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

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Abstract

This paper documents and analyzes the empirical dynamics of the implied volatility (IV) of the SSE 50 ETF option, the only equity options market in China, adopting Zhang and Xiang's (2008) methodology to quantify the IV curve. We find the usual shape of the IV curve in SSE 50 ETF options is a smirk shape, which is skewed to the right. This is different to the left skewed IV smirk commonly found in US and international equity option markets. This IV smirk shows Chinese option traders are willing to pay a premium for the Out-of-The-Money (OTM) call options with the expectation of a bull market. The right-skewed smirk is present prior to the 2015 financial crisis, then becomes even more pronounced during crisis and shifts to a symmetrical smile shape over the steady recovery since the crisis. The symmetrical IV smile shape is still different to the typical IV shape found in the US options market.

Keywords: ETF options, implied volatility, implied volatility curve.

JEL Classification: G13 G14 G15.

1 Introduction

In this paper, we use the methodology of Zhang and Xiang (2008) to quantify and analyze the implied volatility (hereafter IV) curves of the newly established Shanghai Stock Exchange (hereafter SSE) 50 Index exchange-traded-fund (ETF) options market in China. This is the first paper document the IV curves of an options market in China using the quantified IV result from SSE 50 ETF options, we find that the IV curve usually resembles a right smirk, which is different from other international option markets.

Currently, the SSE 50 ETF option is the only equity option traded in China. The underlying asset the SSE 50 ETF fund, 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. With the availability of options, investors are able access volatility trading in the world's largest emerging capital market.

We quantify all the SSE 50 ETF options with a second order polynomial and group the options by their maturity. Examining mean coefficients level, slope and curvature we find that in the SSE 50 ETF options market IV curves usually exhibits a right skewed smirk slope. We also examine interpolated constant maturity factors and we get consisted result with the mean IV smirk across different maturity terms. Furthermore, we examine the dynamics in time series and interpolated two constant maturity terms from market data for IV curve.

An option's IV is calculated from matching the option's market price with the option pricing model (usually the Black and Scholes (1973) and Merton (1973), which are called the BSM model). The IV is a forward-looking measure of expected volatility demand from market option prices. Therefore, IV is believed to contain information about future volatility relative to historical volatility.

In the BSM model, all options across different strikes are assumed to have the same volatility. If this assumption is true, we should observe a flat IV curve calculated from the BSM model with market option prices. However, Rubinstein (1985) find the phenomenon of "smile" shaped IV curve rather than the flat curve, in the US equity index options. Later option pricing models were developed, which can reproduce option's IV shape through stochastic factors (e.g., Heston, 1993; Bakshi, Cao, and Chen, 1997; Pan, 2002, etc.). The IV from the BSM model is widely used by industry practitioners and academicians 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) find that price of Out-of-The-Money (OTM) put options become unusually expensive during the year after the Global Financial Crisis (GFC) in 1987. After GFC in 1987, the S&P 500 IV curve shape changed from the symmetrical "smile" shape 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 causes for the asymmetrical 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 that the IV smile pattern is caused by investors' sentiments. The IV smile/smirk has also been documented around other 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). However, the above papers document the IV smirk skewed to the left, Gemmill (1996) finds that that the IV smirk of the FTSE 100 index options in the UK skewed to the right rather than left skewed in other markets, which indicated that option traders in the UK expect market recovery in the future.

There is a vast literature that focus on IV curve's shape has significant predictive power for the future return of underlying asset. Dumas, Fleming, and Whaley (1998) using IV to examine the predictive and hedging performance of deterministic volatility function with S&P 500 options, they find it is no better than an ad-hoc procedure that merely smooths BSM IV across strikes and time to maturity. Dennis and Mayhew (2002) find that the IV in individual stocks related more to the systematic risk and historical volatility. Dennis, Mayhew, and Stivers (2006) find that index returns have a large negative relation to the IV in short-term at-the-money (ATM) options. 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. Xing, Zhang, and Zhao (2010) find that firms with steepest volatility smirks are those experiencing the worst earnings shocks in the following quarter. Yan (2011) use the similar measure from Xing, Zhang, and Zhao (2010) in IV smirk, with the finding that the slope of IV smirk has negative predictive on the stock returns across 4,000 stocks with options during 1996-2005.

The literature on the newly option and derivatives market in China are rare, 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 IV surface with SSE 50 ETF options. Huang, Liu, Zhang, and Zhu (2018) construct the VIX (Volatility Index) in China with SSE 50 ETF options 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 test. Li, Yao, Chen, and Lee (2018) examine the momentum effect of the SSE 50 ETF options.

To the best of our knowledge, this paper is the first paper to provide a comprehensive analysis for the IV curve and its dynamics of the first options market in China, the SSE 50 ETF option. 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-crisis and post-crisis periods after which it changes to a symmetrical smile slope.

The rest of this paper is organized as follows: Section 2, we discuss the SSE 50 ETF and options market. In Section 3, we report the option data set we used in our study. In section 4, we describe the methodology in our paper. In section 5, we report the empirical result, which include the properties of IV smirk by mean and interpolated constant maturity window. The last section ends the study with conclusion.

2 Background of SSE 50 index ETF and options market

In 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 in SSE. The SSE 50 index reflects the performance of the most influential blue chip stocks in SSE, 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 gradually popularity in passive ETF fund index investments (e.g., Gastineau, 2001; Poterba and Shoven, 2002), there are 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 the summary of leading ETF funds in China.

< *Insert Table 1 about here* >

The SSE introduced the first exchanged traded option in China: SSE 50 ETF option on 9 February 2015. The underlying asset for SSE 50 ETF option is the Hua Xia SSE 50 ETF fund; 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: current month, the next month and the other two months in March-June-September-December cycle. The SSE 50 ETF option will mature on the fourth Wednesday in its maturity month. For each option chains a range of strikes are available on each trading day, at initial trading day there are four OTM, one At-The-Money (ATM) and four In-The-Money (ITM) call (put) options.[1] When the SSE 50 ETF is below CNY 3.0, the strike interval are set at CNY 0.05, whereas SSE 50 ETF is above CNY 3.0, the strike interval are set at CNY 0.1. Along with the increase/decrease of underling asset, the exchange will add new options to the option chain to maintain at least four OTM/ITM and one ATM strikes in the option chain.

The SSE set 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] Investors need to pass corresponding tests to access the trading in SSE option market. According to the SSE 2017 fact book, the SSE 50 ETF option's accumulative option premium was CNY 4.85 trillion and its average daily trading value is CNY 19.894 billion in 2017.[3] In the same year, the turn over value of SSE equity market totaled CNY 51.12 trillion and the constituent stocks in SSE 50 index totaled CNY 8.91 trillion. The Figure 1 below presents the daily trading volume, value and open interest in SSE 50 ETF

[1]The SSE updated the trading rules in 2 January 2018, before 2018, at the initial trading day of option chain, there are only two OTM/ITM and one ATM strike available.

[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 privilege in long positions in call/put, level 3 include privileges in level 2 and privilege in naked short selling of options.

[3]The SSE 2017 fact book http://english.sse.com.cn/indices/publications/factbook/c/4648486.pdf.

option.

< Insert Figure 1 about here >

3 Data

Options are the most actively traded products in derivatives markets, however, there were no options available to the investors in China before Feb 2015. There are US traded options on US listed ETFs replicating Chinese indexes, as documented by (Li, Gehricke, and Zhang, 2018). The SSE 50 ETF option, which is lunched on 9 Feb 2015 is the first and the only equity option traded in China. Our option data sample period is from 9 Feb 2015 to 31 Dec 2017, and the data is sourced from the WIND financial terminal.

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.[4]

(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.[5]

(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]We set the maximum limit of IV to 1,000% and if the IV is higher than 1,000%, they are discarded from our sample.

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

The data set contains end-of-day prices of call and put options written on the SSE 50 ETF, which includes daily open interest, trading volume, trading value, and daily open, close, highest, lowest and settlement price. The SSE 50 ETF fund replicates the SSE 50 index by its NAV times multiplier 1,000, figure 2 below present the adjusted replication of SSE 50 ETF fund with its target index and the mean IV level from ATM call options which we used as average volatility level during our sample period.

< Insert Figure 2 about here >

In Table 2, we report the trading activity of the SSE 50 ETF options by full sample and maturity groups. In the table we can see that with the increase of maturity, options' trading activity which include trading volume, number of strikes and open interest decreased. Most of options' maturity in our sample are less than 180 days.

< Insert Table 2 about here >

Figure 3 shows the distribution of the number of observations as a function of moneyness (measured with standard moneyness $\xi = \frac{\ln(K/F_{t,T})}{\bar{\sigma}\sqrt{T-t}}$) and time to maturity at options' initial date. From the figure, there are less number of options along with the increase/decrease of moneyness, as the SSE only maintain the option chain up to at least 4 OTM/ITM options only. The majority of options are round the -2 to 2 in moneyness level and 0.2 to 0.6 in time to maturity level.

< Insert Figure 3 about here >

4 Methodology

With the IV calculated from the market option price data using the Black and Scholes (1973) and Merton (1973) (BSM) model, we document the IV curve from SSE 50 ETF option. We inspect whether the asymmetrical IV pattern called the IV smirk (Pena, Rubio, and Serna, 1999; Foresi and Wu 2005; Shiu, Pan, Lin, and Wu, 2010; and more) exist in the SSE 50 option market. We use 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 (2018)' methodology by calculating the constant maturity quantified IV factors and inspect their quantified IV factors.

4.1 The calculation of BSM implied volatility

The WIND financial terminal option dataset provides IV based on BSM model with closing price of SSE 50 ETF option. However, WIND assume zero dividend yield in IV calculation, in fact the SSE 50 ETF will pay discrete cash dividends based on the performance of replication. The IV would be more accurate if we use forward price from put-call parity, which contains implied continuous dividend yield. We calculate the IV of SSE 50 ETF option by inverting market option price back to the BSM formula, which is given as following:

$$
\begin{aligned}
c_t &= S_t e^{-\delta(T-t)} N(d_1) - K e^{-r(T-t)} N(d_2) \\
p_t &= K e^{-r(T-t)} N(-d_2) - S_t e^{-\delta(T-t)} N(-d_1),
\end{aligned} \tag{2}
$$

where

$$
d_1 = \frac{\ln(S_t/K) + (r - \delta + \frac{1}{2}\sigma^2)(T-t)}{\sigma\sqrt{T-t}}, \quad d_2 = d_1 - \sigma\sqrt{T-t},
$$

and c_t and p_t are call (put) option price, K is the strike price, $N(\cdot)$ is the cumulative normal density function, σ is the volatility of the underlying asset and $F_{t,T} = S_t e^{(r-\delta)(T-t)}$ is the implied forward price of underling asset.

The ATM strike price K is that with the smallest difference between the call and put option prices (with same strike and maturity). Using the option prices we can calculate the implied forward price from:

$$F_{t,T} = K_{t,T}^{ATM} + e^{r\tau} \times (c_{t,T}^{ATM} - p_{t,T}^{ATM}), \tag{3}$$

where $c_{t,T}^{ATM}$ and $p_{t,T}^{ATM}$ are ATM option prices. The implied forward price $F_{t,T} = S_t e^{(r-\delta)(T-t)}$ could be used to approximate the dividend yield δ.

4.2 Quantifying the implied volatility

Zhang and Xiang (2008) developed an approach for quantifying the IV curve, by fitting the second order polynomial. They further showed that the coefficients of the polynomial can further be used to estimate the option implied risk-neutral moments of the underlying asset's return.

Following Carr and Wu (2003), Zhang and Xiang (2008) and industry practise we define moneyness as the number of standard deviations the log strike price is from the forward price:

$$\xi = \frac{\ln(K/F_{t,T})}{\bar{\sigma}\sqrt{T-t}}, \tag{4}$$

where ξ is the moneyness of the option, T is the option's maturity date, K is the strike price and $F_{t,T}$ is the implied forward price. We use the linearly interpolated IV of the corresponding ATM call options as the measure of constant volatility $\bar{\sigma}$ from the two near maturity terms to 30 days.

With the definition of moneyness in Eq (4), we can quantify the IV curve by fitting the second order polynomial function given by:

$$IV(\xi, t, T) = \alpha_0 + \alpha_1\xi + \alpha_2\xi^2. \tag{5}$$

We can 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:

$$IV(\xi, t, T) = \gamma_0(1 + \gamma_1 \xi + \gamma_2 \xi^2). \tag{6}$$

The first factor γ_0 is the level, which is an estimate of the exact ATM IV. [6] The parameter γ_1 captures the slope of quantified IV curve and γ_2 captures its curvature. The polynomial in Eq (5) is estimated by minimizing the volume-weighted mean square error:

$$VWMSE = \frac{\sum_{\xi_i} Volume(\xi_i) \times [IV_{market}(\xi_i) - IV(\xi_i)]^2}{\sum_{\xi_i} Volume(\xi_i)}, \tag{7}$$

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 (for call: $K_c > F_{i,\tau}$ and for put: $K_p < F_{i,\tau}$).

The level, slope and curvature are related to the risk-neutral volatility (σ), skewness (λ_1) and kurtosis (λ_2), respectively, as shown by (Zhang and Xiang, 2008):

$$\begin{aligned}
\gamma_0 &= \left(1 - \frac{\lambda_2}{24}\right)\sigma + \frac{\lambda_1}{4}\sigma^2\sqrt{\tau} + O(\sigma^3\tau), \\
\gamma_1 &= \frac{\lambda_1}{6(1-(\lambda_2/24))}\frac{\bar{\sigma}}{\sigma} + \frac{\lambda_2(1-(\lambda_2/24)) - (\lambda_1^2/2)}{12(1-(\lambda_2/24))^2}\bar{\sigma}\sqrt{\tau} + O(\sigma\bar{\sigma}\sqrt{\tau}), \\
\gamma_2 &= \frac{\lambda_2\bar{\sigma}^2(1-(\lambda_2/16))}{24\sigma^2(1-(\lambda_2/24))^2} + \frac{\lambda_1\lambda_2\bar{\sigma}^2\sqrt{\tau}(1-(\lambda_2/48))}{96\sigma(1-(\lambda-2/24))^3} + O(\bar{\sigma}^2\sqrt{\tau}),
\end{aligned} \tag{8}$$

which are called the approximate relationship between the option's IV curve factors and its implied risk-neutral moments. They further show that if the second and higher order terms ignored and taking $\bar{\sigma} = \sigma_0$, we have the following appromation:

$$\gamma_0 \approx \left(1 - \frac{\lambda_2}{24}\right)\sigma, \quad \gamma_1 \approx \frac{1}{6}\lambda_1, \quad \gamma_2 \approx \frac{1}{24}\lambda_2. \tag{9}$$

[6]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 and random samples

In this section we report and analyze the dynamics 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, fit statistics and mean trading volume by maturity grouping.

< Insert Table 3 about here >

In Table 3, we can see that the mean SSE50 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 shows us 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 some where maturity is greater than 180 days.

For the slope factor (γ_1), we can see that, on average, the IV curves are upward sloping for all the groups The right skewed IV curve, which indicate 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. Surprisingly, the shortest maturity group's slope is significant is the lowest in maturity groups(58.80%).

For the curvature factor (γ_2) we can see that, 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. As maturity increase the curvature shows a mean reverting manner . The curvature coefficients are significant for 73.98% of the IV curves, the proportion of significant coefficients decreases with the increase of time to maturity.

We can see that the proportion of significant factors and R squared decrease with the increase of maturity, which indicates 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 can be seen by the decrease in trading volume.

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 which are presented in figures 4, 5 and 6 respectively.

< Insert Figure 4 about here >

< Insert Figure 5 about here >

< Insert Figure 6 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. The 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 around the ATM level. Consistent with the positive slope factor, we can see that the IV curves skewed to the right side, which is different from the findings in the US options market. 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. 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, which is different from other option traders worldwide, who are willing to pay more for put option as insurance. Gemmill (1996) find similar right skewed IV curves in the FTSE 100 option market in UK.

In Figure 7, we plot the IV curves predicted by the mean factors across maturity groups. We can again see that, the IV curves are skewed to the right side and with increase in maturity term, IV curves become more convex, on average over the sample.

< *Insert Figure 7 about here* >

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 days factors through linear interpolation. The constant maturity factors will help us study the term structure, time series and evolution of the term structure of the factors for the same horizon of option traders' expectations.

Table 4 reports the summary statistics for the constant maturity factors:

< *Insert Table 4 about here* >

In 2015, due to the deregulation in margin trading, investors have widely 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. Then the market crashed due to liquidation of high leveraged margin position, the SSE index plunged from 5,178 to 2,850 points in 52 trading days. Han and Pan (2017) test the relation between future-cash basis on the 2015 financial crisis in China. We split our sample into before crisis, during crisis and after crisis in the table 4. From the table our 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.

During the financial crisis the IV level almost doubled compared with full sample, the slope coefficients are still positive during/before/after the financial crisis, which indicates that option traders willing to pay more on OTM call options compared with OTM put options. The right skewed IV curve is different from other developed option market like the CBOE SPX with left skewed IV curve. We also plot the mean coefficients from table 4 in the following figure:

< Insert Figure 8 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 9:

< Insert Figure 9 about here >

From figure 9, we can see that the ATM IV in figure 9 c 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 willing to pay more for short term options. For the slope factor in figure 9 e, it also shows a mean reversion manner with small magnitude, however, during the period of financial crisis, there are huge difference between slope of 30 and 120 days maturity term. The short term IV curve indicate that short term option trader even like to pay more on the OTM call options compared with long term option traders. 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 Conclusion

In this paper we calculated the implied volatility in 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.

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) and around worldwide major international option markets (Foresi and Wu, 2005). 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.

Also, 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. This is different from the other option markets with usually negatively sloped IV curves (Foresi and Wu, 2005, and Zhang and Xiang, 2008). The IV curves have positive curvature on average and the IV curve become more convex with an increase in maturity.

We further analyze the quantified IV curve factors by spliting 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 sample before the financial crisis to during the financial crisis. From the fitted IV curves, we can 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 symmetrical smile pattern. This story is very different to the IV curve of the US equity option markets, which has a even more left skewed IV smirk during the GFC in 2008 (Guo, Gehricke, and Zhang, 2018).

We also study the time series of the short term (30 days) and long term (120 days) interpolated IV factors. We find that the IV factors have similar patterns for both maturities while their difference becomes large sometimes, during market turmoils, especially during the 2015 financial crisis.

Our quantified SSE 50 ETF option IV curve contains almost all the information contained in the IV of SSE 50 ETF option, therefore our findings could be used in developing and/or calibrating SSE 50 ETF option pricing models. We could also use quantified IV factors to predict future returns and realized volatility of the ETF, which we leave for future research.

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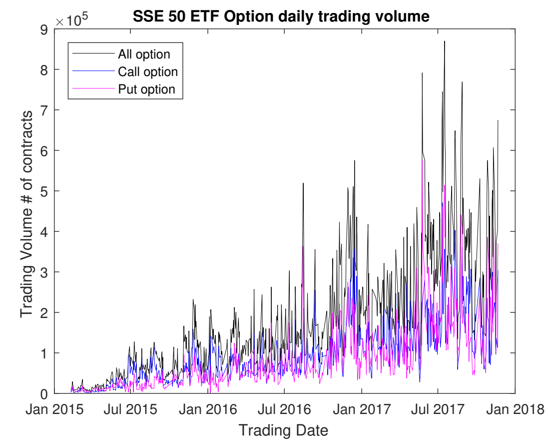
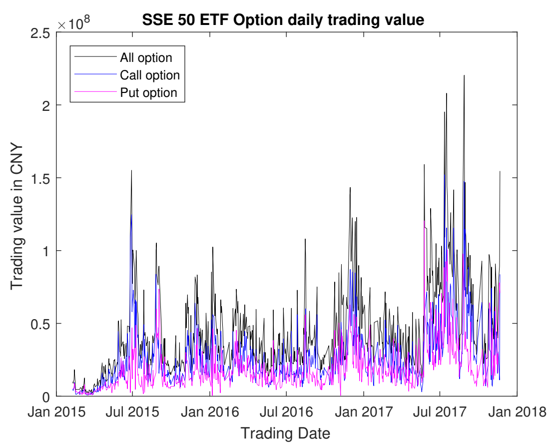
Figure 1: Option trading volume, value and open interest

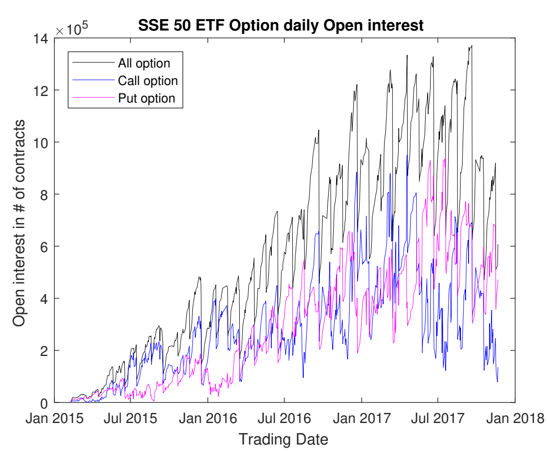
This figure reports the total daily trading volume, value and open interest in SSE 50 ETF option.



(a) Daily trading volume



(b) Daily trading value



(c) Daily open interest

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

Figure 2 reports the performance of SSE 50 index and SSE 50 ETF's index tracking in our sample. 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).

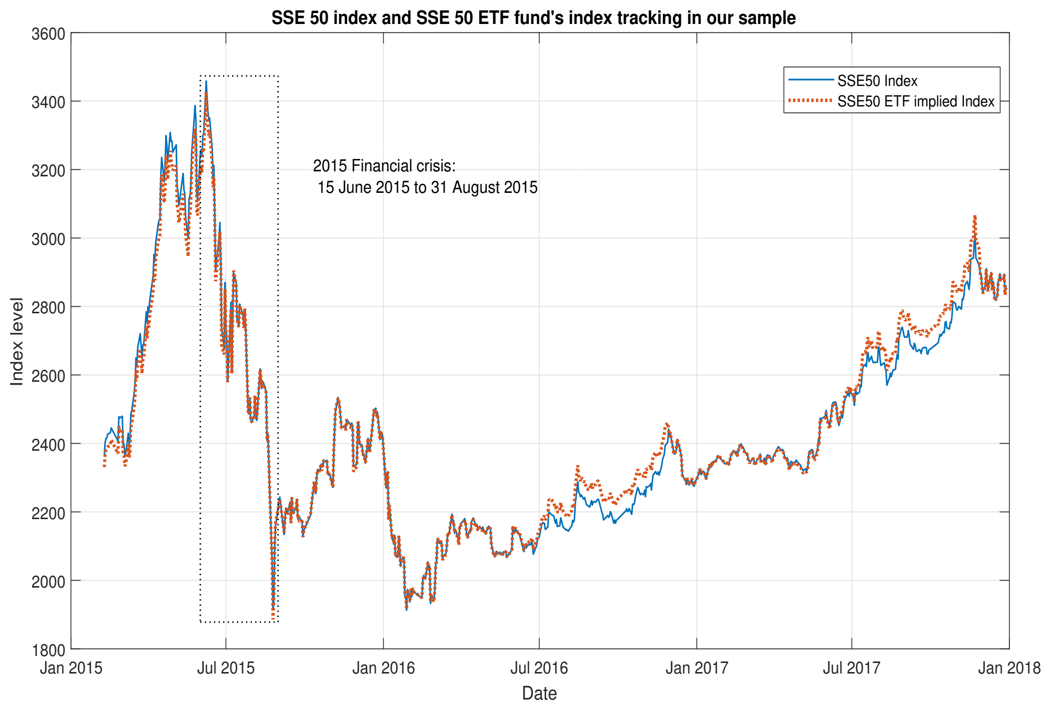


Figure 3: Density of number of SSE 50 option contracts

Figure 3 reports the density of number of SSE 50 option contracts at their initial date with respect to their time to maturity.

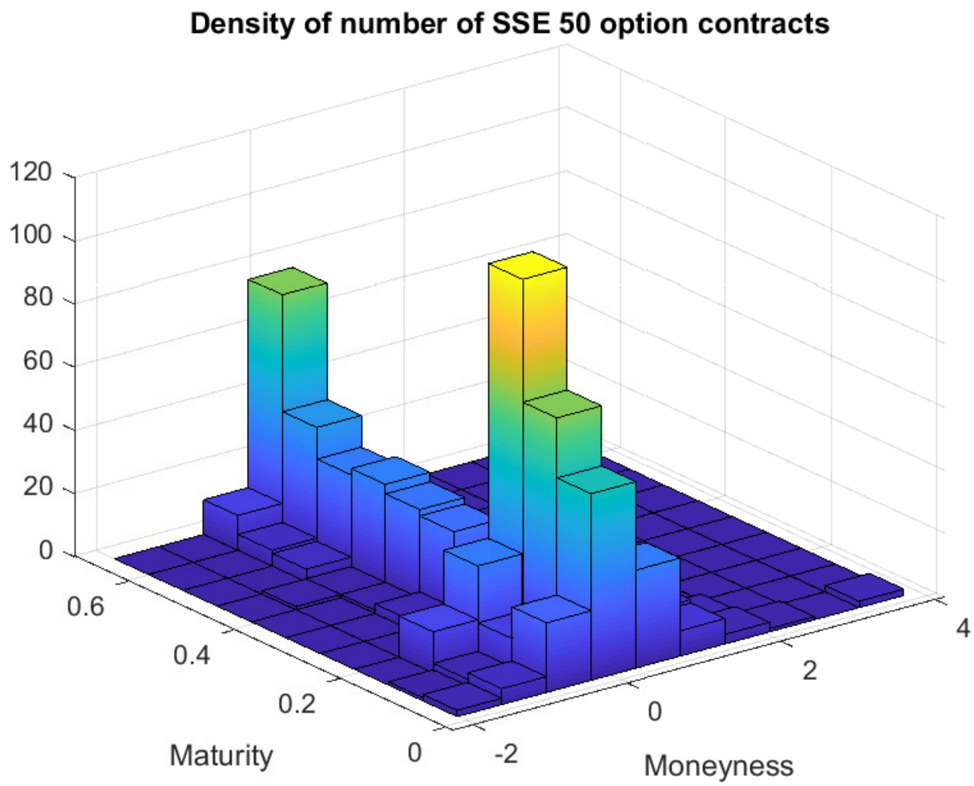
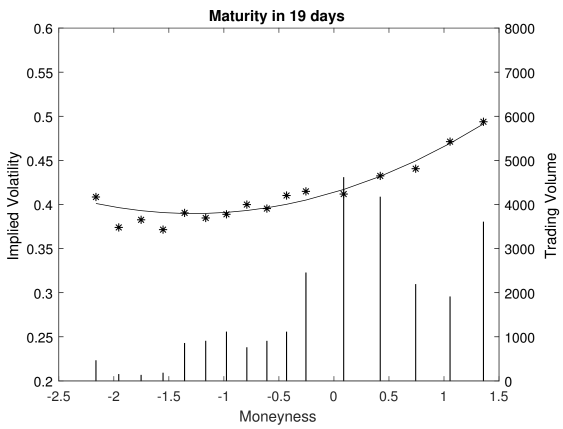
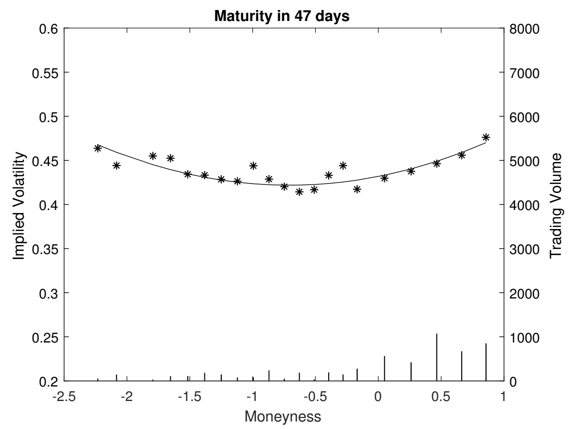


Figure 4: Fitted IV curves on 8 May 2015

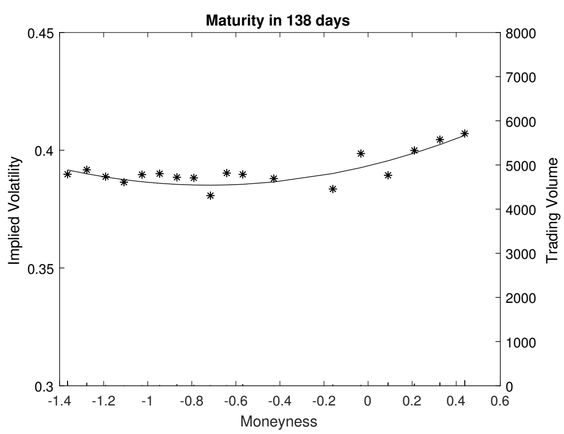
This figure illustrates the fitted IV curves for four different maturity terms (May, June, September and December) on 8 May 2015. The stars in each sub-figures are the marked implied volatility and bars are their trading volume. The solid lines are fitted IV curves.



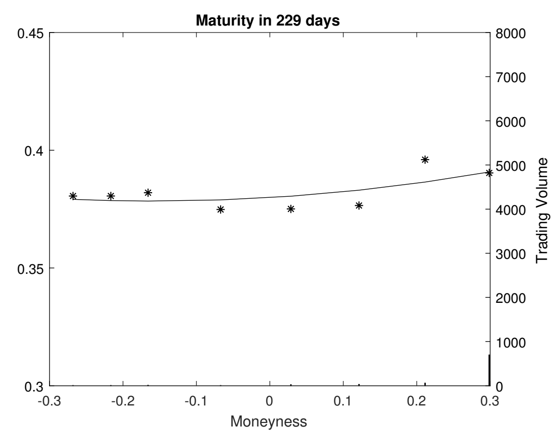
(a) Maturity in 19 days



(b) Maturity in 47 days



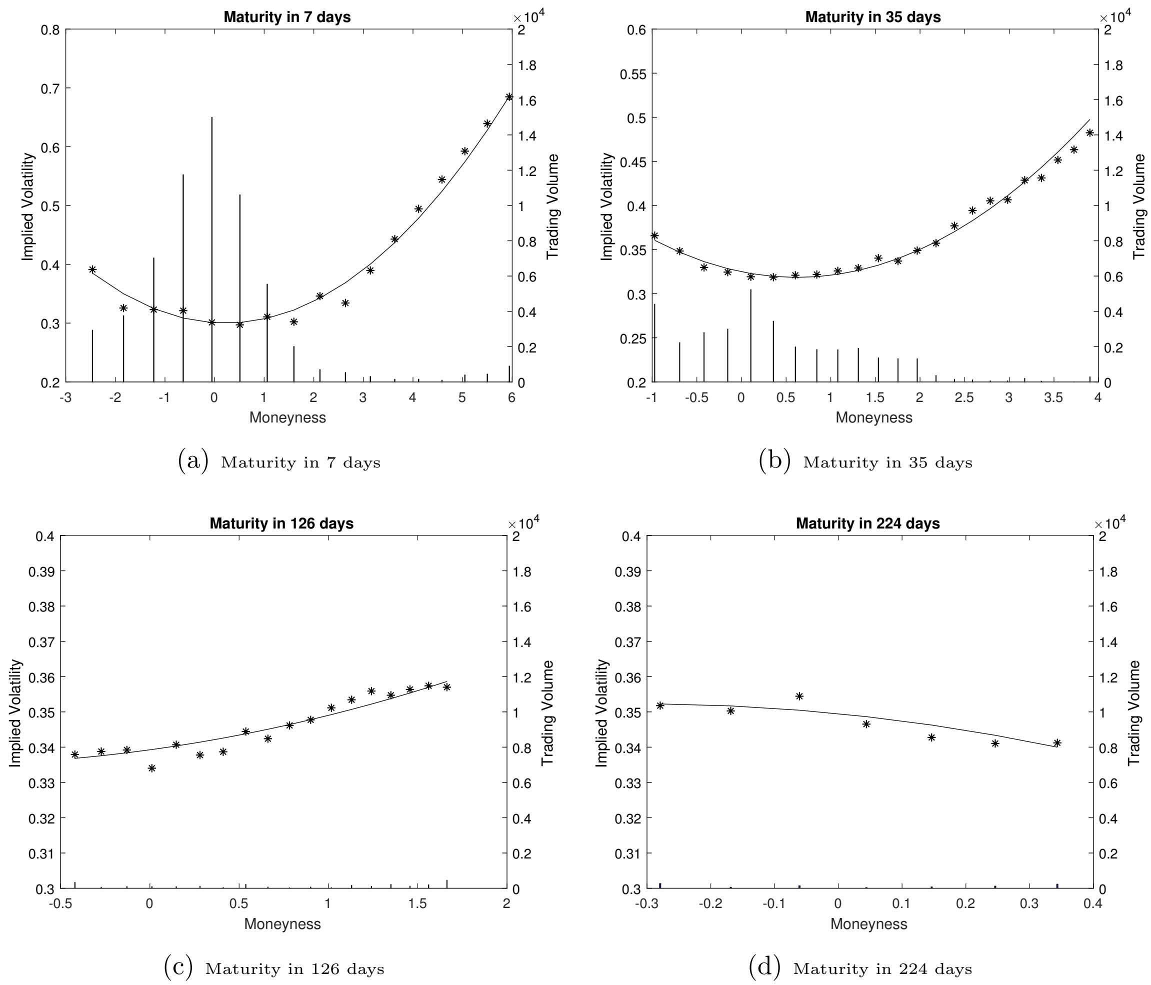
(c) Maturity in 138 days



(d) Maturity in 229 days

Figure 5: 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-figures are the marked implied volatility and bars are their trading volume. The solid lines are fitted IV curves.



(a) Maturity in 7 days

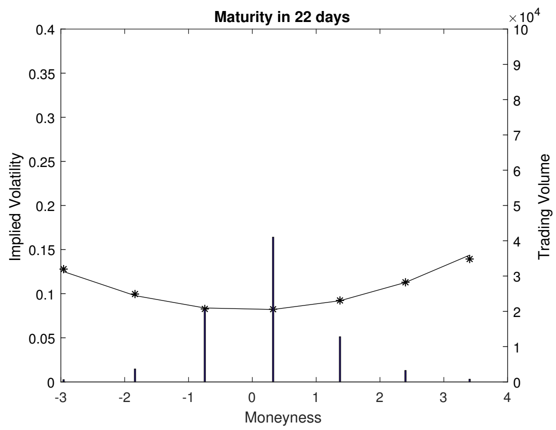
(b) Maturity in 35 days

(c) Maturity in 126 days

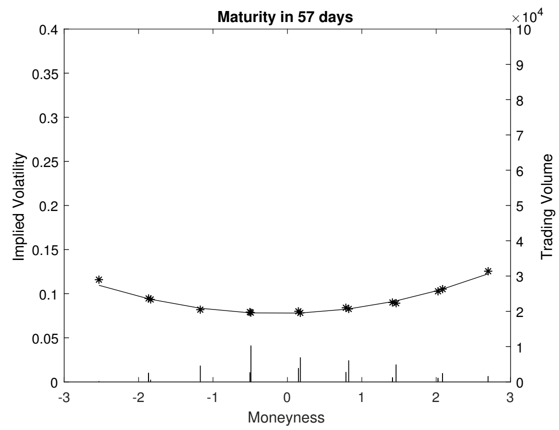
(d) Maturity in 224 days

Figure 6: Fitted IV curves on 2 May 2017

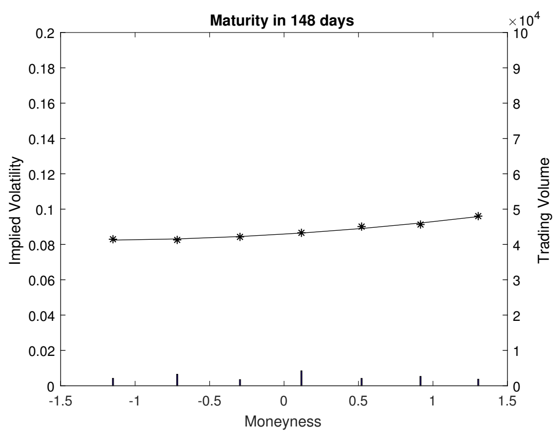
This figure illustrates the fitted IV curves for three different maturity terms (August, September and December) on 1 Aug 2017. The stars in each sub-figures are the marked implied volatility and bars are their trading volume. The solid lines are fitted IV curves.



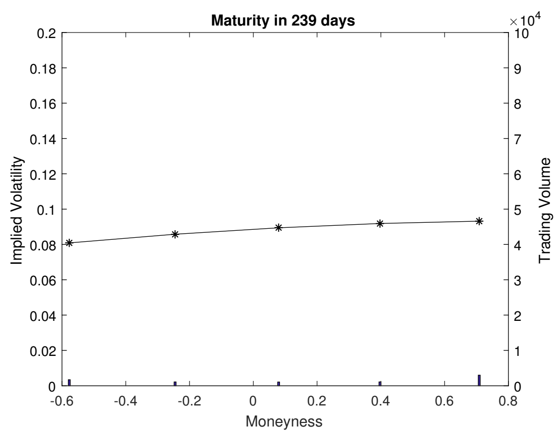
(a) Maturity in 22 days



(b) Maturity in 57 days



(c) Maturity in 148 days



(d) Maturity in 239 days

Figure 7: IV curve from mean coefficients

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

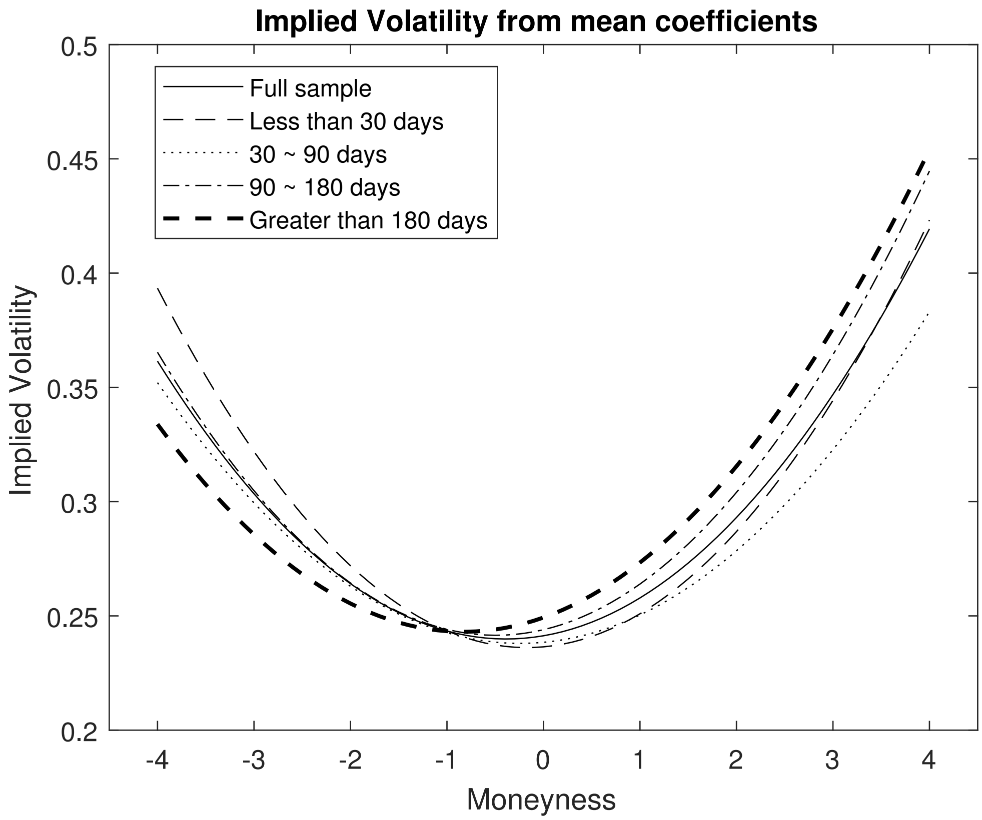
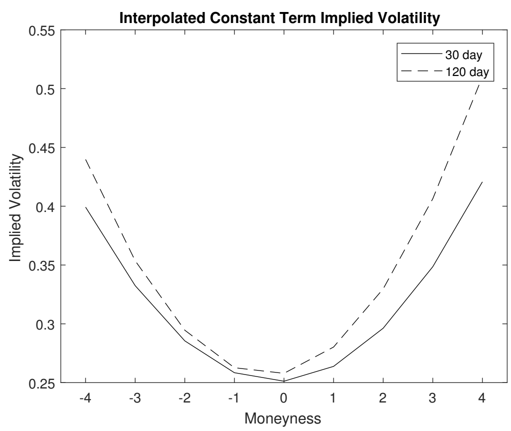


Figure 8: IV curve from mean interpolated coefficients

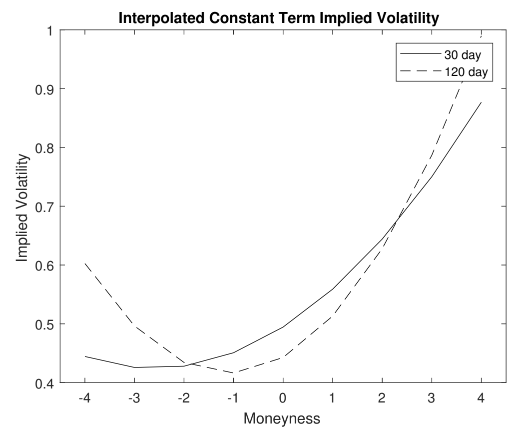
Figure 8 shows the IV curve interpolated from two constant term: 30 days and 120 days with mean coefficients:

$$\hat{IV} = \bar{\bar{\gamma}}_0(1 + \bar{\bar{\gamma}}_1\xi + \bar{\bar{\gamma}}_2\xi^2).$$

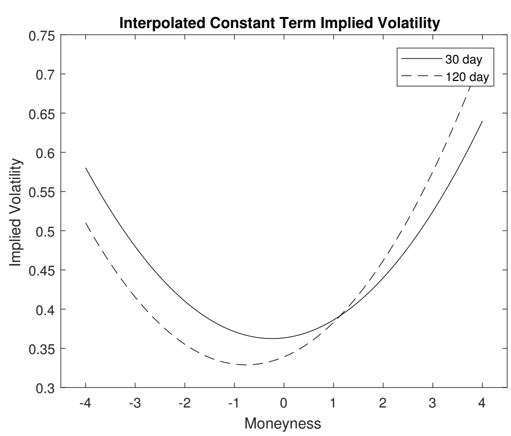
The sub sample include the trading days during financial crisis from 15 June 2015 to 31 August 2015, we follow Han and Pan (2017)'s definition of time period in analysis the pricing and efficiency of stock index futures during this financial crash in 2015.



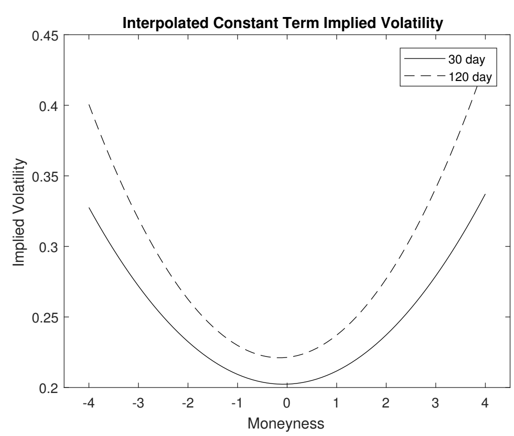
(a) Full Sample



(b) Sub Sample: Financial Crisis 2015



(c) Sub Sample before the Crisis

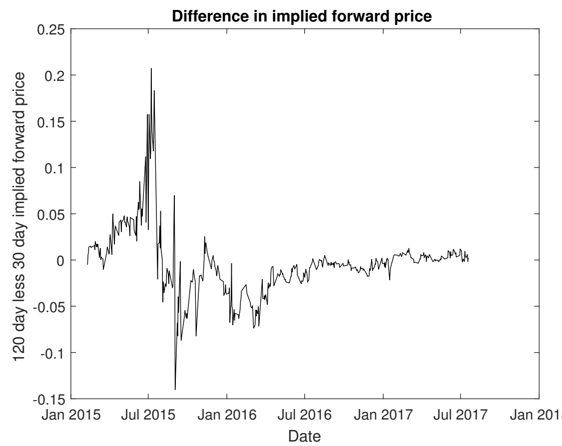


(d) Sub Sample after the Crisis

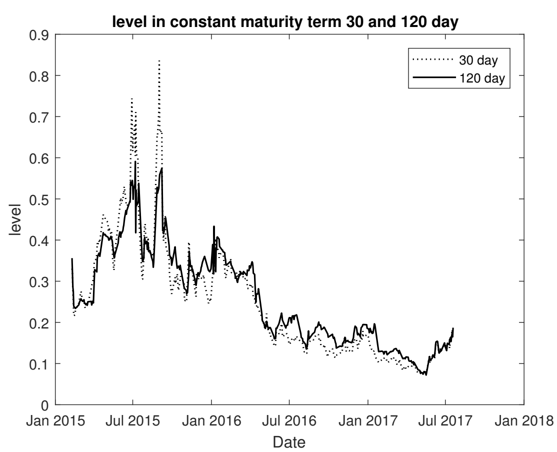
Figure 9: Time series of Interpolated ATM IV Interpolated Term Structure

This figure reports the interpolated time series of ATM IV and forward price for 30 and 120 day maturities and their difference.

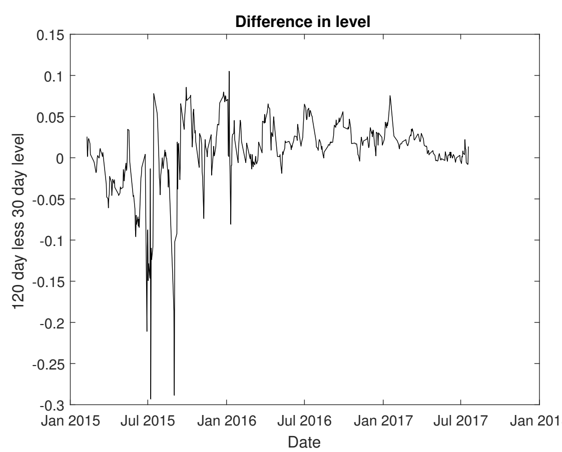
(a) Interpolated implied forward price



(b) Difference in implied forward from two terms

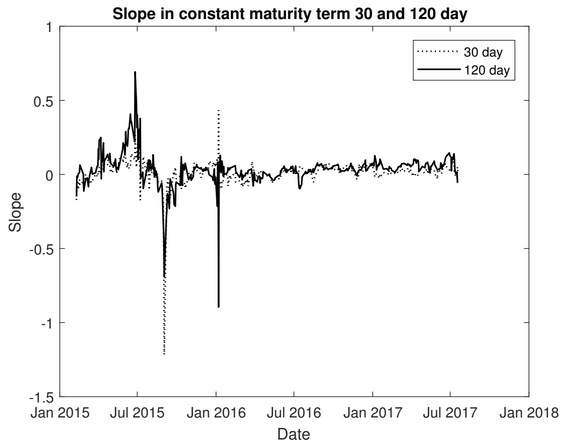


(c) IV level in two terms

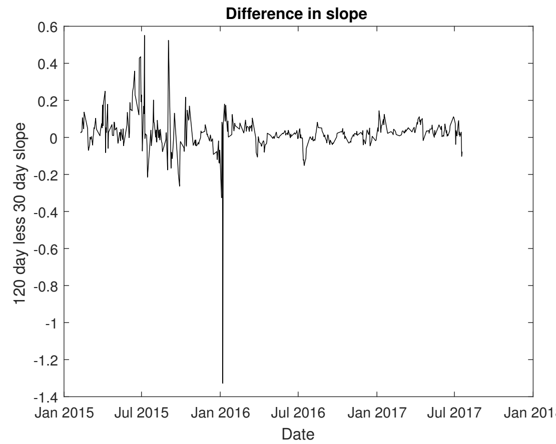


(d) Difference in IV level

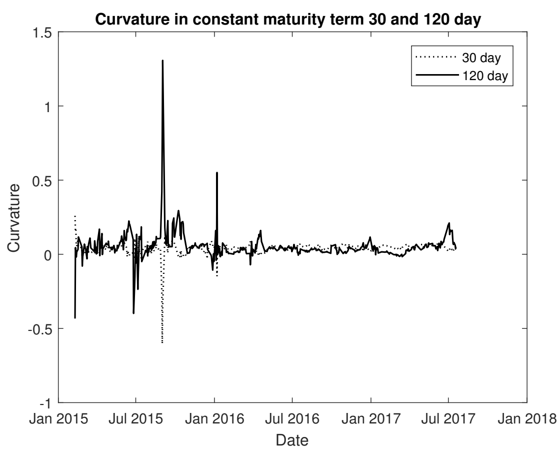
Figure 9 cont.



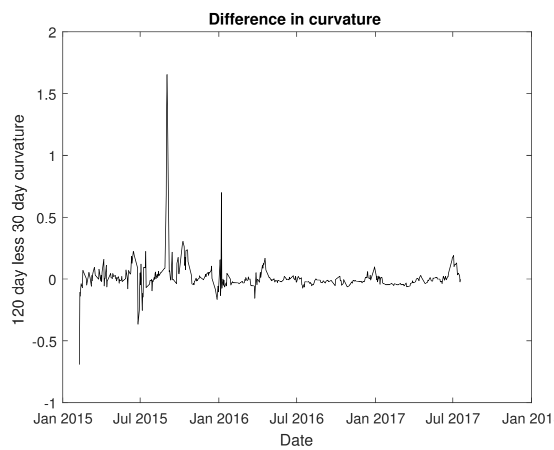
(e) IV slope in two terms



(f) Difference in IV slope



(g) IV Curvature in two terms



(h) Difference in IV curvature

Table 1: Summary of leading ETF funds in China (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 report the fitted results for the Implied volatility function:

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

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. We fit all the OTM option in our dataset. We report the mean coefficient across 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 Adjusted 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 by two terms: 30 and 120 days. We also report the terms in sub samples: during/before/after the financial crisis (FC) sub sample period (15 June 2015 to 31 August 2015). IV(ξ)=α_0+$\alpha_1\xi$+$\alpha_2\xi^2$, where IV is the implied volatility calculated from market price and ξ 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.

	Full Sample		During FC		Before FC		After FC	
Days	30	120	30	120	30	120	30	120
Panel A: Implied Forward Price								
Mean								
F^τ	2.3908	2.3883	2.6154	2.6611	2.8573	2.8847	2.2734	2.2596
Standard deviation								
F^τ	0.3001	0.3252	0.2764	0.3139	0.3608	0.3766	0.1524	0.1666
Panel B: Fitted coefficients								
Mean								
α_0^τ	0.2512	0.2579	0.4945	0.4427	0.3633	0.3391	0.2024	0.2213
α_1^τ	0.0011	0.0095	0.0169	0.0576	0.012	0.0327	-0.0032	-0.0008
α_2^τ	0.0082	0.0155	0.0079	0.0198	0.0158	0.0191	0.0062	0.0153
γ_0^τ	0.2512	0.2579	0.4945	0.4427	0.3633	0.3391	0.2024	0.2213
γ_1^τ	0.0107	0.0341	0.0315	0.1093	0.0205	0.0786	0.0059	0.0164
γ_2^τ	0.0395	0.0526	0.021	0.0499	0.0424	0.0512	0.0401	0.0547
Standard deviation								
α_0^τ	0.1421	0.1178	0.1321	0.076	0.0962	0.0755	0.1075	0.1003
α_1^τ	0.0477	0.0492	0.0573	0.1066	0.0238	0.0461	0.0497	0.0341
α_2^τ	0.0251	0.0491	0.0357	0.0724	0.0153	0.0306	0.0268	0.0506
γ_0^τ	0.1421	0.1178	0.1321	0.076	0.0962	0.0755	0.1075	0.1003
γ_1^τ	0.0859	0.1089	0.0944	0.1975	0.0615	0.1101	0.0889	0.0901
γ_2^τ	0.0466	0.0974	0.0551	0.1286	0.0416	0.0785	0.0488	0.0989