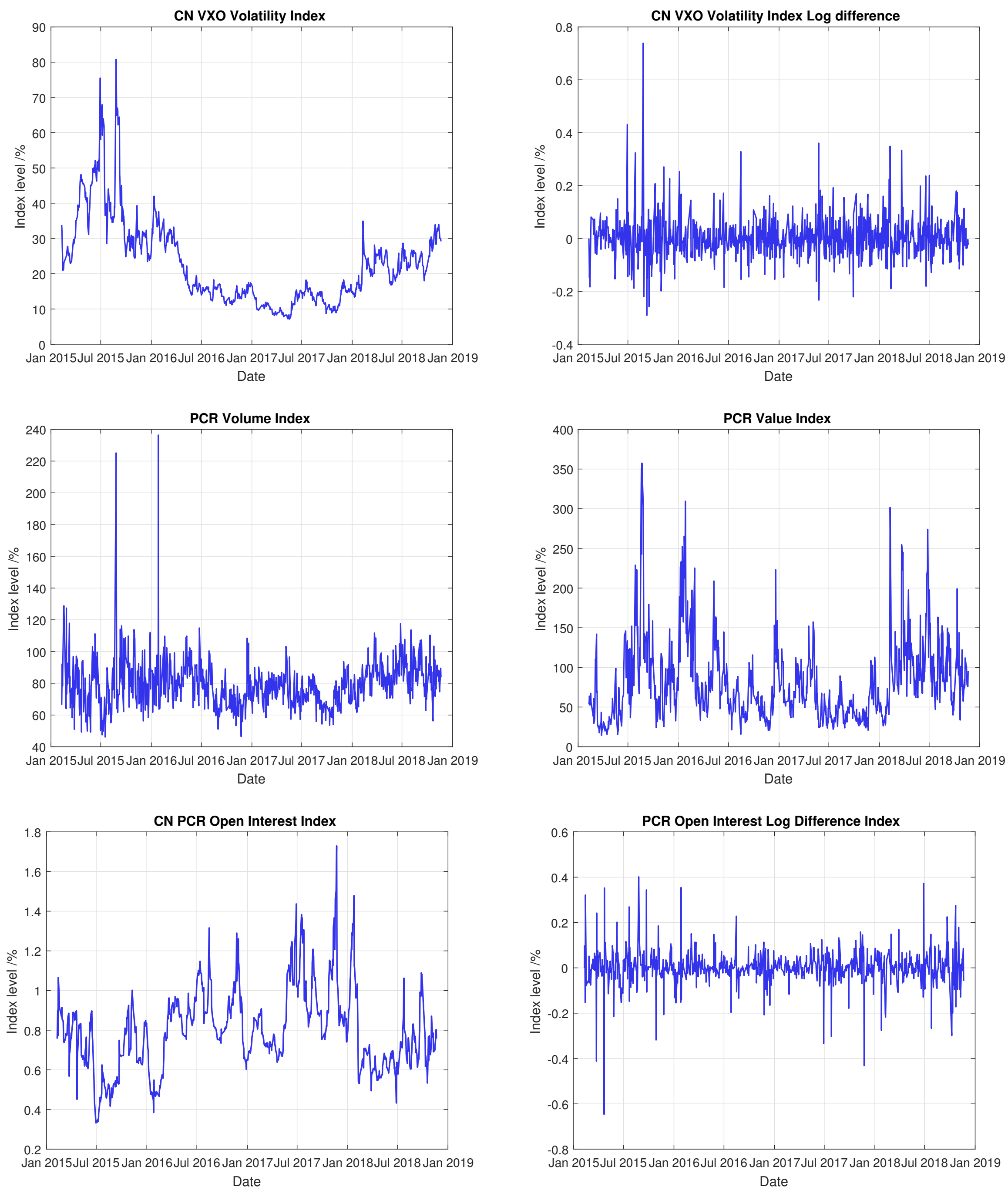


Figure 9 continued: Investor sentiment proxies in China

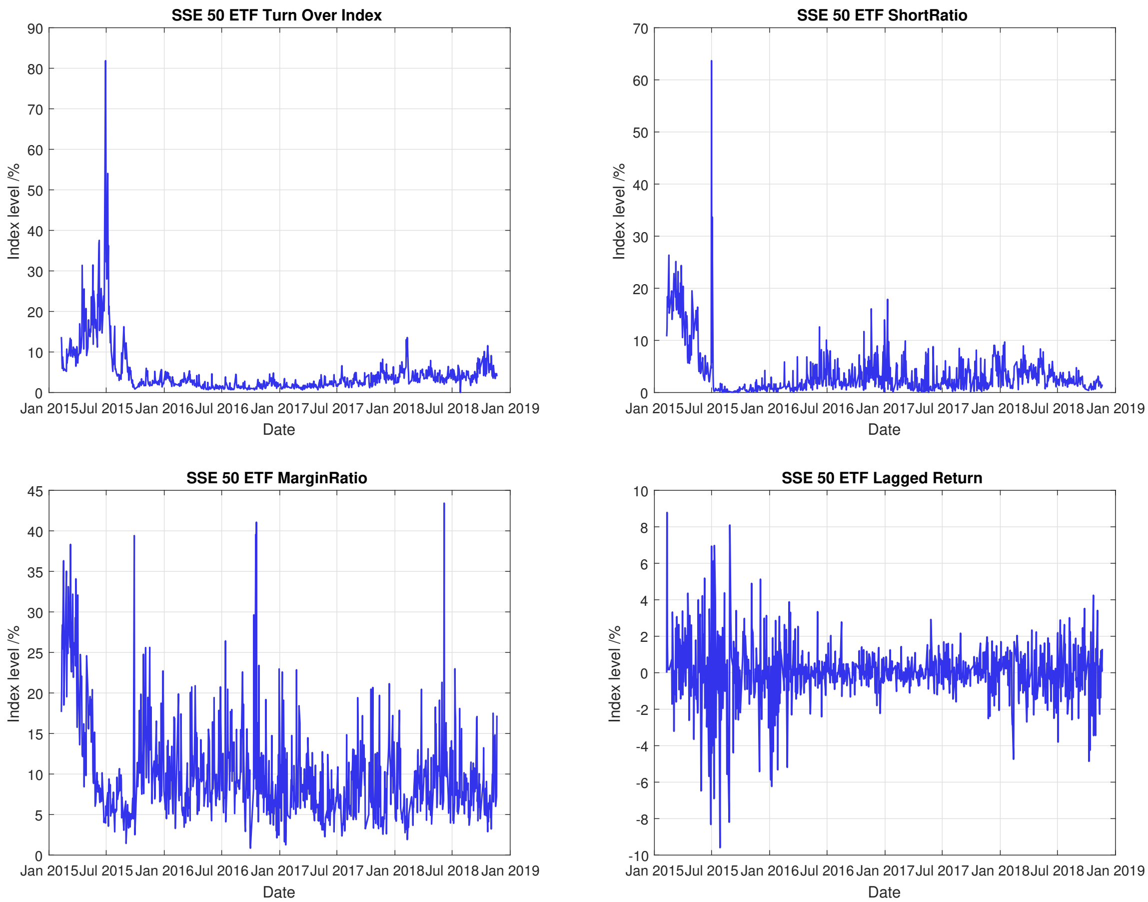


Table 1: Summary of leading ETF funds in China (2017)

This table reports market statistics the major ETF (Exchange traded fund) in China to the end of 2017.

Name	SZE 100 ETF	SZE SME ETF	SZE GEB ETF	SSE 50 ETF	SSE 180 ETF	CSI 300 ETF	CSI 500 ETF
Code	159901.SZ	159902.SZ	159915.SZ	510050.SH	5100180.SH	510300.SH	510500.SH
Tracking Index	SZE 100 Index	SZE SME Index	SZ GEB Index	SSE 50 Index	SSE 180 Index	CSI 300 Index	CSI 500 Index
Inception	24 Apr 2006	05 Sep 2006	09 Dec 2011	23 Feb 2005	18 May 2006	28 May 2012	15 Mar 2013
Fund Management Company	EFund	Hua Xia	EFund	Hua Xia	Hua An	Hua Tai	Nan Fang
Capitalization (¥000,000’s)	4,048	2,628	5,165	38,085	20,070	20,321	18,517
Average Daily Trading Volume (000’s)	6,236	11,065	124,295	310,029	8,832	113,778	26,034
Average Short Selling Volume (000’s)	125	1,091	0	8,016	116	19,088	2,639
Average Daily Trading Value (¥000’s)	27,892	37,792	216,948	825,740	28,816	422,633	171,318
Average Margin Trading Value (¥000’s)	874	4,444	9,795	62,937	876	68,053	9,776
Options	No	No	No	Yes	No	No	No

Table 2: Summary of the SSE 50 option market

This table reports the daily mean and median number of SSE 50 strikes, trading volume(value), open interest of each trading day. The results are reported in mean/median in full sample and sub maturity term groups .

	Full Sample	Maturity Sub-groups (days)					
		< 30	$30 - 90$	$90 - 180$	$180 - 244$	< 120	> 120
Number of observations	2,448	517	881	629	421	1,632	816
Mean number of strikes	13	13	13	15	9	13	11
Median number of strikes	11	13	11	15	8	12	10
Mean Trading volume	180,285	128,127	66,705	14,381	6,976	168,244	13,065
Median Trading volume	137,845	100,828	44,803	9,879	3,468	130,476	6,417
Mean open interest	585,467	343,367	205,873	105,071	41,885	505,314	86,972
Median open interest	564,579	311,250	173,717	89,052	21,417	465,716	61,015

Table 3: Summary of fitted implied volatility coefficients

This table reports the fitted results for the Implied volatility function:

$$\mathrm{IV}(\xi)=\alpha_0+\alpha_1\xi+\alpha_2\xi^2,$$

where IV is the implied volatility calculated from market price and xi is the standard moneyness of the option. The estimated coefficient α_0, α_1 and α_2 can be converted to dimensionless coefficient γ_0, γ_1 and γ_2 as reported in Section 5. We report the mean coefficients across overall and four maturity groups.

	Full Sample	< 30	$30 - 90$	$90 - 180$	> 180
	2448	517	881	629	421
$\hat{F_{t,T}}$	2.4193	2.4334	2.4302	2.4154	2.3849
$\hat{\alpha}$	0.2413	0.2365	0.2384	0.2440	0.2493
$\hat{\alpha_1}$	0.0063	0.0028	0.0016	0.0097	0.0153
$\hat{\alpha_2}$	0.0103	0.0093	0.0060	0.0139	0.0153
$\hat{\gamma_0}$	0.2413	0.2365	0.2384	0.2440	0.2493
$\hat{\gamma_1}$	0.0300	0.0158	0.0163	0.0406	0.0602
$\hat{\gamma_2}$	0.0386	0.0454	0.0339	0.0413	0.0363
			Standard Deviation		
$\hat{F_{t,T}}$	0.3243	0.3104	0.3097	0.3329	0.3551
$\hat{\alpha_0}$	0.1270	0.1487	0.1301	0.1151	0.1073
$\hat{\alpha_1}$	0.0527	0.0354	0.0664	0.0440	0.0482
$\hat{\alpha_2}$	0.0609	0.0097	0.0753	0.0431	0.0822
$\hat{\gamma_0}$	0.1270	0.1487	0.1301	0.1151	0.1073
$\hat{\gamma_1}$	0.1059	0.0637	0.1220	0.0967	0.1159
$\hat{\gamma_2}$	0.1268	0.0217	0.1246	0.0884	0.2207
			% Significant of Coefficient at 5% level		
$\hat{\alpha_0}$	99.96%	100%	100%	100%	99.76%
$\hat{\alpha_1}$	73.00%	58.80%	72.19%	85.69%	73.16%
$\hat{\alpha_2}$	73.98%	91.30%	78.09%	73.77%	44.42%
			R^2 and Adjusted R^2		
Mean volume	4,753	11,890	4,887	1,263	922
Mean R^2	0.9131	0.9226	0.9306	0.9024	0.8422
Mean Adj R^2	0.8704	0.8836	0.8954	0.8624	0.7430

Table 4: Summary of Interpolated Term Structure

This table reports the mean and standard deviation of interpolated implied forward price and implied volatility curve factors for two maturities: 30 and 120 day. We also report the three in sub samples: during/before/after the financial crisis (FC) sub sample period (15 June 2015 to 31 August 2015).

	Full Sample		Before FC		During FC		After FC	
Days	30	120	30	120	30	120	30	120
Panel A: Implied Forward Price								
Mean								
F^τ	2.3908	2.3883	2.8573	2.8847	2.6154	2.6611	2.2734	2.2596
Standard deviation								
F^τ	0.3001	0.3252	0.3608	0.3766	0.2764	0.3139	0.1524	0.1666
Panel B: Fitted coefficients								
Mean								
α_0^τ	0.2512	0.2579	0.3633	0.3391	0.4945	0.4427	0.2024	0.2213
α_1^τ	0.0011	0.0095	0.0120	0.0327	0.0169	0.0576	-0.0032	-0.0008
α_2^τ	0.0082	0.0155	0.0158	0.0191	0.0079	0.0198	0.0062	0.0153
γ_0^τ	0.2512	0.2579	0.3633	0.3391	0.4945	0.4427	0.2024	0.2213
γ_1^τ	0.0107	0.0341	0.0205	0.0786	0.0315	0.1093	0.0059	0.0164
γ_2^τ	0.0395	0.0526	0.0424	0.0512	0.0210	0.0499	0.0401	0.0547
Standard deviation								
α_0^τ	0.1421	0.1178	0.0962	0.0755	0.1321	0.076	0.1075	0.1003
α_1^τ	0.0477	0.0492	0.0238	0.0461	0.0573	0.1066	0.0497	0.0341
α_2^τ	0.0251	0.0491	0.0153	0.0306	0.0357	0.0724	0.0268	0.0506
γ_0^τ	0.1421	0.1178	0.0962	0.0755	0.1321	0.076	0.1075	0.1003
γ_1^τ	0.0859	0.1089	0.0615	0.1101	0.0944	0.1975	0.0889	0.0901
γ_2^τ	0.0466	0.0974	0.0416	0.0785	0.0551	0.1286	0.0488	0.0989

Table 5: Stationary test of investor sentiment proxies

This table reports the stationary test of all the sentiment proxies we constructed. CNVXO is the volatility index in China, LNCNVXO is the log difference of CNVXO, PCRVAL is the put to call ratio of trading value, PCRVOL is the put to call ratio of trading volume, PCROI is the put to call ratio of open interest, LNPCROI is the log difference PCROI, TurnOver is the turn over of the underlying asset, Lag Ret is the lagged return of underlying asset, Short Ratio is the short selling volume to the trading volume, Margin Ratio is the margin trading value to the total trading value.

	Stationary	ADF-stats	Stationary	KPSS-stats
CNVXO	No	-1.5952*	No	14.6378***
LNCNVXO	Yes	-32.6774***	Yes	0.0236*
PCRVAL	Yes	-4.1224***	No	2.5267**
PCRVOL	Yes	-2.9981***	No	2.1622**
PCROI	No	-1.3082	No	0.0450
LNPCROI	Yes	-30.9290***	Yes	0.0000
TurnOver	Yes	-6.7926***	No	7.7917**
Lag Ret	Yes	-30.5993***	Yes	0.0594*
Short Ratio	Yes	-12.2181***	No	3.5927**
Margin Ratio	Yes	-8.6404***	No	1.6960**

*** significant at the 1% level.
** significant at the 5% level.
* significant at the 10% level.

Table 6: Correlation of investor sentiment proxies in China

This table reports the correlation matrix of sentiment factors: LNCNVXO is the log difference of CNVXO (China Volatility Index), PCRVAL is the put to call ratio of trading value, PCRVOL is the put to call ratio of trading volume, LNPCROI is the log difference of put to call ratio of open interest, TurnOver is the turn over of the underlying asset, Lag Ret is lagged return of underlying asset, Short Ratio is the short selling volume to the total trading volume, Margin Ratio is the margin trading value to the total trading value.

	LNCNVXO	PCR VOL	PCR VAL	LNPCROI	TurnOver	LagRet	ShortRatio	MarginRatio
LNCNVXO	1							
PCRVOL	0.1400	1						
PCRVAL	0.0819	0.5488	1					
LNPCROI	0.0131	0.0139	-0.1759	1				
TurnOver	0.1415	-0.0801	-0.0211	-0.0313	1			
LagRet	-0.0549	-0.2672	-0.3722	0.1400	-0.0477	1		
ShortRatio	-0.0452	-0.0396	-0.1871	0.0041	0.2957	0.0979	1	
MarginRatio	-0.0426	0.0268	-0.1473	-0.0392	0.0159	0.0695	0.5509	1

Table 7: Regression analysis of 30 day constant maturity coefficient: level (γ_0)

This table reports the regression analysis of investor sentiment proxies' relation to the level of IV in 30 day constant maturity group, as described in Section 6.2. Based on multivariate regression of the following variables: LNVCNVXO (log difference of CN Volatility Index), PCRVOL (Put-to-Call ratio of trading volume of SSE 50 ETF option), PCRVAL (Put-to-Call ratio of trading value of SSE 50 ETF option), LNPCROI (Log difference of Put-to-Call ratio of open interest of SSE 50 ETF option), TurnOver (the turn over of SSE 50 ETF), LagRet (the lagged return of SSE 50 ETF), ShortRatio (the short selling volume/total trading volume) and MarginRatio (the margin trade value/total trading value). The value in the parentheses are t-stats, *, ** and *** denote 10%, 5% and 1% significance level.

		Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8	Model 9	Model 10
Inteceptor	$\hat{\beta}_0$	0.2476***	0.2571***	0.1969***	0.2473***	0.1854***	0.2475***	0.2346***	0.2466***	0.1097***	0.1160***
		(37.3750)	(6.5548)	(15.8078)	(37.4058)	(32.7486)	(37.3831)	(29.3225)	(19.8493)	(3.7759)	(11.2813)
LNCNVXO	$\hat{\beta}_1$	0.0139								-0.1377**	-0.1161**
		(0.1626)								(-2.2443)	(-2.0282)
PCRVOL	$\hat{\beta}_2$		-0.0122							0.1025***	
			(-0.2481)							(2.8629)	
PCRVAL	$\hat{\beta}_3$			0.0650***							0.0888***
				(4.7597)							(8.7285)
LNPCROI	$\hat{\beta}_4$				0.1526					0.0701	0.2129**
					(1.3036)					(0.7994)	(2.5551)
TurnOver	$\hat{\beta}_5$					0.0120***				0.0131***	0.0127***
						(20.3874)				(20.9605)	(22.1158)
LagRet	$\hat{\beta}_6$						-0.0108			0.5434*	0.9836***
							(-0.0295)			(1.9258)	(3.6816)
ShortRatio	$\hat{\beta}_7$							0.3045***		-0.2591***	-0.1126
								(2.8271)		(-3.1705)	(-1.4505)
MarginRatio	$\hat{\beta}_8$								0.0079		
									(0.0839)		
R^2		0.0001	0.0001	0.0480	0.0038	0.4807	0.0000	0.0175	0.0000	0.5086	0.5728

Table 8: Regression analysis of 120 day constant maturity coefficient: level (γ_0)

This table reports the regression analysis of investor sentiment proxies' relation to the level of IV in 120 day constant maturity group, as described in Section 6.2. Based on multivariate regression of the following variables: LNVCNVXO (log difference of CN Volatility Index), PCRVOL (Put-to-Call ratio of trading volume of SSE 50 ETF option), PCRVAL (Put-to-Call ratio of trading value of SSE 50 ETF option), LNPCROI (Log difference of Put-to-Call ratio of open interest of SSE 50 ETF option), TurnOver (the turn over of SSE 50 ETF), LagRet (the lagged return of SSE 50 ETF), ShortRatio (the short selling volume/total trading volume) and MarginRatio (the margin trade value/total trading value). The value in the parentheses are t-stats, *, ** and *** denote 10%, 5% and 1% significance level.

		Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8	Model 9	Model 10
Inteceptor	$\hat{\beta}_0$	0.2549***	0.2311***	0.2073***	0.2550***	0.2109***	0.2553***	0.2464***	0.2487***	0.1284***	0.1501***
		(46.31)	(7.0981)	(20.1957)	(46.2691)	(40.0356)	(46.3071)	(36.974)	(24.0688)	(4.8088)	(15.6764)
LNCNVXO	$\hat{\beta}_1$	-0.1026								-0.2142***	-0.1969***
		(-1.4441)								(-3.7992)	(-3.6953)
PCRVOL	$\hat{\beta}_2$		0.0307							0.1089***	
			(0.7493)							(3.3094)	
PCRVAL	$\hat{\beta}_3$			0.0613***							0.0767***
				(5.4541)							(8.0996)
LNPCROI	$\hat{\beta}_4$				0.0735					0.0375	0.1613**
					(0.755)					(0.4654)	(2.0794)
TurnOver	$\hat{\beta}_5$					0.0085***				0.0096***	0.0092***
						(15.5962)				(16.6089)	(17.074)
LagRet	$\hat{\beta}_6$						-0.1818			0.2547	0.6001**
							(-0.6001)			(0.9811)	(2.4115)
ShortRatio	$\hat{\beta}_7$							0.2105**		-0.2261**	-0.0909
								(2.3087)		(-2.9419)	(-1.2286)
MarginRatio	$\hat{\beta}_8$								0.0584		
									(0.7411)		
R^2		0.0047	0.0013	0.0625	0.0013	0.3529	0.0008	0.0118	0.0012	0.3981	0.4630

Table 9: Regression analysis of 30 day constant maturity coefficient: Slope (γ_1)

This table reports the regression analysis of investor sentiment proxies' relation to the slope of IV in 30 day constant maturity group, as described in Section 6.2. Based on multivariate regression of the following variables: LNVCNVXO (log difference of CN Volatility Index), PCRVOL (Put-to-Call ratio of trading volume of SSE 50 ETF option), PCRVAL (Put-to-Call ratio of trading value of SSE 50 ETF option), LNPCROI (Log difference of Put-to-Call ratio of open interest of SSE 50 ETF option), TurnOver (the turn over of SSE 50 ETF), LagRet (the lagged return of SSE 50 ETF), ShortRatio (the short selling volume/total trading volume) and MarginRatio (the margin trade value/total trading value). The value in the parentheses are t-stats, *, ** and *** denote 10%, 5% and 1% significance level.

		Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8	Model 9	Model 10
Inteceptor	$\hat{\beta}_0$	0.009**	0.0384*	0.0393***	0.0092**	0.0038	0.0091**	0.0038	0.0036	0.0344	0.0457***
		(2.3152)	(1.664)	(5.354)	(2.3692)	(0.8229)	(2.3408)	(0.8066)	(0.4967)	(1.4339)	(5.1971)
LNCNVXO	$\hat{\beta}_1$	0.0381								0.0257	0.0117
		(0.7541)								(0.5065)	(0.2384)
PCRVOL	$\hat{\beta}_2$		-0.0376							-0.0417	
			(-1.2962)							(-1.4093)	
PCRVAL	$\hat{\beta}_3$			-0.0389***							-0.0525***
				(-4.8399)							(-6.0398)
LNPCROI	$\hat{\beta}_4$				-0.1531**					-0.1343*	-0.2183***
					(-2.2269)					(-1.8522)	(-3.0665)
TurnOver	$\hat{\beta}_5$					0.0010**				0.0006	0.0008
						(2.0649)				(1.1403)	(1.5306)
LagRet	$\hat{\beta}_6$						-0.3691*			-0.2963	-0.5845**
							(-1.7213)			(-1.2698)	(-2.5605)
ShortRatio	$\hat{\beta}_7$							0.1198**		0.1085	0.024
								(1.8787)		(1.6054)	(0.3621)
MarginRatio	$\hat{\beta}_8$								0.0473		
									(0.8528)		
R^2		0.0013	0.0037	0.0496	0.0109	0.0094	0.0066	0.0078	0.0016	0.0325	0.1019

*** significant at the 1% level.
** significant at the 5% level.
* significant at the 10% level.

Table 10: Regression analysis of 120 day constant maturity coefficient: Slope (γ_1)

This table reports the regression analysis of investor sentiment proxies' relation to the slope of IV in 120 day constant maturity group, as described in Section 6.2. Based on multivariate regression of the following variables: LNVCNVXO (log difference of CN Volatility Index), PCRVOL (Put-to-Call ratio of trading volume of SSE 50 ETF option), PCRVAL (Put-to-Call ratio of trading value of SSE 50 ETF option), LNPCROI (Log difference of Put-to-Call ratio of open interest of SSE 50 ETF option), TurnOver (the turn over of SSE 50 ETF), LagRet (the lagged return of SSE 50 ETF), ShortRatio (the short selling volume/total trading volume) and MarginRatio (the margin trade value/total trading value). The value in the parentheses are t-stats, *, ** and *** denote 10%, 5% and 1% significance level.

		Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8	Model 9	Model 10
Inteceptor	$\hat{\beta}_0$	0.0357***	0.0932***	0.0622***	0.0353***	0.0081*	0.0353***	0.0238***	0.0454***	0.0369	0.0421***
		(8.0312)	(3.5425)	(7.3267)	(7.8947)	(1.6966)	(7.9083)	(4.4406)	(5.4205)	(1.4887)	(4.5755)
LNCNVXO	$\hat{\beta}_1$	0.1682***								0.1062**	0.0955*
		(2.9365)								(2.0325)	(1.8648)
PCRVOL	$\hat{\beta}_2$		-0.0741**							-0.0373	
			(-2.2393)							(-1.2219)	
PCRVAL	$\hat{\beta}_3$			-0.0346***							-0.0412***
				(-3.7263)							(-4.531)
LNPCROI	$\hat{\beta}_4$				-0.0903					-0.1063	-0.1724**
					(-1.1432)					(-1.4226)	(-2.3123)
TurnOver	$\hat{\beta}_5$					0.0052***				0.0048***	0.005***
						(10.5461)				(9.0239)	(9.6228)
LagRet	$\hat{\beta}_6$						-0.3608			-0.1161	-0.3337
							(-1.469)			(-0.4822)	(-1.3951)
ShortRatio	$\hat{\beta}_7$							0.2723***		0.0718	0.002
								(3.7107)		(1.0081)	(0.0281)
MarginRatio	$\hat{\beta}_8$								-0.0926		
									(-1.4489)		
R^2		0.019	0.0111	0.0302	0.0029	0.1996	0.0048	0.0299	0.0047	0.2156	0.248

Table 11: Regression analysis of 30 day constant maturity coefficient: Curvature (γ_2)

This table reports the regression analysis of investor sentiment proxies' relation to the curvature of IV in 30 day constant maturity group, as described in Section 6.2. Based on multivariate regression of the following variables: LNVCNVXO (log difference of CN Volatility Index), PCRVOL (Put-to-Call ratio of trading volume of SSE 50 ETF option), PCRVAL (Put-to-Call ratio of trading value of SSE 50 ETF option), LNPCROI (Log difference of Put-to-Call ratio of open interest of SSE 50 ETF option), TurnOver (the turn over of SSE 50 ETF), LagRet (the lagged return of SSE 50 ETF), ShortRatio (the short selling volume/total trading volume) and MarginRatio (the margin trade value/total trading value). The value in the parentheses are t-stats, *, ** and *** denote 10%, 5% and 1% significance level.

		Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8	Model 9	Model 10
Inteceptor	$\hat{\beta}_0$	0.0402***	0.0221*	0.0417***	0.0403***	0.0422***	0.0402***	0.0407***	0.0392***	0.0296**	0.0482***
		(18.5885)	(1.7276)	(10.0175)	(18.7313)	(16.5018)	(18.6691)	(15.4481)	(9.6704)	(2.2133)	(9.4945)
LNCNVXO	$\hat{\beta}_1$	0.0137								0.0184	0.0151
		(0.4905)								(0.6518)	(0.5334)
PCRVOL	$\hat{\beta}_2$		0.023							0.0158	
			(1.4348)							(0.9607)	
PCRVAL	$\hat{\beta}_3$			-0.002							-0.0071
				(-0.4449)							(-1.4151)
LNPCROI	$\hat{\beta}_4$				-0.081**					-0.066	-0.0769*
					(-2.127)					(-1.6326)	(-1.8692)
TurnOver	$\hat{\beta}_5$					-0.0004				-0.0004	-0.0005
						(-1.5004)				(-1.4575)	(-1.6002)
LagRet	$\hat{\beta}_6$						-0.1896			-0.1134	-0.1843
							(-1.5963)			(-0.8719)	(-1.397)
ShortRatio	$\hat{\beta}_7$							-0.013		0.0115	0.0025
								(-0.3665)		(0.3054)	(0.0652)
MarginRatio	$\hat{\beta}_8$								0.0082		
									(0.2678)		
R^2		0.0005	0.0046	0.0004	0.01	0.005	0.0056	0.0003	0.0002	0.0203	0.0227

Table 12: Regression analysis of 120 day constant maturity coefficient: Curvature (γ_2)

This table reports the regression analysis of investor sentiment proxies' relation to the curvature of IV in 120 day constant maturity group, as described in Section 6.2. Based on multivariate regression of the following variables: LNVCNVXO (log difference of CN Volatility Index), PCRVOL (Put-to-Call ratio of trading volume of SSE 50 ETF option), PCRVAL (Put-to-Call ratio of trading value of SSE 50 ETF option), LNPCROI (Log difference of Put-to-Call ratio of open interest of SSE 50 ETF option), TurnOver (the turn over of SSE 50 ETF), LagRet (the lagged return of SSE 50 ETF), ShortRatio (the short selling volume/total trading volume) and MarginRatio (the margin trade value/total trading value). The value in the parentheses are t-stats, *, ** and *** denote 10%, 5% and 1% significance level.

		Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8	Model 9	Model 10
Inteceptor	$\hat{\beta}_0$	0.0520***	0.0255	0.0475***	0.0519***	0.0528***	0.0519***	0.0569***	0.0648***	0.0148	0.0447***
		(11.864)	(0.9867)	(5.6309)	(11.8667)	(10.1289)	(11.8863)	(10.6932)	(7.9127)	(0.548)	(4.3618)
LNCNVXO	$\hat{\beta}_1$	-0.0379								-0.0324	-0.0316
		(-0.6693)								(-0.5685)	(-0.554)
PCRVOL	$\hat{\beta}_2$		0.0339							0.0519	
			(1.0428)							(1.5609)	
PCRVAL	$\hat{\beta}_3$			0.0060							0.0134
				(0.649)							(1.3167)
LNPCROI	$\hat{\beta}_4$				0.1295*					0.0807	0.103
					(1.6777)					(0.9909)	(1.2393)
TurnOver	$\hat{\beta}_5$					-0.0001				0.0005	0.0003
						(-0.2144)				(0.8626)	(0.5972)
LagRet	$\hat{\beta}_6$						0.5283**			0.5787**	0.5894**
							(2.2035)			(2.204)	(2.2107)
ShortRatio	$\hat{\beta}_7$							-0.1136		-0.1582**	-0.1302*
								(-1.5609)		(-2.0356)	(-1.6426)
MarginRatio	$\hat{\beta}_8$								-0.1143*		
									(-1.8303)		
R^2		0.001	0.0024	0.0009	0.0063	0.0001	0.0108	0.0054	0.0075	0.0274	0.0259