How do US Option Traders "Smirk" on China: Evidence from FXI Options Market

Jianhui Li
Department of Accountancy and Finance
Otago Business School, University of Otago
Dunedin 9054, New Zealand

Sebastian Gehricke
Department of Accountancy and Finance
Otago Business School, University of Otago
Dunedin 9054, New Zealand

Jin E. Zhang
Department of Accountancy and Finance
Otago Business School, University of Otago
Dunedin 9054, New Zealand

First Version: 23 May 2018
This Version: 30 July 2018

Abstract

Motivated by the rising attention to the Chinese equity market, we investigate the shape and dynamics of the implied volatility of FXI options. The FXI options market is the largest and most active China-targeted options market. We demonstrate that the IV curve of FXI options can be quantified well by three factors, the level, slope and curvature, adopting the methodology of Zhang and Xiang (2008), and is usually in a smirk shape. We further study the term structure of the IV factors and find that, on average, the smirk becomes steeper and more convex as the maturity of the options increases. The dynamics of the level and curvature are usually positive and those of the slope are usually negative. The implications of our findings also provide empirical features that an FXI option pricing model must be able to produce, namely the average risk-neutral standard deviation, skewness and excess kurtosis need to be positive, negative and slightly positive, respectively.

Keywords: FXI options; China equities; Implied volatility; FXI smirk;

1 Introduction

This study quantifies and examines the shape and dynamics of the implied volatility (IV) of FXI options. The FXI options market has become the largest and most liquid China-related options market. This is the first paper concentrating on the FXI options market and presenting the feature of the IV smirk of FXI options. We adopt and expand the methodology developed by Zhang and Xiang (2008) to quantify the IV by fitting a quadratic function. This results in three IV factors, the level, slope and curvature. On average, the FXI IV exhibits a smirk shape, similar to that of S&P 500 options. To look at the dynamics of the IV, we estimate the regression each day and for each maturity over our 12 year sample. We further develop the constant maturity IV factors to study the term structure and time series dynamics more accurately. As the maturity of FXI options increases the IV smirk becomes steeper and more convex. The empirical features we present provide implications for the development of an FXI option pricing model.

FXI option contracts are traded in the U.S. and have become the largest and most active options targeted on Chinese equities available to global traders. The underlying ETF, iShares China Large-Cap Exchange-Traded Fund, is an exchange-traded fund seeking to replicate the performance of the Financial Times Stock Exchange (FTSE) China 50 Index. In 2001, when it was first launched, the index consisted of 25 large-capitalization Chinese equities that trade on the Hong Kong stock exchange. After a tremendous expansion of the Chinese equity market, on 22 Sept. 2014, the index was enhanced from 25 to 50 constituents. The FXI tracks the performance of the FTSE China 50 Index very closely. The FXI slightly underperforms the underling index due to the fund fees. It is far larger and more liquid than other China-targeted ETFs, and therefore it is the most important fund providing exposure to Chinese equities. From reading news on Chinese equities it is obvious that the FXI is the For example, the tariff war with America is among the factors depressing stocks in China recently and making some traders to go bearish on FXI. "One options trader is betting on bigger losses for Beijing's big-cap stocks, targeting iShares China Large-Cap ETF (FXI) put options in today's trading," notes Schaeffers Investment Research (Venema (2018, July 13)). "Without a clear answer, a recent 6% run-up in the iShares China Large-Cap exchange-traded fund (ticker: FXI) looks like a one-off driven by an off-again turn in trade tensions and the June 1 inclusion of some Chinese A-shares in MSCI global indexes," Wall Street Journal (Mellow (2018, July 11)). It is valuable to work on FXI options market to provide more modelling implications for global traders to invest in the Chinese market.

In this paper, we study the shape and the dynamics of the IV of FXI options. We can usually find a smirk shape in the fitted IV curves. The overall level, which also estimates the exact at-the-money IV (ATM IV), and slope, are usually positive and negative, respectively, while the curvature fluctuates around zero with a positive mean. The term structure of the level is upward sloping, while the term structures of the slope and curvature are downward sloping. We also explore time series dynamics of the FXI IV curves and find that the level (ATM IV) and curvature mean revert above zero while the slope is downward sloping. The 30- and 180-day level (ATM IV) factors mean revert with prolonged periods of high volatility during some periods of economics of recession and revival. The spikes of longer maturity slope and curvature are larger and more frequent.

Theories on the IV smirk have made vast progress in the recent decade. Under Black and Scholes (1973), options with the same time to maturity are supposed to have the same IV regardless of strike price. However, the IV calculated by the standard Black and Scholes (1973) method is different across strikes, which is called the IV skewness. To address this issue, a number of stochastic volatility models have been created (such as Stein and Stein (1991); Heston (1993); Bates (1996); Barndorff-Nielsen and Shephard (2004)). IV is useful to measure the performance of a stochastic volatility option pricing model.

Literature on the IV "smile" and "smirk" in the US market has been growing since Rubinstein (1985) (Corrado and Su (1997); Skiadopoulos et al. (2000); Cont and Da Fonseca (2002); Carr and Wu (2003); Foresi and Wu (2005); Yan (2011); Fajardo (2017)). They find the phenomenon of the implied volatility smile has became to be a smirk since the global market crash in 1987, i.e. the implied volatility has been left-skewed since then. There is a handful of studies exploring the same pattern in other popular stock markets and also trying to explain the phenomenon. Pena et al. (1999) reports the pattern of IVs of options on the Spanish IBEX-35 index and tries to explain the smile using transaction costs and time to expiration. Shiu et al. (2010) finds that the shape of IVs of Taiwan TAIEX options changes from a smile before the sub-prime mortgage crisis to a smirk after the beginning of the crisis, and explain that the reason was the net buying pressure for index calls.

There is also a vast strand of literature trying to explain the causes of the shape of the IV smile and smirk (Garleanu et al. (2009); Xing et al. (2010); DeMiguel et al. (2013); An et al. (2014)). The errors of measurement and/or investor behavior are among the proposed explanations for the volatility skewness (Pan (2002); Hentschel (2003); Bollen and Whaley (2004); Han (2007); Xing et al. (2010); DeMiguel et al. (2013); An et al. (2014)). There is also growing literature focusing on the predictive power of IV for the future returns of the underlying asset (Corrado and Su (1997); Dennis and Mayhew (2002); Jiang and Tian (2005); Dennis et al. (2006); Xing et al. (2010); Doran and Krieger (2010); Yan (2011); Conrad et al. (2013); DeMiguel et al. (2013); Cremers et al. (2015); Vasquez (2017)).

Studies on China-related options are rare. Chang et al. (2013) compares the warrants in China to typical options on the risks and returns using the historical volatility. Wu (2011), and Xiong and Yu (2011), study the warrant bubbles empirically related to the dramatic crash in 2007. There is a few studies focusing on modeling the IV of the Chinese stock market (Lee et al. (2001)), and the impact of IV on the market (Zhou et al. (2012)).

This work delivers two novel contributions. Our first contribution is that we provide the first comprehensive analysis of the IV shape and its dynamics of the world's largest emerging equity market, the Chinese market. The FXI options market is largest and most liquid China-related options market and thus an ideal target to work on for investors and practitioners who are interested in the Chinese equity market. Our second contribution is that we calculate term structures and its dynamics of the quantified FXI IV factors, the level, slope and curvature, which could be used to calibrate an FXI option pricing model. Our empirical findings provide the starting point for the development of an FXI option pricing model.

The rest of this study is organized as follows. In section 2 we provide a background of the FXI options market including its underlying, FXI ETF, and the FXI's target index. In section 3, we present our sample data. Then in section 4 we describe the methodology for data processing and and for quantifying the IV of the FXI options. section 5 presents and analyzes the results and lastly, section 6 concludes.

2 Background of FXI Options Market

FXI option contracts have been traded at the CBOE from 2004 and are physically settled American style options. Figure 1 reviews the volume and open interest growth on a daily basis during our sample period from 2004 to 2016. As we can see the market has been growing in activity and size significantly over the past decade.

The iShares China Large-Cap Exchange-Traded Fund (ETF), which is known as FXI, was created by BlackRock in 2004, seeking to track the investment results of the FTSE China 50 Index. The FXI option contracts are equity-settled American-style options traded on CBOE.

2.1 FTSE China 50 Index

The FTSE China 50 Index is composed of 50 large-capitalization Chinese equities that trade on the Hong Kong stock exchange.[1] It was designed by FTSE/Xinhua Index Ltd. and launched in 2001.

The index originally consisted only of H-shares and Red-chip stocks.[2] Along with the development of private enterprises in the Mainland China and the ownership distribution of large companies in China shifting a lot, it became hard to ignore the importance of these companies on both the stock market and the economy of China. As a result, P-chip stocks have been included into the index since 18 March 2013.[3] Only two P-chips were added into the index on that day grabbing 9.5% of the total market capitalization of the index. At the end of April 2018, there were seven P-chip stocks (Table 1), which accounted for nearly 20% of the total market capitalization of the index. The largest P-chip added, the Internet Company Tencent, has been one of the top three holdings for many years.

The index was originally composed of 25 large-capitalization Chinese equities that trade on the Hong Kong stock exchange. Considering that the market had been through a tremendous growth phase, the index was approved to be enhanced from 25 holdings to 50 by the FTSE Russell advisory committee on 22 Sept. 2014. The newly included 25 stocks accounted for only 6.76% of the total weights on the transaction day.

[1] The 50 components of the index as of April 2018 are listed in Table 1, ranked by their weights. Table 2 reports the breakdown of the constituents by ICB (Industry Classification Benchmark)

[2] According to FTSE Russell, H-shares are securities of companies incorporated in the Peoples Republic of China and nominated by the central government for listing and trading on the Hong Kong stock exchange. Like other securities trading on the Hong Kong stock exchange, there are no restrictions on who can trade H-shares. A Red-chip a company incorporated outside the Peoples Republic of China (PRC) that trades on the Hong Kong stock exchange and is a company that is substantially owned, directly or indirectly, by Mainland China state entities with the majority of its revenue or assets derived from Mainland China.

[3] A P-chip is a company controlled by mainland individuals, with the establishment and origin of the company in Mainland China. It must be incorporated outside of Mainland China and traded on the Hong Kong stock exchange with a majority of its revenue or assets derived from Mainland China.

2.2 FXI ETF

The FXI ETF is an exchange-traded fund designed to track the investment results of its underlying index, the FTSE China 50 Index, which represents the performance of the 50 largest and most liquid Chinese companies currently traded on the Hong Kong stock exchange. No less than 90% of the fund's assets shall be invested in the securities in the underlying index and depository receipts representing the securities of the underlying index, while the rest may be invested in derivatives, cash, cash equivalent etc[4]. FXI delivers a fairly close but slight underperformance relative to the underlying index (benchmark), as shown in Figure 2. The cumulative underperformance relative to the index is mostly due to the fund fees.

Table 3 reports the four most liquid China-targeted U.S. traded ETFs including FXI for comparison.[5] Of these ETFs FXI is the most mature, the most liquid and the largest fund. The total asset of iShares MCSI China ETF, the second largest of the ETFs, is less than one fifth of that of FXI and is far larger than the other two ETFs, as of 30 April 2018. The FXI is by far the most traded of the China-targeted ETFs, as shown by the dollar trading volume over the whole sample and just for April 2018.

The FXI ETF's underlying index consists of stocks that are traded on the Hong Kong stock exchange, a crucial developed market in Asia. The Shanghai and Shenzhen stock exchanges in Mainland China are tricky for international investors because of restrictions. By contrast the Hong Kong stock exchange is more developed and less restricted, and provides the access, transparency and liquidity required by global traders. For those who want to invest in or are interested in the emerging market of China, we believe that research on FXI would help provide the most reliable information compared to those on other China-

[4]Table 1 lists securities that the FXI ETF invests in as of 30 April 2018.

[5]It should be noted that Direxion Daily China 3x Bull Shares (Ticker: YINN) delivers three times return of FXI.

related ETFs. The FXI consists of the 50 largest capitalization equities in one single fund and is therefore more representative of the entire Chinese economy, compared to those funds tracking the performance of small capitalizations. In summary, FXI delivers a cheap, easy, transparent, liquid and reliable way for global traders to invest in the Chinese market.

3 Data

We obtain the FXI options data, including the IVs from OptionMetrics IvyDB for the sample period from 19 October 2004 to 29 April 2016. The underlying index data is obtained from the Bloomberg professional service and so is the ETF trading data and dividends. The treasury yield data is downloaded from the website of the United States Department of the Treasury.

As FXI options are American-style, the IV provided by OptionMetrics is calculated using an algorithm based on the industry-standard Cox-Ross-Rubinstein binomial tree model(Cox et al. (1979)). To get the IV, first the model option price at time $t = 0$ is calculated using the binomial tree model, and then they extract the corresponding IV that results in the model price matching the market price.

Table 4 reports a summary of the options data. We clean the data by deleting those options with no IV, zero IV or zero open interest. Options with less than six days to expiration are also removed because they may induce liquidity-related biases (Bakshi et al. (1997)) though there is some literature studying the small-time smile pattern (Forde and Jacquier (2009) and Forde et al. (2012)). No obvious pattern can be observed across maturity groups for the number of observations or mean number of strikes and contracts. However, the trading volume and open interest seem to be decreasing as maturity increases. This indicates that the closer the expiration is, the more reliable the IV data will be. The dividends distributed in the sample period are from OptionMetrics IvyDB and listed in

Table 5.

4 Methodology

4.1 Risk Free Rate

We proxy the risk free rate by using US treasury yields. In order to get the risk free rate with the same maturities we adopt the linear interpolation and extrapolation method. The appropriate risk free rate is given by:

$$r_\tau = r_{\tau_1} + \frac{\tau - \tau_1}{\tau_2 - \tau_1}(r_{\tau_2} - r_{\tau_1})$$

where r_τ is the target maturity risk free rate, τ is the target corresponding time to maturity. r_{τ_1} and r_{τ_2} are the treasury yield rates of maturity τ_1 and τ_2, respectively, that are closest to τ.[6]

4.2 Forward Price

We remove those option quotes with zero bid price or zero volume for calculation. The mid-value of the best bid and ask price is used as a proxy for the market price of options.

According to the no arbitrage rule the forward price can be expressed as:

$$F_{t,T} = S_t e^{(r-q)(T-t)}, \tag{1}$$

where $F_{t,T}$ is the forward price at time t with expiration day T, S_t is the price of the underlying asset, i.e. the FXI ETF, and q is the continuously compounded dividend yield through time t to T.

Assuming that the dividend is reinvested we approximate the dividend yield over the

[6]For calculation, we transform the original risk free rate data in 1, 3, 6 months, and 1, 2, 3 years to 30, 91, 182, 365, 730 and 1095 days, respectively.

sample using the following equation:

$$(1+\frac{D_1}{S_1})(1+\frac{D_2}{S_2})...(1+\frac{D_n}{S_n}) = e^{q(T-t)} \tag{2}$$

where D_i is the i-th time that dividend is paid in our sample and S_i is the price of FXI ETF on the payment date of D_i. Both sides of this equation are the cumulative growth of one share of the FXI ETF due to the reinvestment of the dividends. The left hand side represents the actual growth of one share using discretely paid dividends, while the right hand side is the equivalent growth represented by a continuously paid dividend. We solve the equation over our sample period to get the average continuously compounded dividend yield $q = 0.0193$, which we use in Eq. 1 to approximate the forward price $F_{t,T}$.

The market ATM strike price K_0 is the one closest to $F_{t,T}$ for each maturity and each day. Following Carr and Wu (2003), the methodology used by CBOE in the calculation of the VIX index and market practise, we select the IV of out-of-the-money options to represent the FXI options market. An out-of-the-money option is normally more liquid and more model-sensitive than the in-the-money options, and therefore is widely used when examining IV curves by investigators, researchers and exchange holding companies, such as CBOE. For put options we select those whose strike prices are smaller than the forward price, i.e. $K < F_{t,T}$, and for calls we select those whose strike prices are larger than the forward price, i.e. $K > F_{t,T}$.

4.3 Moneyness

Following Zhang and Xiang (2008) the moneyness of an option, ξ, is defined as,

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

where K is the strike price, $F_{t,T}$ is the forward price, τ is the time to maturity of the option on an annual basis, and $\bar{\sigma}$ denotes the average 30-day volatility of the underlying asset price. The $\bar{\sigma}$ in the denominator of moneyness is designed for comparisons across different underlying assets. We proxy $\bar{\sigma}$ each day by the 30-day ATM IV, which is calculated by interpolation between the two IVs with maturities closest to 30 days, from above and below.

4.4 Quantifying Implied Volatility

We then follow Zhang and Xiang (2008) in order to quantify the IV curve using the model given by:

$$IV(\xi) = \gamma_0(1 + \gamma_1\xi + \gamma_2\xi^2), \tag{3}$$

where the factors γ_0, γ_1 and γ_2 capture the level, slope and curvature of the IV, respectively. The level is also referred to as an estimate of the exact ATM IV.

For the convenience of fitting and ANOVA test, we construct a simple second-order polynomial, i.e.

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

where the coefficients α_0, α_1 and α_2 can be easily converted to the quantified IV curve factors by:

$$\gamma_0 = \alpha_0, \tag{5}$$

$$\gamma_1 = \frac{\alpha_1}{\alpha_0}, \tag{6}$$

$$\gamma_2 = \frac{\alpha_2}{\alpha_0}, \tag{7}$$

We fit the quadratic function, Eq.4, by volume-weighted least square method (VWLS), minimizing the volume-weighted mean square error given by:

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

to obtain coefficients (α_0,α_1,α_2) of Eq.4 and scaled parameters (γ_0,γ_1,γ_2) of Eq.3.

For precision of the fittings, we first delete those maturities with less than five non-zero volumes on each day. We then filter the data by medians of non-zero volumes for each day and maturity. When the median volume is less than 10 we adopt Ordinary Least Squares (OLS) to fit the function instead of VWLS. Ideally we would always use VWLS to emphasize information from more liquid contracts, but we also want to fit the market IVs well when trading is a small number of contracts.

5 Results

In this section, we report and discuss the results of quantifying the IV curves of FXI options. Following the method above we plot the fitted IVs for each available maturity using three random days 8 December 2014, 15 May 2015 and 28 April 2016. We also fit the quadratic function Eq. 3 for the full sample of options to study the dynamics of the FXI IV by examining the resulting level, slope and curvature factors. We then calculate the constant maturity IV factors in order to study the FXI IV term structure and its time series dynamics.

Figure 3 (a) shows the IV and trading volumes, provided by OptionMetrics Ivy DB, and the fitted IV using the methodology described in Section 4 on 28 April 2018 for the time to maturity of 22 days. From this figure a smirk can be observed. We will show that this kind of smirk is the typical shape of the FXI IV curve. Figure 3 (b) and (c) show the IVs of all the put and call option contracts for the same maturity and on the same day as Figure 3 (a). As we can see there is a slight jump at $\xi = 0$, i.e. the IV of calls and puts are not equal at the money. Cremers and Weinbaum (2010) and Doran et al. (2013) study this gap between put and call American option prices as a predictor of future returns of the underlying. This is not our focus in this paper. On this day for the 22 days to maturity options our fitted IV curve matches the market data very closely.

We use the volume filter mentioned in the methodology to get more precise fittings. This filter eliminates some of the strange fitted curves (Figure 4 (h)) that result from relative large volumes in a particular OTM option, forcing too much emphasis on fitting this IV. Using OLS in these cases results in a much better fit (Figure 5 (h)). The affected sample using OLS fittings accounts for 12% of the entire sample.

Figures 5, 6 and 7 show the market IV, fitted IV curves and the trading volumes for all available maturities on 28 April 2016, 15 May 2015 and 8 December 2014, respectively. As we can see, the smirk pattern can be observed in most of these graphs. The fitted curves seem to approximate the IV well, while there still exists a handful of abnormally shaped fitted curves which don't approximate the data well even after the filter (Figure 5 (f) and (g)). This could be due to the relatively large trading volumes of a small number of deep out-of-the-money contracts forcing an unusual fitting by VWLS.

We further quantify the IV for the entire sample of FXI options. Table 6 summaries the resulting parameters and factors as well as the forward prices, by maturity groups. The maturity groups are less than 30, 30 to 90, 90 to 180, 180 to 360 and more than 360 days, because we initially want to analyze the general term structures of the factors. Overall, the exact ATM IV (level) is positive and the curves tend to be negatively sloped with some positive curvature (convexity), i.e. a smirk shape as is found for S&P 500 options by Carr and Wu (2003), Foresi and Wu (2005) and Fajardo (2017), amongst others. The overall average level, slope and curvature are 0.3094, -0.1992 and 0.0771, respectively, with corresponding standard deviation of 0.1235, 0.1615 and 0.1482. Therefore, the level is mostly positive and the slope is mostly negative, while the curvature fluctuates between positive and negative values. The term structures of $F_{t,T}$ and the level are upward sloping and in contrast those of the slope are downward sloping. The term structure of the curvature is also downward sloping until the time to maturity is more than 360 days and then increases drastically. The standard deviations of $F_{t,T}$ and the factors increase with maturity except that of the level, which shows a downward trend across the maturity categories. This decrease in the standard deviation of the level with larger maturities may be a hint that the ATM IV mean reverts, consistent with the common finding that the implied volatility of ATM US equity options mean reverts (Dueker (1997); Fouque et al. (2000); Higgs and Worthington (2008)). Table 6 also provides the proportion of fitted curves for which the coefficients are significant at the 5% level of significance. The proportion of significant coefficients decrease as the maturity increases and for the curvature this decrease is very dramatic when the time to maturity is more than 360 days. The mean R^2 and R^2_{adj} are also shown in Table 6. Overall and for each maturity group they are close to 100%, indicating that our quantification of the FXI IV is reliable. However, we can observe that the fit quality (R^2) decreases slightly as the maturity increases.

Previously we divided the IV curve factors into groups by maturity. However, this often groups many different maturities each day into one category. In order to examine the term structures of the level, slope and curvature factors and their time series dynamics more accurately, we create the constant maturity factors. The constant maturity factors for the maturities of 30, 60, 90, 120, 150, 180 and 360 days are obtained by interpolation and extrapolation. Table 7 presents the constant maturity IV factors. The overall level, slope and curvature are as discussed above, that is, the level and slope are mostly positive and negative, respectively, while the curvature fluctuates around zero. The term structure of the level is now flat, different from the above result of being upward sloping as shown in Table 6. Consistent with the results in Table 6 the term structure of the curvature is flat and that of the slope is downward sloping, and the standard deviations of the factors are increasing with maturity except the level, which decreases with maturity. In Figure 8 we present the predicted IV curves using the mean constant maturity factors to visualize the results presented in Table 7. We can see that the IV curve of the FXI options market is usually in a smirk shape. As maturity increases the smirk becomes more negatively sloped and more convex.

We plot the time series of the 30-day and 180-day constant maturity factors in the left panel of Figure 9 in order to observe the time series dynamics of the FXI IV curve. In general the dynamics of 30- and 180-day constant maturity are consistent with the above results that the level time series is always positive, the slope is usually negative and the curvature fluctuates around a slightly positive value. Specifically, in Figure 9 (a) the 30- and 180-day level factors mean revert with prolonged periods of high volatility during the global financial crisis (GFC) period (late 2007 to early 2009), the rapid recovery period (the second half of 2011) and the most recent depression period in China (early 2015 to 2016). In Figure 9 (c), we can see that the slope is usually negative, but the 180-day slope fluctuates a lot more. In Figure 9 (e), we can see that curvature tends to be slightly positive most of the time and the longer maturity options IV curvature spikes are larger and more frequent. Turning to the difference in the 180- and 30-day factors in Figure 9 (b), (d) and (f), we can see that the term structures of the level (ATM IV), slope and curvature are usually downward sloping, downward sloping and flat. However, the level (ATM IV) experiences a period of extremely steep downward sloping term structure during the GFC.

To summarize we find that overall, the level is always positive and has a fairly flat term structure, the slope is negative and has a downward sloping term structure and the curvature fluctuates around a slightly positive average with a downward sloping term structure for maturity of less than 360 days. The level seems to mean revert with prolonged periods of increased maturity during the GFC, recovery period and recent depression in China. The time series of the slope and curvature are usually fluctuating around a positive, negative and slightly positive value, respectively, with times of spikes.

In this section, we present and examine the IV smirk pattern in FXI options and break down the IV of FXI options to three factors, the level, slope and curvature, and calculate the corresponding term structures and dynamics, which could be converted to estimates of the FXI risk-neutral moments. Therefore, we can also provide recommendation for an FXI option pricing model. It must exhibit a positive risk-neutral standard deviation that mean reverts with a flat term structure, a negative risk-neutral skewness with a downward sloping term structure and a slightly positive risk-neutral excess kurtosis with a flat term structure.

6 Conclusion

In this paper we study the IV smirk of FXI options and its dynamics, and further provide a modelling implication for option pricing for investors and practitioners. Following the methodology in Zhang and Xiang (2008), we fit a quadratic regression using VWLS each day and for each maturity over a sample period of 12 years to quantify the IV. The IV can be summarized by three factors the level, slope and curvature. We then extend the methodology in Zhang and Xiang (2008) and calculate the constant maturity factors of the IV of FXI options to examine the term structure and dynamics of the factors. We can usually find a smirk shape in the fitted curves of IV. A volume filter is used to get more precise fittings, resulting 12% of the regressions to be fitted by OLS.

We divide the IV curve factors into groups by maturity to analyze the term structures of the factors. The IV usually has a positive level (ATM IV) with a negative slope and a curvature that fluctuates between positive and negative values. The term structure of the level and slope is upward and downward sloping, respectively, and that of the curvature is downward sloping until the maturity is more than 360 days and then increases drastically. The standard deviation of the level is decreasing across the maturity categories while others are increasing, which could imply that the ATM IV mean reverts.

To examine the term structures more accurately, we then calculate the constant maturity factors by interpolation and extrapolation finding consistent results as above on average. However, the term structure of the level is flat. From the predicted IV curves using the mean constant maturity factors, we can observe the IV smirk of the FXI options clearly. In order to investigate the time series dynamics of the FXI IV curve, we plot the 30-day and 180-day dynamics and find that the 30- and 180-day levels are in the similar shape with periods of high volatility related to the Chinese and global economy. The slope and curvature are usually negative and slightly positive, but spikes of the 180-day ones are larger and more frequent. The term structures of the difference of the 180- and 30-day level (ATM IV) and slope are downward sloping while that of the curvature is flat.

In this work, we show the overall IV smirk in FXI options, its term structures and dynamics. We quantify the IV curves through three factors, the level, slope, curvature. They could be used to calibrate the FXI option pricing model by converting them to neutral moments as in Zhang and Xiang (2008). An FXI option pricing model must have a positive risk neutral standard deviation, a negative risk neutral skewness and a slightly positive risk neutral excess kurtosis. These recommendations will help build the FXI option pricing model and further be able to predict future returns.

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Table 1: Holdings of FXI ETF as of 30 April 2018

This table reports the 50 individual stocks and other investment of FXI ETF, and corresponding weights as of 30 April 2018.

Rank	Name	Asset Class	Weight%	Rank	Name	Asset Class	Weight%
1	China Construction Bank	Equity	9.19	29	China Vanke	Equity	0.92
2	Industrial and Commercial Bank of China	Equity	8.63	30	China Communications Construction	Equity	0.86
3	Tencent Holdings (P Chip)	Equity	8.21	31	China Minsheng Banking	Equity	0.84
4	Ping An Insurance	Equity	5.70	32	Fosun International (P Chip)	Equity	0.81
5	China Mobile (Red Chip)	Equity	5.64	33	BYD	Equity	0.81
6	Bank of China	Equity	4.59	34	Haitong Securities	Equity	0.79
7	CNOOC	Equity	4.25	35	Longfor Properties (P Chip)	Equity	0.74
8	China Petroleum & Chemical	Equity	4.19	36	New China Life Insurance	Equity	0.69
9	China Life Insurance	Equity	3.49	37	Guangzhou Automobile Group	Equity	0.69
10	China Merchants Bank	Equity	2.80	38	Postal Savings Bank of China	Equity	0.68
11	Petrochina	Equity	2.58	39	People's Insurance Company (Group)	Equity	0.68
12	Country Garden Holdings (P Chip)	Equity	2.56	40	CRRC	Equity	0.60
13	Agricultural Bank of China	Equity	2.44	41	Huatai Securities	Equity	0.59
14	China Overseas Land & Inv (Red Chip)	Equity	2.18	42	China Huarong Asset Management	Equity	0.56
15	Geely Automobile Holdings (P Chip)	Equity	2.16	43	China Railway Group	Equity	0.52
16	China Pacific Insurance (Group)	Equity	1.93	44	China Molybdenum	Equity	0.50
17	Sunny Optical Technology Group (P Chip)	Equity	1.81	45	GF Securities	Equity	0.46
18	China Resources Land (Red Chip)	Equity	1.70	46	Air China	Equity	0.41
19	China Evergrande Group (P Chip)	Equity	1.58	47	China Railway Construction	Equity	0.38
20	China Shenhua Energy	Equity	1.42	48	Guotai Junan Securities	Equity	0.33
21	China Unicom Hong Kong Ltd (Red Chip)	Equity	1.42	49	ZTE	Equity	0.29
22	PICC Property	Equity	1.36	50	China Everbright Bank	Equity	0.26
23	CITIC (Red Chip)	Equity	1.26	51	HKD Cash	Cash	0.07
24	Anhui Conch Cement	Equity	1.25	52	BLK CSH FND Treasury SL Agency	Money Market	0.06
25	China Telecom	Equity	1.14	53	Cash Collateral HKD UBFUT	Cash Collateral and Margins	0
26	Bank of Communications	Equity	1.08				
27	China Citic Bank	Equity	1.00	54	H-Shares Index May 18	Futures	0
28	CITIC Securities	Equity	0.94	55	USD Cash	Cash	-0.06
Totals							99.98

Table 2: Constituent breakdown as of 30 April 2018

This table reports the industry classification of 50 individual stocks and corresponding group weights of the FTSE China 50 Index as of 30 April 2018.

ICB Code	ICB Supersector	Number of Constituents	Weight%
8300	Banks	10	31.51
8500	Insurance	6	13.84
0500	Oil&Gas	3	11.01
8600	Real Estate	6	9.68
9500	Technology	2	8.62
6500	Telecommunications	3	8.19
8700	Financial Services	6	3.68
2700	Industrial Goods&Services	3	3.68
3300	Automobiles&Parts	3	3.65
2300	Construction&Materials	4	3.01
1700	Basic Resources	3	2.73
5700	Travel&Leisure	1	0.41
Totals		50	100

Table 3: Summary of relevant ETF's

This table reports summary information for the top 4 largest China-related ETFs as of 30 April 2018.

Symbol	ETF Name	Leverage	Issuer	Inception	Total Assets ($M)	Avg. Dollar Trading Volume since Inception	Avg. Dollar Trading Volume in Apr 2018
FXI	iShares China Large-Cap ETF	1	BlackRock	5-Oct-2004	4,481.12	586,319,037	1,122,664,445
MCHI	iShares MSCI China ETF	1	BlackRock	31-Mar-2011	3,508.17	43,678,452	205,829,647
ASHR	Deutsche X-trackers Harvest CSI 300 China A-Shares Fund	1	Deutsche Bank	6-Nov-2013	511.89	37,307,169	25,963,462
YINN	Direxion Daily China 3x Bull Shares	3	Direxion	3-Dec-2009	309.06	11,380,554	35,925,974

Table 4: Sample summary

This table reports the mean daily number of strikes, contracts, trading volume and open interest of the options data for the sample period 19 October 2004 to 29 April 2016 in each maturity category. The daily numbers of open interest or volume are calculated as the mean of the daily trading volume for overall and for each maturity category.

Maturity	Overall	< 30	$30 - 90$	$90 - 180$	$180 - 360$	> 360
Number of Observations	22,145	4,019	5,878	4,209	4,120	3,919
Mean Number of Strikes	39	42	44	47	38	20
Mean Number of Contracts	78	85	88	95	76	40
Mean Daily Trading Volume	55,919	22,709	23,642	8,538	4,750	1,563
Mean Daily Open Interest	1,511,243	434,264	520,272	322,366	253,253	102,963

Table 5: FXI dividend schedule

This table reports the dividend distributed in our sample period from 19 October 2004 to 29 April 2016. The forward price,

$$F_{t,T} = S_t e^{(r-q)(T-t)},$$

where $F_{t,T}$ is the forward price at time t with expiration day T, S_t is the price of the underlying asset, and q is the continuously compounded dividend yield through time t to T.
We assume that the dividend is reinvested. q can be approximated using the following equation:

$$(1+\frac{D_1}{S_1})(1+\frac{D_2}{S_2})...(1+\frac{D_n}{S_n}) = e^{q(T-t)}$$

where D_i is the i-th time that dividend is paid as in the table below and S_i is the price of FXI ETF on the payment date of D_i. We solve the equation over our sample period to get the average continuously compounded dividend yield $q = 0.0193$, which we use to approximate the forward price $F_{t,T}$.

Record Date	Payment Date	Dollar Amount	Record Date	Payment Date	Dollar Amount
28-Dec-05	30-Dec-05	1.25	21-Dec-11	29-Dec-11	0.08
26-Dec-06	28-Dec-06	1.31	22-Jun-12	27-Jun-12	0.85
27-Dec-07	04-Jan-08	2.09	19-Dec-12	27-Dec-12	0.09
25-Jun-08	27-Jun-08	1.68	27-Jun-13	02-Jul-13	0.84
24-Dec-08	31-Dec-08	0.21	19-Dec-13	27-Dec-13	0.17
24-Jun-09	26-Jun-09	0.33	26-Jun-14	01-Jul-14	0.54
23-Dec-09	31-Dec-09	0.22	23-Dec-14	29-Dec-14	0.51
23-Jun-10	25-Jun-10	0.46	26-Jun-15	30-Jun-15	0.25
22-Dec-10	30-Dec-10	0.17	23-Dec-15	28-Dec-15	0.77
23-Jun-11	27-Jun-11	0.69			

Table 6: Summary of coefficients

This table reports summary results for the estimated IV function:

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

where IV is the implied volatility and ξ is the moneyness of the option. We include a filter of those maturities with contracts whose median volume is smaller than ten. We fit those particular regressions using OLS, which account for 12% of all regressors. The estimated coefficients $\hat{\alpha}_0$, $\hat{\alpha}_1$, $\hat{\alpha}_2$ can be converted to the quantified IV factors $\hat{\gamma}_0$, $\hat{\gamma}_1$, $\hat{\gamma}_2$. We fit the regression for each day and each maturity over the entire sample as described in Section 4. The percentage of the significant coefficients is the percentage of parameter estimates that are significant at the 5% level of significance. We remove IV curves which have less than five contracts that have non-zero trading volumes.

Maturity	Overall	< 30	$30-90$	$90-180$	$180-360$	> 360
			Mean			
$F_{t,T}$	52.8957	49.2058	52.2675	52.4790	53.0587	61.4866
$\hat{\alpha}_0$	0.3094	0.3037	0.3098	0.3085	0.3060	0.3249
$\hat{\alpha}_1$	-0.0640	-0.0374	-0.0513	-0.0704	-0.0812	-0.1063
$\hat{\alpha}_2$	0.0209	0.0229	0.0185	0.0180	0.0178	0.0346
γ_0	0.3094	0.3037	0.3098	0.3085	0.3060	0.3249
γ_1	-0.1992	-0.1147	-0.1624	-0.2216	-0.2565	-0.3181
γ_2	0.0766	0.0892	0.0716	0.0665	0.0659	0.1074
			Standard Deviation			
$F_{t,T}$	38.2849	32.2338	36.5272	37.8987	38.2603	50.0689
$\hat{\alpha}_0$	0.1232	0.1342	0.1373	0.1171	0.1038	0.0996
$\hat{\alpha}_1$	0.0592	0.0373	0.0475	0.0566	0.0644	0.0769
$\hat{\alpha}_2$	0.0429	0.0266	0.0241	0.0354	0.0539	0.0800
γ_0	0.1232	0.1342	0.1373	0.1171	0.1038	0.0996
γ_1	0.1621	0.1009	0.1295	0.1505	0.1727	0.2058
γ_2	0.1469	0.1145	0.0977	0.1194	0.1845	0.2510
			%Significant Coefficients at 5% level of significance			
$\hat{\alpha}_0$	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%
$\hat{\alpha}_1$	98.24%	94.45%	98.95%	99.22%	99.40%	99.48%
$\hat{\alpha}_2$	81.31%	89.49%	84.84%	81.16%	76.22%	65.76%
			R^2			
Mean R^2	98.25%	98.54%	98.49%	98.33%	98.08%	97.19%
Mean R^2_{adj}	98.00%	98.23%	98.31%	98.19%	97.85%	96.62%
			Daily Trading Volume			
Mean Daily Volume	49,238	19,840	21,382	8,414	4,956	1,815

Table 7: Summary of constant maturity coefficients

This table reports a summary of the fitting results overall and for constant maturities of 30, 60, 90, 120, 150, 180 and 360 days, which are calculated interpolating and extrapolating the estimated coefficients and factors.

Maturity	Overall	30	60	90	120	150	180	360
				Mean				
$\hat{\alpha}_0$	0.3174	0.3221	0.3225	0.3203	0.3195	0.3190	0.3193	0.3267
$\hat{\alpha}_1$	-0.0678	-0.0528	-0.0586	-0.0656	-0.0714	-0.0766	-0.0813	-0.0950
$\hat{\alpha}_2$	0.0197	0.0194	0.0168	0.0167	0.0163	0.0167	0.0177	0.0255
γ_0	0.3174	0.3221	0.3225	0.3203	0.3195	0.3190	0.3193	0.3267
γ_1	-0.2080	-0.1588	-0.1790	-0.2016	-0.2191	-0.2343	-0.2477	-0.2809
γ_2	0.0705	0.0745	0.0636	0.0621	0.0597	0.0602	0.0630	0.0843
				Standard Deviation				
$\hat{\alpha}_0$	0.1247	0.1502	0.1414	0.1323	0.1265	0.1223	0.1193	0.1080
$\hat{\alpha}_1$	0.0530	0.0370	0.0477	0.0516	0.0551	0.0592	0.0616	0.0676
$\hat{\alpha}_2$	0.0229	0.0184	0.0216	0.0258	0.0274	0.0325	0.0415	0.0512
γ_0	0.1247	0.1502	0.1414	0.1323	0.1265	0.1223	0.1193	0.1080
γ_1	0.1336	0.0864	0.1234	0.1357	0.1435	0.1524	0.1561	0.1697
γ_2	0.0814	0.0811	0.0838	0.0961	0.0965	0.1072	0.1322	0.1591

Figure 1: The FXI options market growth

This figure illustrates the daily total volume and open interest of the FXI options market from 19 October, 2004 to 29 April, 2016.

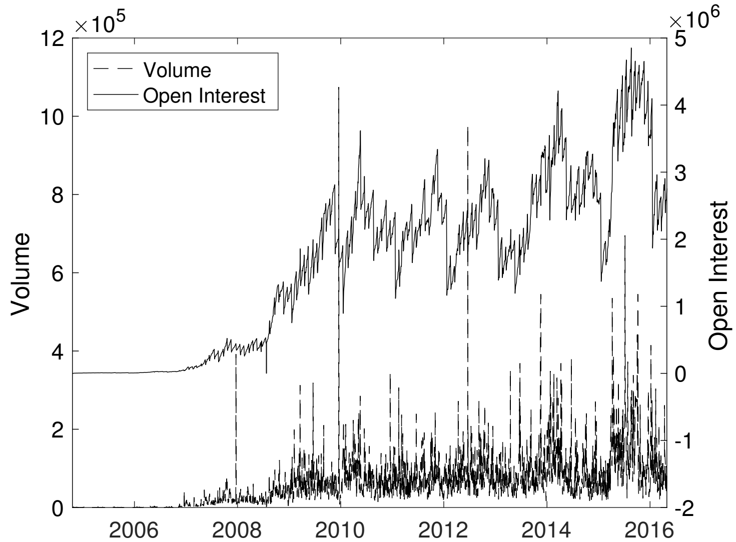


Figure 2: Performance of FXI and its benchmark

This figure reflects the hypothetical growth of a $10,000 investment in the FXI ETF and the benchmark index (Ticker: XIN0I) from 08 October 2004 to 30 April 2018. Dividends are assumed to be reinvested. Fund expenses are deducted for the FXI ETF.

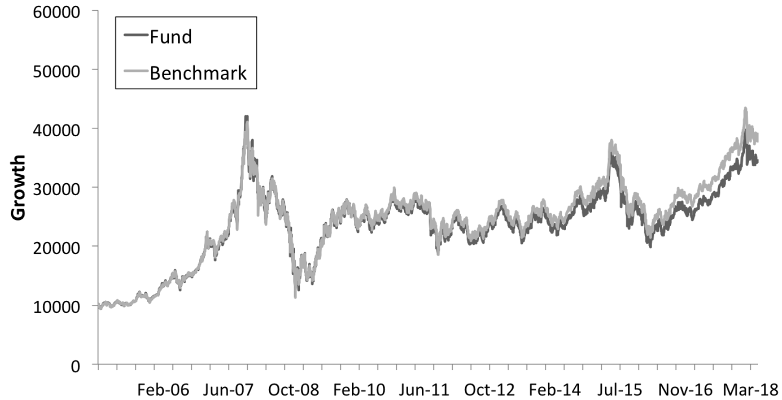


Figure 3: The IV smile on 28 April 2016 expiring on 20 May 2016

Graph 3 (a) illustrates the market IV (crosses) and the fitted IV curves on 28 April 2016. The time to maturity is 22 days and the options will expire on 20 May 2016. Bars in the figure represent the volume. Graph (b) and (c) show the market put and call option IV against moneyness and strike price, respectively.

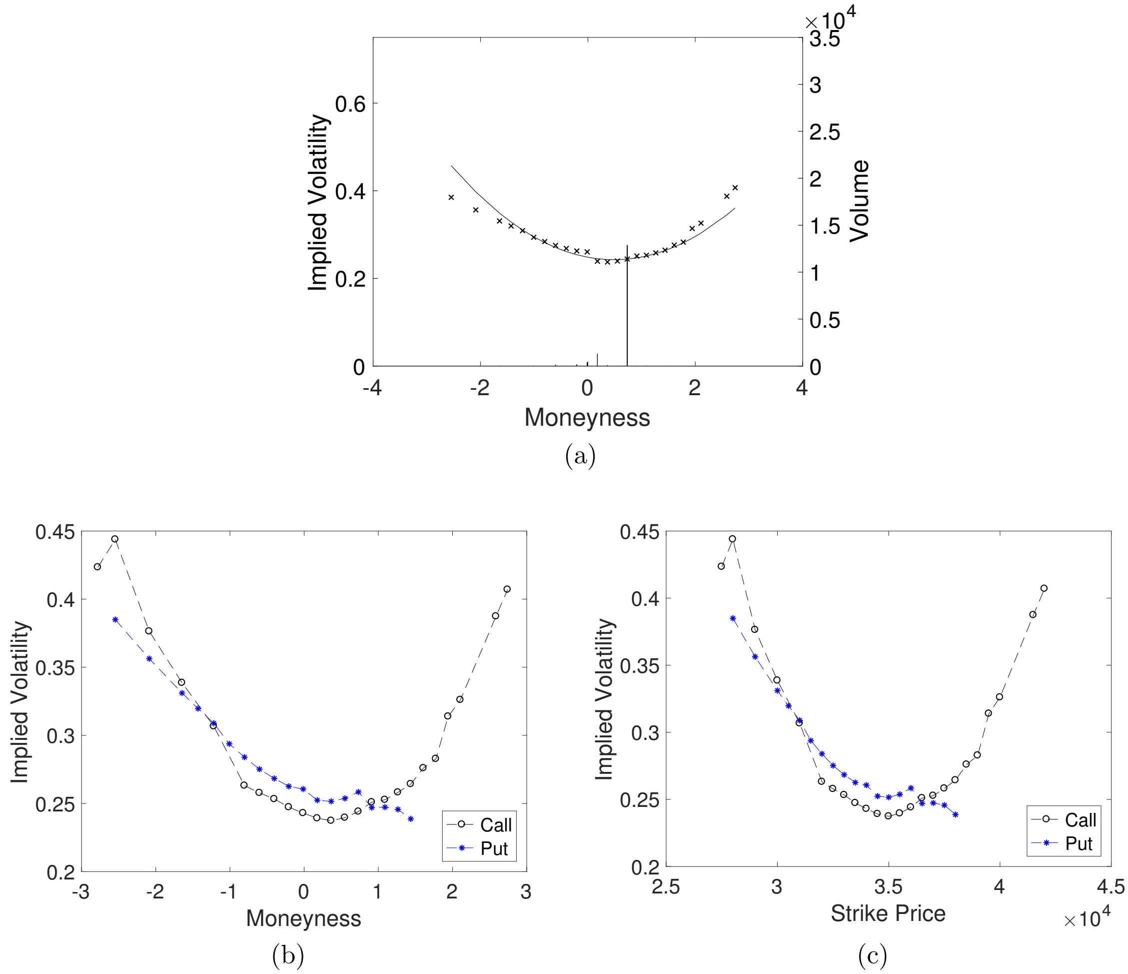
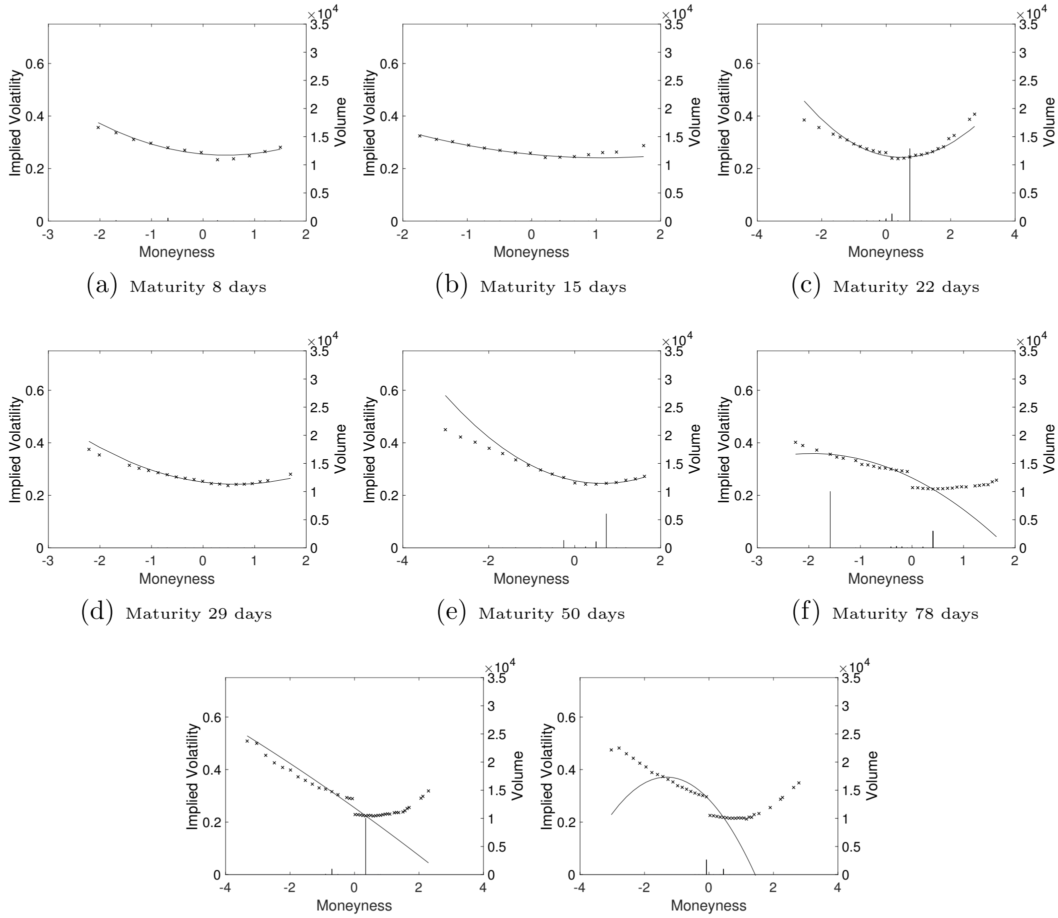


Figure 4: The IV curves without the volume filter

This figure illustrates the market and fitted IV curves for each available time to maturity on 28 April 2016, without the median volume filter. Crosses in each graph are the market IVs. The solid lines are fitted IV and the bars are the trading volumes.



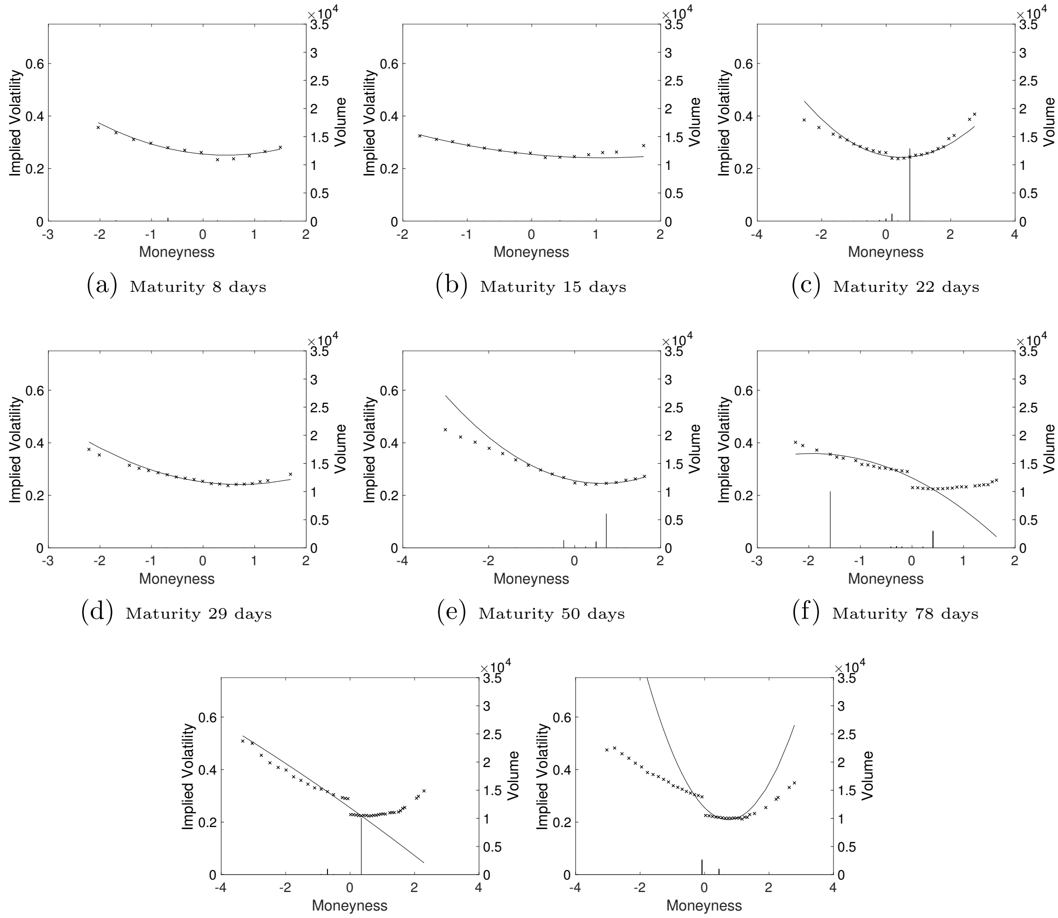
(a) Maturity 8 days (b) Maturity 15 days (c) Maturity 22 days

(d) Maturity 29 days (e) Maturity 50 days (f) Maturity 78 days

(g) Maturity 113 days (h) Maturity 267 days

Figure 5: The IV curves on 28 April, 2016

This figure illustrates market and fitted IV curves for each available time to maturity 8, 15, 22, 29, 50, 78, 113 and 267 days, with the median volume filter. Crosses in each graph are the market IVs. The solid lines are fitted IV curves and the bars are the trading volumes.



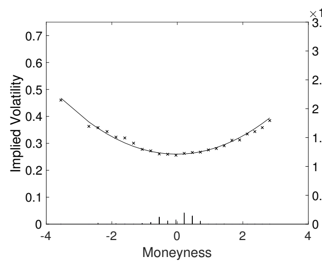
(a) Maturity 8 days (b) Maturity 15 days (c) Maturity 22 days

(d) Maturity 29 days (e) Maturity 50 days (f) Maturity 78 days

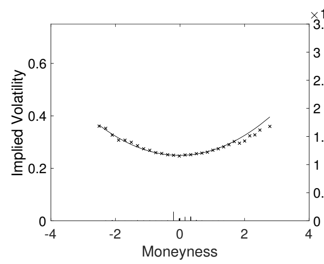
(g) Maturity 113 days (h) Maturity 267 days

Figure 6: The IV curves on 15 May, 2015

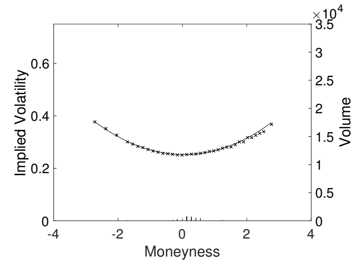
This figure illustrates market and fitted IV curves for each available time to maturity 7, 14, 21, 28, 35, 42, 63, 98, 189, 245 and 616 days, with the median volume filter. Crosses in each graph are the market IVs. The solid lines are fitted IV curves and the bars are the trading volumes.



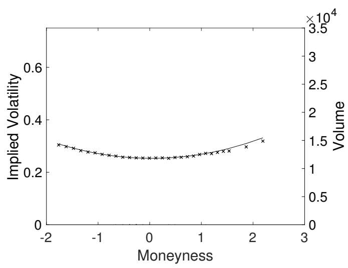
(a) Maturity 7 days



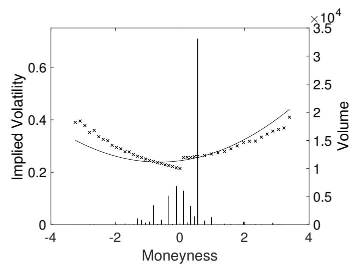
(b) Maturity 14 days



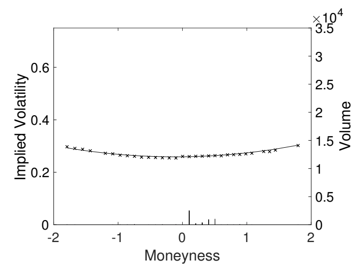
(c) Maturity 21 days



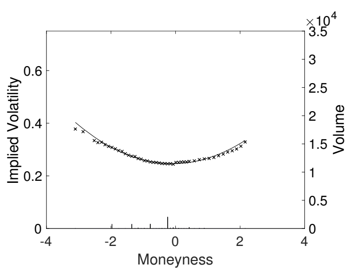
(d) Maturity 28 days



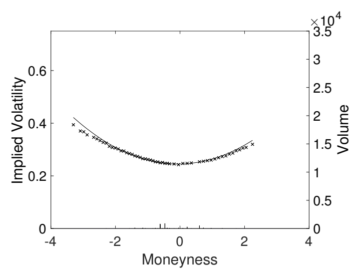
(e) Maturity 35 days



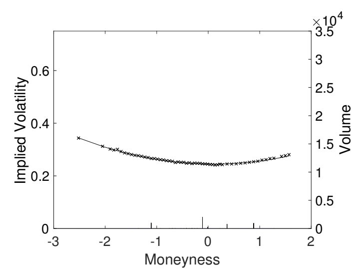
(f) Maturity 42 days



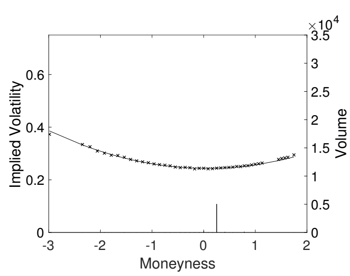
(g) Maturity 63 days



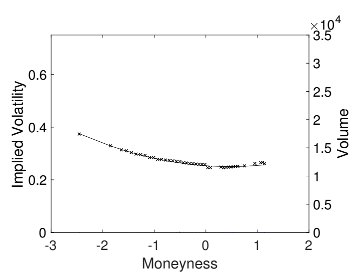
(h) Maturity 98 days



(i) Maturity 189 days



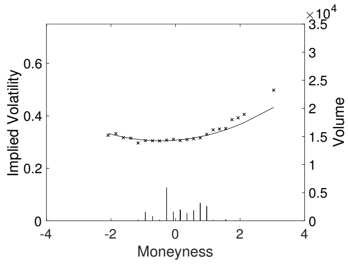
(j) Maturity 245 days



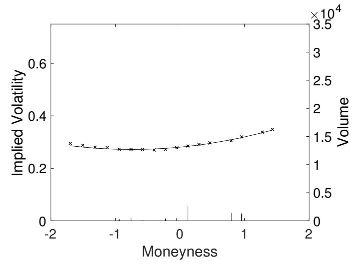
(k) Maturity 616 days

Figure 7: The IV curves on 08 December, 2014

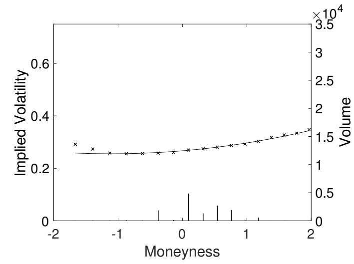
This figure illustrates market and fitted IV curves for each available time to maturity 12, 18, 25, 40, 74, 102, 158, 256 and 403 days, with the median volume filter. Crosses in each graph are the market IVs. The solid lines are fitted IV curves and the bars are the trading volumes.



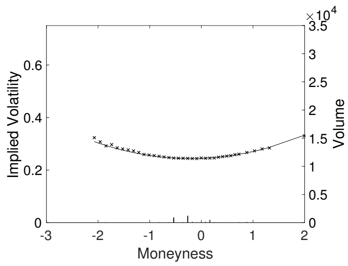
(a) Maturity 12 days



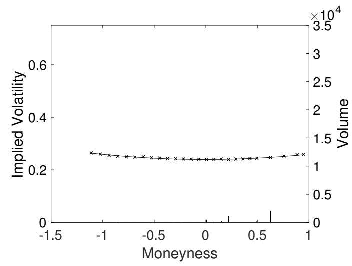
(b) Maturity 18 days



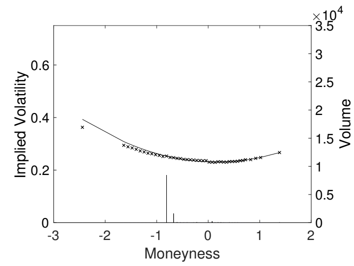
(c) Maturity 40 days



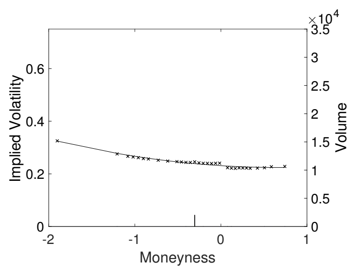
(d) Maturity 74 days



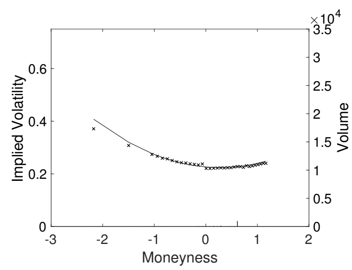
(e) Maturity 102 days



(f) Maturity 158 days



(g) Maturity 256 days



(h) Maturity 403 days

Figure 8: The average IV smile by the constant maturity

This figure shows the fitted IV curves resulting from the mean constant maturity factors.

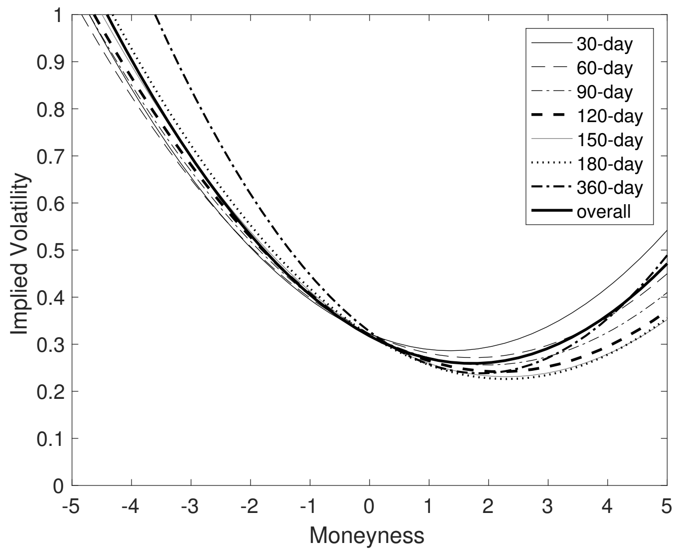
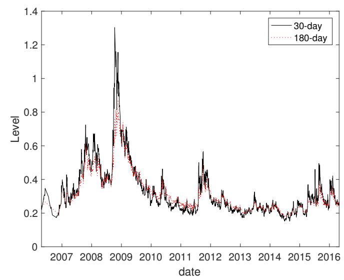
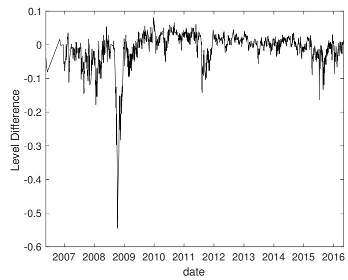


Figure 9: Constant maturity implied volatility dynamics

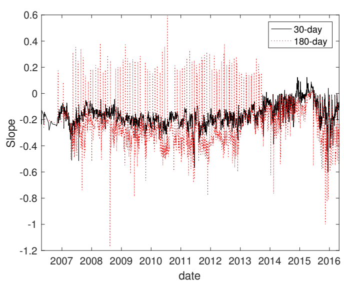
This figure shows the 30-day and 180-day constant maturity dynamics of the ATMIV, γ_0, the slope, γ_1, and the curvature, γ_2, factors that quantify the IV curve. The left column graphs represent the time series of the constant maturity IV factors, while the right column shows the difference of the 180- less 30-day factors.



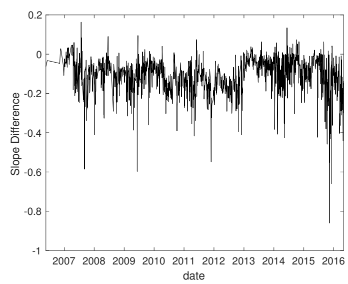
(a) ATM IV



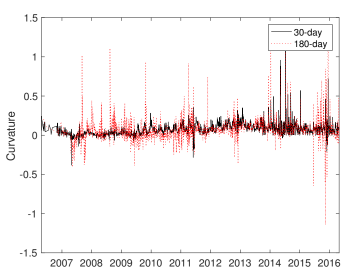
(b) Level Difference



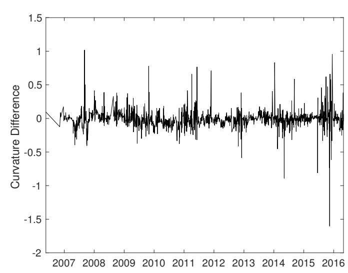
(c) Slope



(d) Slope Difference



(e) Curvature



(f) Curvature Difference