Received: 3 February 2019 | Accepted: 3 February 2019

DOI: 10.1002/fut.22005

RESEARCH ARTICLE

WILEY THE JOURNAL OF FUTURES MARKETS

How do US options traders "smirk" on China? Evidence from FXI options

Jianhui Li | Sebastian A. Gehricke | Jin E. Zhang

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

Correspondence
Jianhui Li, Department of Accountancy and Finance, Otago Business School, University of Otago, Dunedin 9054, New Zealand.
Email: liji1479@student.otago.ac.nz

Funding information
University of Otago; National Natural Science Foundation of China, Grant/Award Number: 71771199

Abstract
In this paper, we study the implied volatility smirk (IVS) of options written on the FXI, the Financial Times Stock Exchange/Xinhua China 50 Index exchange-traded fund (ETF). Using the methodology of Zhang and Xiang (2008, *Quant Financ*, 8, pp. 263–284), we document the empirical characteristics of the level, slope, and curvature of IVS of the FXI options. We find that, on average, IVS becomes steeper and more convex as time to maturity increases. The level and curvature are usually positive, and the slope is negative. We provide evidence that the information in the quantified IV factors has some predictive power for the future monthly FXI ETF returns.

KEYWORDS
China equities, FXI options, FXI smirk, implied volatility

1 | INTRODUCTION

This study quantifies and examines the shape and dynamics of the implied volatility (IV) of iShares China Large-Cap exchange-traded fund (ETF) options, and tests the quantified IV factors as predictors of the underlying monthly FXI ETF returns. 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 documents the empirical features 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. We further develop the constant maturity IV factors to study the term structure and time-series dynamics more accurately. On average, the FXI IV curve exhibits a smirk shape, similar to that of S&P 500 options. As the maturity of FXI options increases, the IV smirk becomes steeper and more convex. US options traders smirk on China just as they do on the United States. They prefer to buy out-of-the-money (OTM) put options to hedge the risk of market crashes. We also find that the first difference of the third cumulants, derived from the factors, has some predictability of the future FXI returns. The empirical features we present provide implications for the development of an FXI option pricing model and for traders to better understand this market.

FXI option contracts are traded in the United States and have become the largest and most active options targeted on Chinese equities available to global traders. The underlying ETF, FXI, seeks 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 the 25 largest-capitalization Chinese equities that trade on the Hong Kong stock exchange. After a tremendous expansion in volume of the Chinese equity market, on September 22, 2014, the index expanded from 25 to 50 constituents. The FXI tracks the performance of the FTSE China 50 Index very closely, as can be observed in Figure 1. The FXI slightly underperforms the underlying index due to the fund fees. In Table 1, we can see that the FXI ETF has a larger market and is more liquid than other US-traded China-targeted ETFs, and therefore, it is the most important fund providing exposure to Chinese equities. From reading the news on Chinese equities, it is obvious that the FXI is a reflection of the

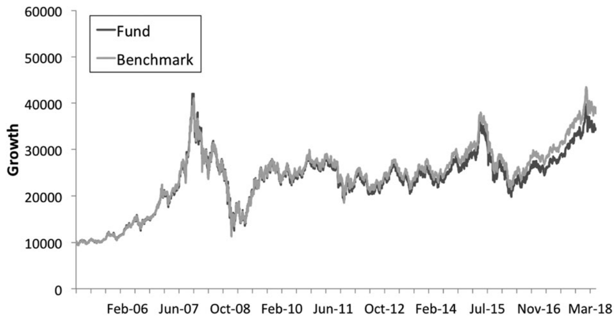


FIGURE 1 Performance of the FXI ETF and its benchmark index. It reflects the hypothetical growth of a $10,000 investment in the FXI ETF and the benchmark index (ticker: XIN0I) from October 08, 2004 to April 30, 2018. Dividends are assumed to be reinvested. Fund expenses are deducted for the FXI ETF. ETF: exchange-traded fund

opportunities for investment in the economy of China. For example, the tariff war with America is among the factors depressing stocks in China recently and making some traders 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 Schaeffer's Investment Research (Venema, 2018). "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).

In this paper, we first study the shape and dynamics of the IV of FXI options. We find that the FXI IV usually exhibits a smirk shape. The overall level, which 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, on average. We also explore the 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 mostly negative. The level (ATM IV) factor mean-reverts with prolonged periods of high values (high ATM IV) during economic downturns, such as the global financial crisis (GFC). The spikes in the long-maturity slope and curvature factors are larger in magnitude and more frequent than their short-maturity counterparts.

Next, inspired by Zhang and Xiang (2008), we believe that the factors of the IV curve are good proxies of the risk-neutral moments. Therefore, they are expected to have predictability of the future excess returns of the underlying FXI ETF, as is the case in other equity option markets (Ang, Hodrick, Xing, & Zhang, 2006; Chang, Christoffersen, & Jacobs, 2013; Chatrath, Miao, Ramchander, & Wang, 2016; Xing, Zhang, & Zhao, 2010). We test the predictability of FXI monthly excess returns using the factors and the risk-neutral third and fourth cumulants (Zhang, Chang & Zhao, 2019; Ruan & Zhang, 2018), as well as their first differences (Ang et al., 2006) for the in-sample and out-of-sample univariate regressions. We find that the first differences of the third cumulants can predict the future FXI monthly excess returns significantly in both in-sample and out-of-sample tests.

Theories on the IV smirk have made vast progress in recent decades. 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 was found to be different across strikes with the same underlying asset and time to maturity (Rubinstein, 1985). Literature on the IV "smile" and "smirk" in the US market has been growing since the initial study by Rubinstein (1985). Many studies have found that the phenomenon of the IV smile shape has become a smirk shape since the global market crash in 1987; that is, the IV has become left-skewed since then (Carr & Wu, 2003; Cont & Da Fonseca, 2002; Corrado & Su, 1997; Fajardo, 2017; Foresi & Wu, 2005; Skiadopoulos, Hodges, & Clewlow, 2000; Yan, 2011).

To address the issue of different IVs at different strike prices, a number of stochastic volatility models have been created (such as Barndorff-Nielsen & Shephard, 2004; Bates, 1996; Heston, 1993; Stein & Stein, 1991). IV is useful to measure the performance of a stochastic volatility option pricing model.

There is also a vast strand of literature trying to explain the causes of the shape of the IV curve (An, Ang, Bali, & Cakici, 2014; DeMiguel, Plyakha, Uppal, & Vilkov, 2013; Garleanu, Pedersen, & Poteshman, 2009; Xing et al., 2010). The errors of measurement and/or investor behavior are among the proposed explanations for the volatility skewness (An et al., 2014; Bollen & Whaley, 2004; DeMiguel et al., 2013; Han, 2007; Hentschel, 2003; Pan, 2002; Xing et al., 2010).

TABLE 1 Summary of relevant ETFs

Symbol	ETF name	Leverage	Issuer	Inception	Total assets ($M)	Average dollar Trading volume since inception	Average dollar Trading volume in April 2018
FXI	iShares China Large-Cap ETF	1	BlackRock	October 5, 2004	4,481.12	586,319,037	1,122,664,445
MCHI	iShares MSCI China ETF	1	BlackRock	March 31, 2011	3,508.17	43,678,452	205,829,647
ASHR	Deutsche X-trackers Harvest CSI 300 China A-Shares Fund	1	Deutsche Bank	November 06, 2013	511.89	37,307,169	25,963,462
YINN	Direxion Daily China 3x Bull Shares	3	Direxion	December 03, 2009	309.06	11,380,554	35,925,974

Note. The summary information for the top four largest China-related ETFs as of April 30, 2018 is reported.
ETF: exchange-traded fund.

A growing literature is also focusing on the predictive power of the IV for the future returns of the underlying asset (Conrad, Dittmar, & Ghysels, 2013; Corrado & Su, 1997; Cremers, Halling, & Weinbaum, 2015; DeMiguel et al., 2013; Dennis & Mayhew, 2002; Dennis, Mayhew, & Stivers, 2006; Doran & Krieger, 2010; Jiang & Tian, 2005; Vasquez, 2017; Xing et al., 2010; Yan, 2011).

There is a handful of studies exploring the IV shape in other popular stock markets and also trying to explain the phenomenon. Pena, Rubio, and Serna (1999) report the pattern of IVs of options written on the Spanish IBEX-35 index and try to explain the smile using transaction costs and time to expiration. Shiu, Pan, Lin, and Wu (2010) find that the shape of IVs of Taiwan TAIEX options changes from a smile before the subprime mortgage crisis to a smirk after the beginning of the crisis, and explain that the reason was the net buying pressure for index calls.

Studies on China-related options are rare and rather different from what we focus on. Chang, Luo, Shi, and Zhang (2013) compare the warrants in China to typical options. Wu (2011) and Xiong and Yu (2011) study the warrant bubbles which are empirically related to the dramatic crash in 2007. Huang, Liu, Zhang, and Zhu (2018) construct China VIX with ETFs option data from Shanghai Stock Exchange (SSE), Hong Kong Exchange (HKEx), and Chicago Board Options Exchange (CBOE) and find that China's volatility premiums exist in all three markets, which are significantly negative during market crash. There are a few studies focusing on modeling the IV of the Chinese stock market (Lee, Chen, & Rui, 2001), and the impact of IV on the market (Zhou, Zhang, & Zhang, 2012).

This study delivers three novel contributions. Our first contribution is that we provide the first comprehensive analysis of the IV shape and its dynamics in the world's largest emerging equity market, the Chinese market. The FXI options market is the largest and most liquid China-related equity 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 the term structures and their dynamics of the quantified FXI IV factors, the level, slope, and curvature, which are useful for developing and calibrating an FXI option pricing model. Our empirical findings provide the starting point for the development of an FXI option pricing model. Lastly, we derive the first differences of the third cumulants from the factors and find they have some predictability of the future FXI returns. The empirical features we present provide implications for the development of an FXI option pricing model and for traders to better understand this market.

The rest of this study is organized as follows. In Section 2, we provide a background of the FXI options, 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, for quantifying the IV of the FXI options and for predictive regressions. Section 5 presents and analyses the results, and lastly Section 6 concludes.

2 | BACKGROUND OF THE FXI OPTIONS MARKET

The FXI ETF was created by BlackRock in 2004, seeking to track the investment results of the FTSE China 50 Index.

FXI option contracts have been traded at the CBOE from 2004 and are physically settled American-style options. Figure 2 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.

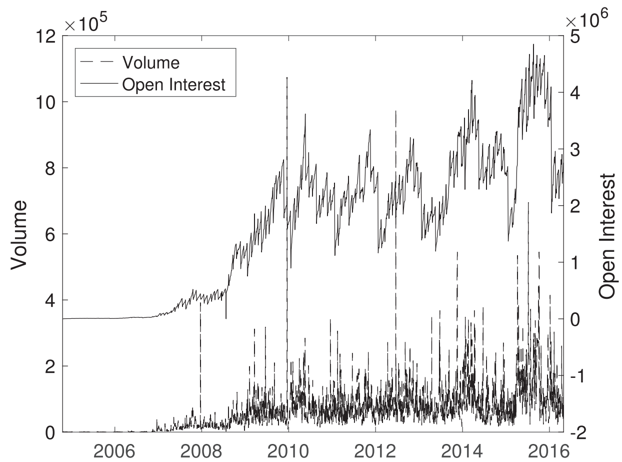


FIGURE 2 The FXI options market growth. It illustrates the daily total volume and open interest of the FXI options market from October 19, 2004 to April 29, 2016

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 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 in the economy of China. As a result, P-Chip stocks have been included in the index since March 18, 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 2), 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 enlarged from 25 holdings to 50 by the FTSE Russell advisory committee on September 22, 2014. The newly included 25 stocks accounted for only 6.76% of the total weights on the transaction day.

2.2 | FXI ETF

The FXI ETF is an ETF designed to track the investment results of its underlying index, the FTSE China 50 Index. 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, and so forth.[4] FXI delivers a fairly close but slight underperformance relative to the underlying index (benchmark), as shown in Figure 1. The cumulative underperformance relative to the index is mostly due to the cumulated fund fees.

Table 1 reports the four most liquid China-targeted US-traded ETFs.[5] Of these ETFs, FXI is the most mature, most liquid, and largest fund. The total assets of the iShares MCSI China ETF (MCHI), the second largest of the ETFs, are less than one-fifth of those of FXI and are far larger than the other two ETFs, as of April 30, 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 crucially 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 with those on other China-related ETFs. 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, trading volumes, open interests and last prices and dividend distributions of the underlying from OptionMetrics Ivy DB for the sample period from October 19, 2004 to April 29, 2016. The underlying index data and the other ETF data are obtained from Bloomberg. The Treasury yield data, used to proxy the risk-free rate, is downloaded from the website of the United States Department of the Treasury.

As FXI options are American-style, the IV provided by OptionMetrics Ivy DB is calculated using an algorithm based on the industry-standard Cox–Ross–Rubinstein binomial tree model (Cox, Ross, & Rubinstein, 1979). To get the IV, first the model

[1] The 50 components of the index as of April 2018 are listed in Table 2, ranked by their weights. Table 3 reports the breakdown of the constituents by Industry Classification Benchmark.

[2] According to FTSE Russell, H-shares are securities of companies incorporated in the People's Republic of China (PRC) 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 is a company incorporated outside the 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.

[4] Table 2 lists securities that the FXI ETF invests in as of April 30, 2018.

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

TABLE 2 Holdings of FXI ETF as of April 30, 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 & Investment (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	54	H-Shares Index May 18	Futures	0
27	China Citic Bank	Equity	1.00	55	USD Cash	Cash	−0.06
28	CITIC Securities	Equity	0.94				
Totals							99.98

Note. The 50 individual stocks and other investment of FXI ETF, and corresponding weights as of April 30, 2018 are reported.
ETF: exchange-traded fund.

TABLE 3 Constituent breakdown as of April 30, 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

Note. The industry classification of 50 individual stocks and corresponding group weights of the FTSE China 50 Index as of April 30, 2018 are reported. ICB: Industry Classification Benchmark.

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 before cleaning as described below. 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 liquid the option is, and therefore the more reliable the IV data will be.

We clean the data by the following steps. First, we delete those options with a missing IV, zero IV, zero bid price, or zero open interest for calculation. Second, options with less than 6 days to expiration are also removed because they may induce liquidity-related biases (Bakshi, Cao, & Chen, 1997) though there is some literature studying the small-time smile pattern (Forde & Jacquier, 2009; Forde, Jacquier, & Lee, 2012). Lastly, we delete those maturities with less than five nonzero volumes on each day for precision of the fittings.

4 | METHODOLOGY

To define the moneyness of options, we need to obtain the risk-free rate and the forward price with the correct maturity as follows.

4.1 | Risk-free rate

We proxy the risk-free rate by using US Treasury yields. To get the risk-free rate with the same maturities as the option contracts, we adopt the linear interpolation and extrapolation method. The approximate risk-free rate is given by

TABLE 4 Sample summary

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

Note. The mean daily number of strikes, contracts, trading volume, and open interest of the options data for the sample period October 19, 2004 to April 29, 2016 in each maturity category are reported. 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.

TABLE 5 FXI dividend schedule

Record date	Payment date	Dollar amount per share
December 28, 2005	December 30, 2005	1.25
December 26, 2006	December 28, 2006	1.31
December 27, 2007	January 04, 2008	2.09
June 25, 2008	June 27, 2008	1.68
December 24, 2008	December 31, 2008	0.21
June 24, 2009	June 26, 2009	0.33
December 23, 2009	December 31, 2009	0.22
June 23, 2010	June 25, 2010	0.46
December 22, 2010	December 30, 2010	0.17
June 23, 2011	June 27, 2011	0.69
December 21, 2011	December 29, 2011	0.08
June 22, 2012	June 27, 2012	0.85
December 19, 2012	December 27, 2012	0.09
June 27, 2013	July 02, 2013	0.84
December 19, 2013	December 27, 2013	0.17
June 26 2014	July 01, 2014	0.54
December 23, 2014	December 29, 2014	0.51
June 26, 2015	June 30, 2015	0.25
December 23, 2015	December 28, 2015	0.77

Note. The dividend distributed in our sample period from October 19, 2004 to April 29, 2016 is reported.

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

where r_τ is the target maturity risk-free rate and τ is the corresponding target 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

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 sample using the following equation:

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

where D_i is the ith time that dividend is paid in our sample and S_i is the price of FXI ETF on the payment date of D_i. The dividend schedule is reported in Table 5. 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 Equation (1) to approximate the forward price $F_{t,T}$.

[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.

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 practice, we select the IV of OTM options to represent the FXI options IV curve. An OTM 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 the CBOE. For put options, we select those whose strike prices are smaller than the forward price, that is, $K < F_{t,T}$, and for calls we select those whose strike prices are larger than the forward price, that is, $K > F_{t,T}$.

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 ATM IVs with maturities closest to 30 days, from above and below.

4.4 | Quantifying IV

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

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

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 econometric modeling and analysis, we construct a simple second-order polynomial, that is,

$$IV(\xi) = \alpha_0 + \alpha_1\xi + \alpha_2\xi^2, \tag{3}$$

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

$$\gamma_0 = \alpha_0,$$

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

$$\gamma_2 = \frac{\alpha_2}{\alpha_0}.$$

We fit the quadratic function, Equation (3), by a volume-weighted least-square method (VWLS), that is, minimizing the volume-weighted mean square error given by

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

to obtain the coefficients (α_0, α_1, α_2) of Equation (3) which are converted to the dimensionless factors (γ_0, γ_1, γ_2) of Equation (2). IV_{market} is the IV of FXI options we obtain from OptionMetrics Ivy DB.

When the median volume of a particular maturity contract 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 concentrated in a small number of contracts.

4.5 | Predicting FXI returns

Zhang and Xiang (2008) show that the factors used to quantify the IV curve are proportionately related to the risk-neutral moments, that is, the risk-neutral volatility, the skewness, and the excess kurtosis. In line with Ang et al. (2006), Chang, Christoffersen, et al. (2013), Chatrath et al. (2016), and Xing et al. (2010), we expect that those moments, and therefore the quantified IV factors, contain information on the future returns of the underlying FXI ETF. Then we test the predictability of the quantified IV factors and their first differences. Following Zhang et al. (2019) and Ruan and Zhang (2018), we are also interested in the predictive power of the risk-neutral third and fourth cumulants and that of their first differences.

Following An et al. (2014), Conrad et al. (2013), and Ruan and Zhang (2018), we test the predictability of FXI monthly excess returns using the IV factors. The FXI monthly excess returns are defined as

$$R_t = \ln \frac{S_t}{S_{t-1}} - r_t,$$

where S_t is the price of the FXI ETF in the end of month t and r_t is the 1-month risk-free rate provided by the 30-day US Treasury yields.

We then calculate the factors at the end of each month using interpolation to match the days until the end of the predicted month. Following Bakshi, Kapadia, and Madan (2003) and Bali, Hu, and Murray (2017), the risk-neutral third and fourth cumulants are given by

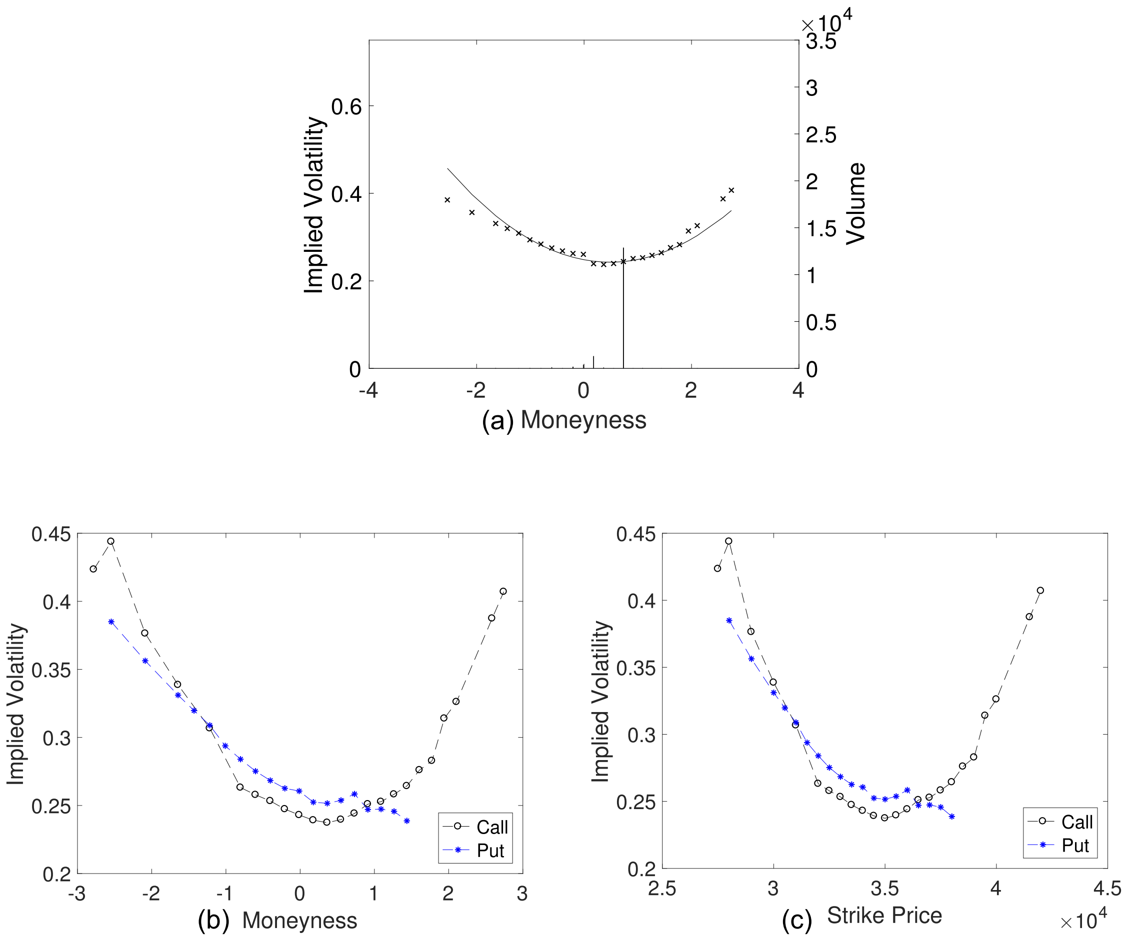


FIGURE 3 The IV smile on April 28, 2016 for options expiring on May 20, 2016. Graph (a) illustrates the market IV (crosses) and the fitted IV curve on April 28, 2016. The time to maturity is 22 days and the options will expire on May 20, 2016. Bars in the figure represent the volume. Graphs (b) and (c) show the market put and call option IV against moneyness and strike price, respectively. IV: implied volatility [Color figure can be viewed at wileyonlinelibrary.com]

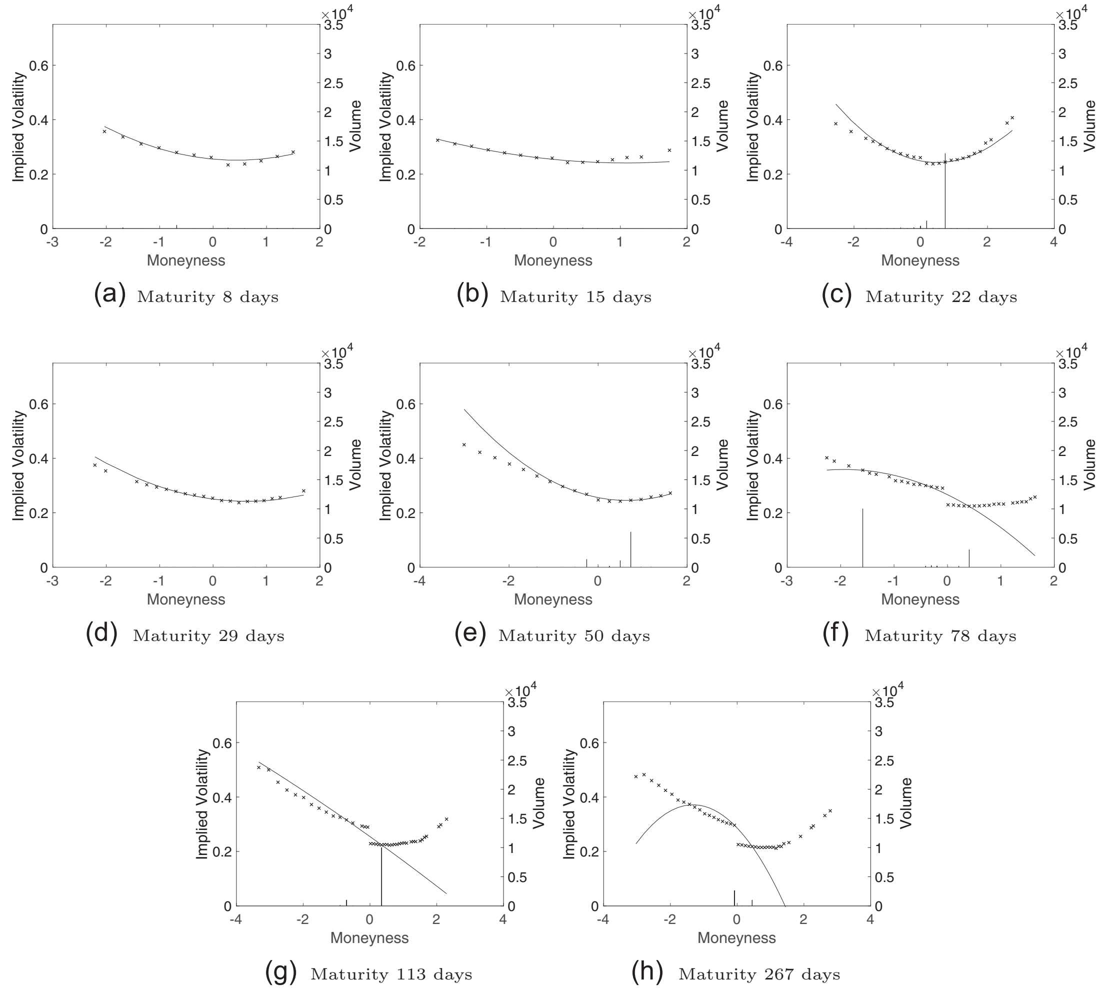


FIGURE 4 The IV curves without the volume filter on April 28, 2016. It illustrates the market and fitted IV curves for each available time to maturity 8, 15, 22, 29, 50, 78, 113, and 267 days in panel a to h, without the median volume filter, described in Section 4. Crosses in each graph are the market IVs. The solid lines are fitted IV and the bars are the trading volumes. IV: implied volatility

$$TC = \gamma_1 \times \gamma_0^3, \quad FC = \gamma_2 \times \gamma_0^4, \tag{4}$$

where γ_0, γ_1, and γ_2 proxy the risk-neutral volatility, skewness, and excess kurtosis, respectively.

We then run the following predictive regression for FXI monthly excess returns:

$$R_{t+1} = \alpha + \beta X_t + \epsilon_{t+1}, \tag{5}$$

where R_{t+1} is the FXI monthly excess return of month $t+1$ and ϵ_{t+1} is the residual. X_t is one of the predictors, that is, the level, slope, curvature, the third and fourth cumulants, or the first differences of these predictors, at the end of the month t.

In addition to the in-sample regressions, we also test the out-of-sample predictions for the FXI monthly excess returns. The evaluation sample is considered as an important parameter in terms of the power of the forecast evaluation tests (Hansen & Timmermann, 2012; Rapach, Strauss, & Zhou, 2010; Welch & Goyal, 2007). The out-of-sample R-squared (R^2_{OS}) is defined as

$$R^2_{\text{OS}} = 1 - \frac{\sum_{t=n}^{N-1} (y_{t+1} - \hat{y}_{t+1|t})^2}{\sum_{t=n}^{N-1} (y_{t+1} - \bar{y}_{t+1|t})^2},$$

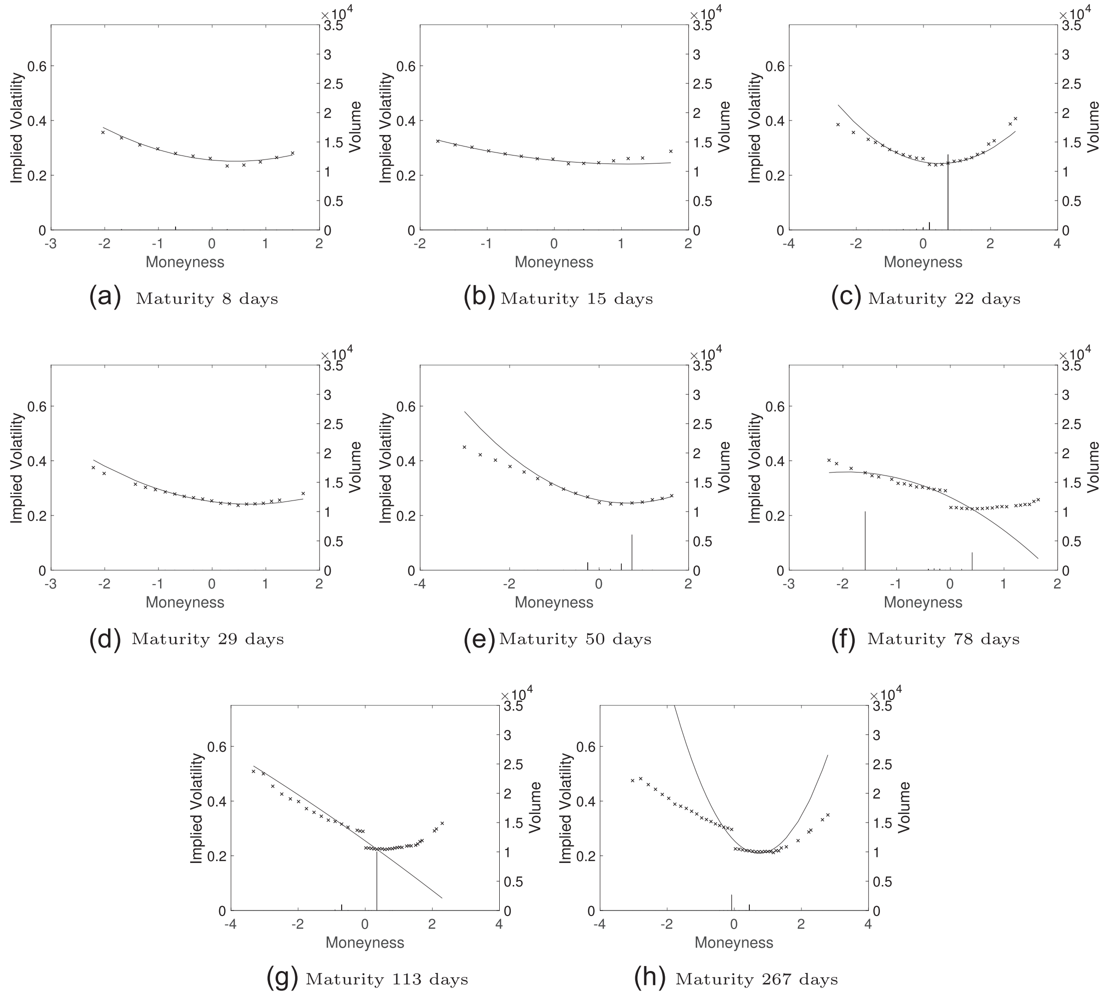


FIGURE 5 The IV curves on April 28, 2016. It illustrates market and fitted IV curves for each available time to maturity 8, 15, 22, 29, 50, 78, 113, and 267 days in panels a to h, respectively, with the median volume filter. Crosses in each graph are the market IVs. The solid lines are fitted IV curves and the bars are the trading volumes. IV: implied volatility

where $\bar{y}_{t+1|t} = (1/t)\sum_{i=1}^{t} y_i$. The null hypothesis is that the unconditional forecast is not inferior to the conditional forecast (Welch & Goyal, 2007). We also define the initial estimation ratio ρ and set $\rho = 1/3$ and $1/2$ following Ruan and Zhang (2018).[7]

5 | EMPIRICAL RESULTS

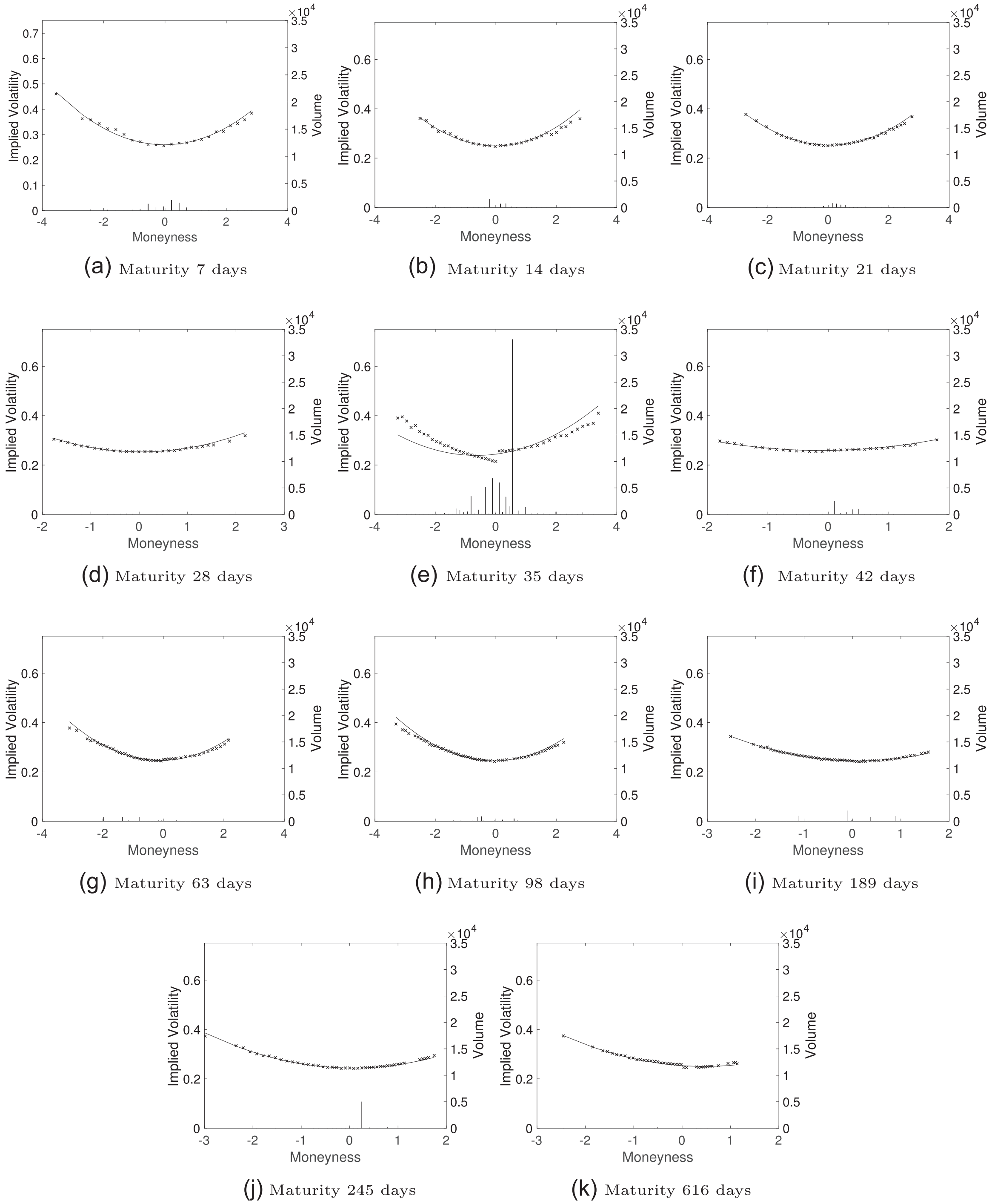
In this section, we report and discuss the results of quantifying the IV curves of FXI options. Following the method above, we plot the fitted IV curves for each available maturity every day to study the dynamics of the FXI option IV by examining the resulting level, slope and curvature factors. We then calculate the constant maturity IV factors to further study the FXI IV term structure and its time-series dynamics. Finally, we conduct an empirical test of FXI return predictability of the quantified IV factors.

5.1 | Dynamics of the quantified IV curve

Figure 3a shows the IV and trading volumes, provided by OptionMetrics Ivy DB, and the fitted IV curves using the methodology described in Section 4 on April 28, 2018 for the time to maturity of 22 days. From this figure, a smirk can

[7]The product of the initial estimation ratio ρ and the total number of months of our full data sample is the number of observations for the first forecast.

be observed. We will show that this kind of smirk is the typical shape of the FXI IV curve. Figure 3b,c shows the IVs of all the put and call option contracts for the same maturity and on the same day as Figure 3a. As we can see there is a slight jump at $\xi = 0$; that is, the IV of calls and puts are not equal at the ATM strike price. Cremers and Weinbaum (2010) and Doran, Fodor, and Jiang (2013) study this gap between put and call American option prices as a predictor of future returns of the underlying. This is not the focus in this paper. On this day for the 22 days to maturity options, our fitted IV curve matches the market data very closely.



(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 6 The IV curves on May 15, 2015. It 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 in panels a to k, respectively, 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. IV: implied volatility

We use the median volume filter mentioned in the methodology to get more precise fittings. Panels a to h in Figure 4 display the different maturity option implied volatility curves fitted without the volume filter, while panels a to h in Figure 5 show the implied volatility curves fitted with the volume filter on the same day, respectively. This filter eliminates some of the strange fitted curves (Figure 4h) 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 5h). The affected sample using OLS fittings accounts for 12% of the entire sample.

Figures 5a-h, 6a-k and 7a-h show the market IV, fitted IV curves and the trading volumes for all available maturities on April 28, 2016, May 15, 2015 and December 8, 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 exist a handful of abnormally shaped fitted curves which do not approximate the data well, even after the filter (Figure 5f,g). This could be due to the relatively large trading volumes of a small number of deep OTM contracts forcing an unusual fitting by VWLS.

Table 6 summarizes the resulting parameters and factors as well as the forward prices, by maturity groups. The maturity groups are less than 30, 30–90, 90–180, 180–360, and more than 360 days, to provide initial analyses of the term structures of the factors. Overall, the exact ATM IV (level factor) is positive and the curves tend to be negatively sloped with some positive curvature (convexity), that is, a smirk shape as is found for S&P 500 options by Carr and Wu (2003), Foresi and Wu (2005), and Fajardo (2017), among others. The overall average level, slope, and curvature are 0.3094, −0.1992, and 0.0771, respectively, with corresponding standard deviations 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 average term structures of $F_{t,T}$ and the level are upward sloping, and in contrast that of the

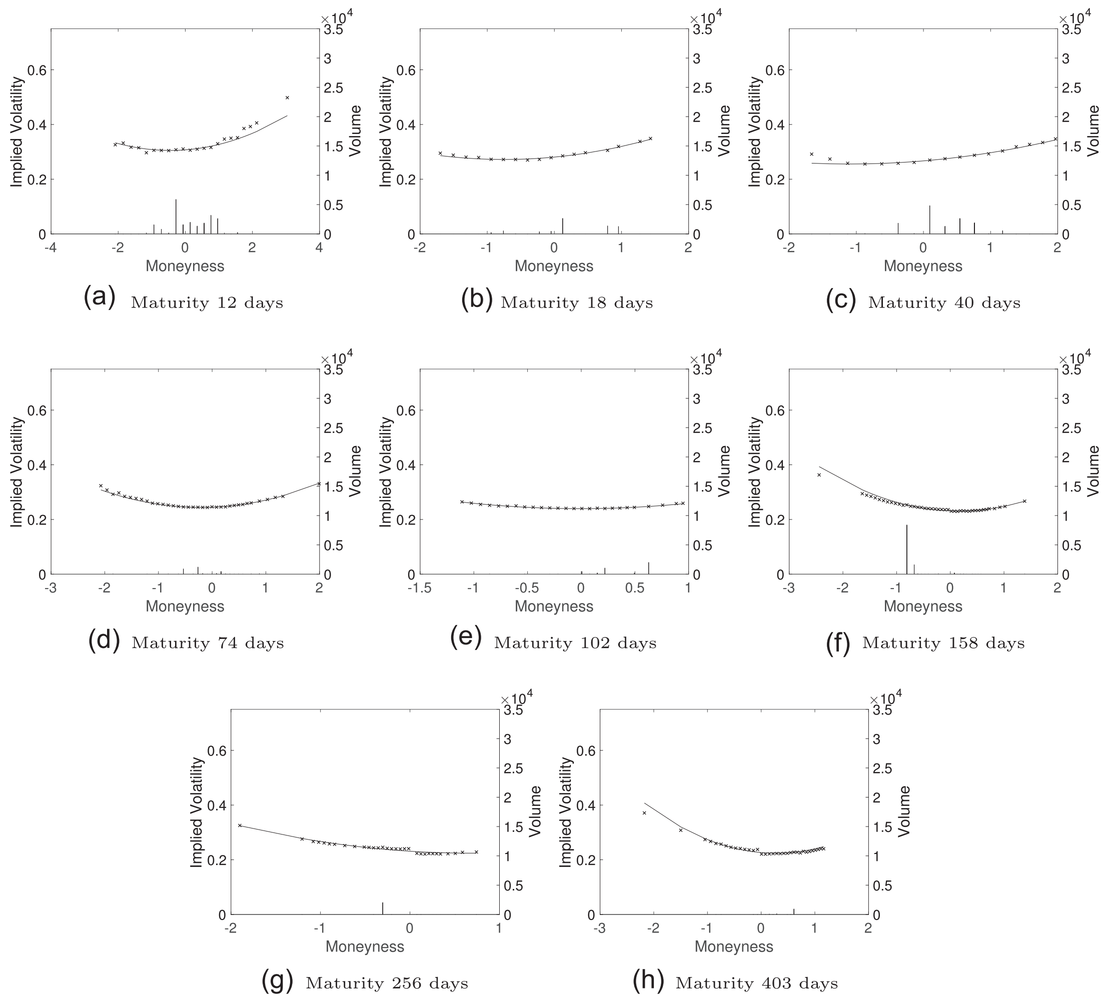


FIGURE 7 The IV curves on December 08, 2014. It illustrates market and fitted IV curves for each available time to maturity 12, 18, 25, 40, 74, 102, 158, 256, and 403 days in panels a to h, respectively, with the median volume filter. Crosses in each graph are the market IVs. The solid lines are fitted IV curves and the bars are the trading volumes. IV: implied volatility

TABLE 6 Summary of quantified IV curve coefficients and factors

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
SD						
$F_{t,T}$	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						
MeanR^2 (%)	98.25	98.54	98.49	98.33	98.08	97.19
MeanR^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

Note. Summary results for the estimated IV function: $IV(\xi) = \alpha_0 + \alpha_1\xi + \alpha_2\xi^2$, 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 10. 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.

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 exact ATM IV mean-reverts, consistent with the common finding that the IV of ATM US equity options mean-reverts (Dueker, 1997; Fouque, Papanicolaou, & Sircar, 2000; Higgs & 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 of the ATM IV are always 100% while that of the slope decreases as the maturity increases, and for the curvature the 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, which could be due to a decrease in trading activity and less consistent views by different options traders about long-term volatility.

5.2 | Constant maturity quantified IV curve

Previously, we divided the IV curve factors into groups by maturity. However, this often groups many different maturities into one category on any given day. 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 summary statistics for 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

TABLE 7 Summary of constant maturity quantified IV 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
SD								
$\hat{\alpha}_0$	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

Note. Summary statistics 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, are reported.
IV: implied volatility.

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 is usually in a smirk shape. As maturity increases, the smirk becomes more negatively sloped and more convex.

Panels a, c and e in Figure 9 present the time series of the 30- and 180-day constant maturity level, slope and curvature factors, respectively. Panels b, d and f in Figure 9 show the difference between the 30- and 180-day maturity factors for the level, slope and curvature, respectively. In general, the dynamics of 30- and 180-day constant maturities are consistent with the above results that the level time series is always positive, the slope is usually negative, and the curvature fluctuates around essentially zero. Specifically, in Figure 9a the 30- and 180-day level factors mean-revert with prolonged periods of high volatility during the 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 2015–2016). In Figure 9c, we can see that

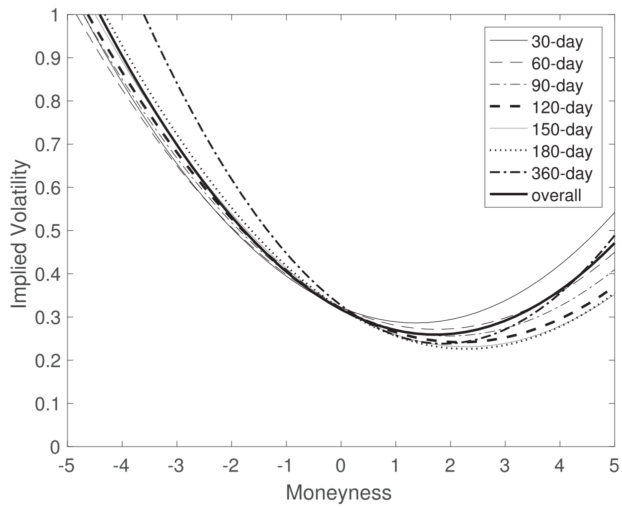


FIGURE 8 The fitted IV curves using the constant maturity IV factors. It shows the fitted IV curves resulting from the mean constant maturity IV factors. IV: implied volatility

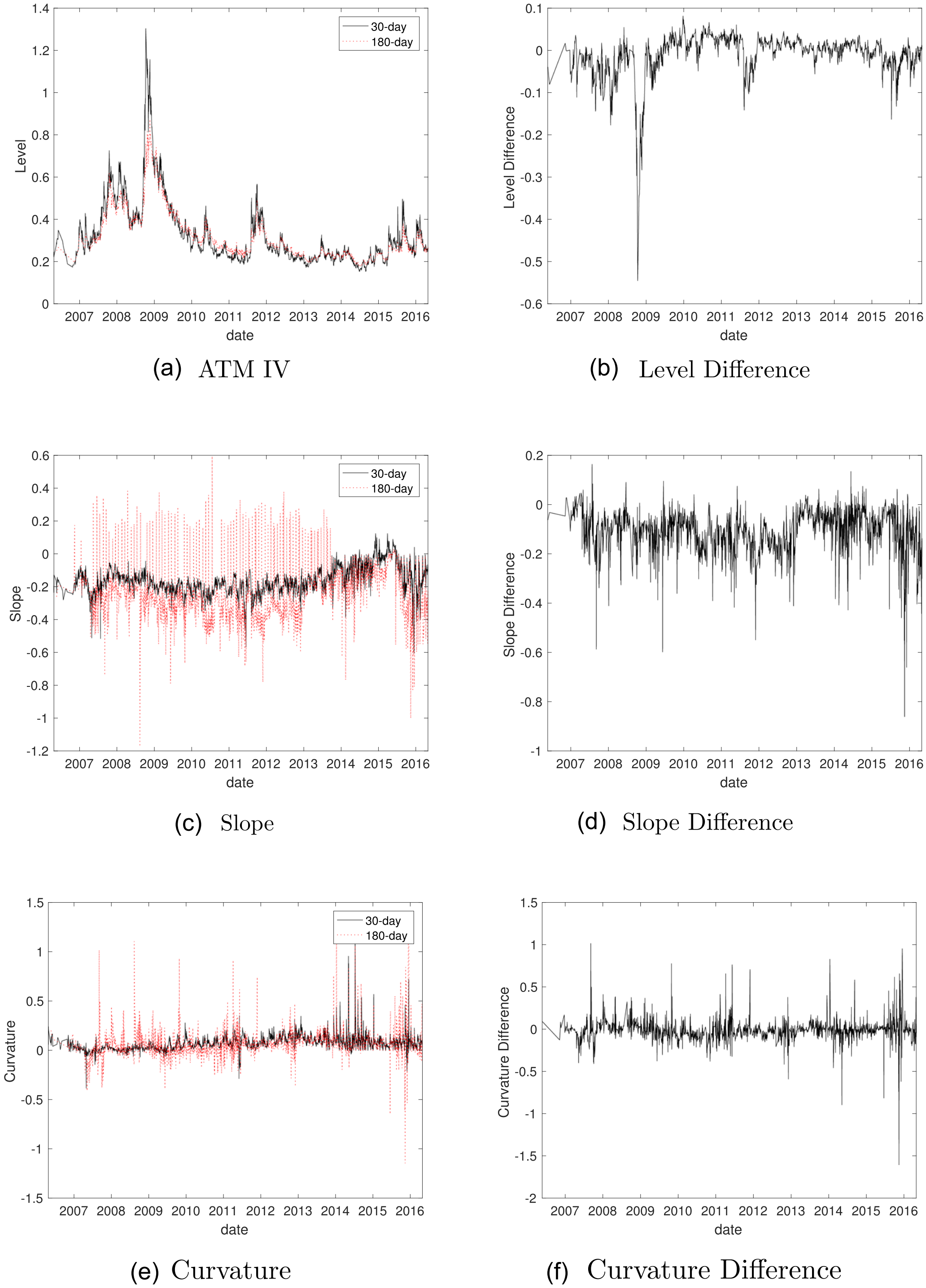


FIGURE 9 Constant maturity implied volatility dynamics. It shows the 30- and 180-day constant maturity dynamics of the exact ATM IV, γ_0, the slope, γ_1, and the curvature, γ_2, factors that quantify the IV curves. The left column graphs a, c, e represent the time series of the constant maturity IV factors, while the right column graphs b, d, f show the difference of the 180- less 30-day factors, respectively. ATM: at-the-money; IV: implied volatility [Color figure can be viewed at wileyonlinelibrary.com]

the slope is usually negative, but the 180-day slope fluctuates a lot more. In Figure 9e, we can see that curvature tends to be slightly positive most of the time and the long-maturity options IV curvature spikes are larger and more frequent. Turning to the difference in the 180- and 30-day factors in Figure 9b,d,f, we can see that the short end term structures of the level (ATM IV), slope, and curvature are usually downward sloping, downward sloping, and flat, respectively.

TABLE 8 Predictability of FXI returns

	$\hat{\beta}$	t	R^2(%)	R^2_{OS} $\rho = 1/3$	R^2_{OS} $\rho = 1/2$
Full sample (2004.10–2016.04)					
Level	−0.04	(−0.49)	0.22	−16.93	−2.50
Slope	−0.12	(−0.84)	0.64	−339.55	−41.38
Curv	0.09	(0.48)	0.21	−25.87	−0.43
DLevel	0.17	(−1.07)	1.05	−8.40	−6.76
DSlope	0.00	(0.01)	0.00	−8.74	−2.08
DCurv	−0.05	(−0.29)	0.08	−7.36	−3.07
TC	−0.14	(−0.33)	0.10	−28.32	−4.28
FC	2.49	(0.63)	0.36	−0.92	−11.46
DTC	41.00	(2.40)	5.00	5.54	5.95
DFC	141.41	(1.79)	2.84	−2.91	−6.70

Note. The estimated slope coefficients $\hat{\beta}$, their t-statistics, the in-sample R^2 statistics and out-of-sample R-squared (R^2_{OS}) statistics for the predictive regression described in Equation (5) are reported. TC and FC are the third and fourth cumulants obtained through Equation (4). DLevel, DSlope, DCurv, DTC, and DFC are the first differences of the corresponding predictors. $\rho = 1/3$ and $\rho = 1/2$ are the initial estimation ratios of the evaluation samples that we choose.

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 zero with a downward-sloping term structure for a maturity of less than 360 days. The level seems to mean-revert with prolonged periods of increased volatility during the GFC, recovery period, and recent depression in China. The time series of the level, slope, and curvature are usually fluctuating around positive, negative, and slightly positive values, respectively, with times of spikes.

5.3 | Predictability of FXI returns

Table 8 shows the results of the in-sample and out-of-sample regressions. As we can see, in the in-sample tests, the first differences of the third cumulants appear to be useful to predict the future monthly excess returns of FXI, with a t statistic 2.40, which is significant at the 1% level of significance, and an R-squared statistic (R^2) of 5.00%. In the out-of-sample predictions, the first differences of the third cumulants show evidence of predictability with the out-of-sample R-squared statistic (R^2_{OS}) of 5.54% ($\rho = 1/3$) and 5.95% ($\rho = 1/2$). However, we find the other predictors have poor predictive performance in both in-sample and out-of-sample. Thus, we conclude that the first differences of the third cumulants can be used to predict the future FXI monthly excess returns. The first difference of the third cumulants is the difference of monthly jump frequencies in this case. The positive estimation of the first difference of the third cumulants to the FXI monthly returns means that when the option investors hold the opinion of less catastrophic events in the following month, they expect higher returns. These are initial results demonstrating the predictability using a simple method and may be vastly improved in future work.

6 | CONCLUSION

In this paper, we study the IV smirk of FXI options and its dynamics, which further provide a modeling 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 curve. The IV curve can be summarized by three factors: the level, slope, and curvature every day and for each maturity. 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 IV curves.

First, 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 (exact 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, after which it 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 over the sample.

To examine the IV factor dynamics and term structures more accurately, we then calculate the constant maturity factors by interpolation and extrapolation, finding consistent results on average. However, the term structure of the level is flat, rather than upward sloping. From the fitted IV curves using the mean constant maturity factors, we can observe the IV smirk of the FXI options clearly. To investigate the time-series dynamics of the FXI IV curve, we plot the 30- and 180-day dynamics and find that the 30- and 180-day levels have a similar shape with periods of high volatility related to the Chinese and global economy, indicating that the investors expect a similar volatility of the FXI returns. The slope and curvature are usually negative and slightly positive, but spikes of the 180-day ones are larger and more frequent. We can say that the slope and curvature are more volatile as the maturity increases. 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. Further explanation of the fluctuation in the factors over time is necessary, and further work on finding the determinants of these time-series fluctuations would be of interest in our future work.

Lastly, we test the predictability of the FXI monthly excess returns using the factors, which proxy for the risk-neutral volatility, slope and curvature, and the risk-neutral third and fourth cumulants, their first differences. We test this with in-sample and out-of-sample regressions. We find that the first differences of the third cumulants can predict the future FXI monthly excess returns significantly in both the in-sample and out-of-sample regressions. The economic intuition of this result is an interesting future research topic.

In this study, 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, and curvature. These could be used to calibrate the FXI option pricing model by converting them to risk-neutral moments, as in Zhang and Xiang (2008). Our empirical findings show that an FXI option pricing model must exhibit positive risk-neutral volatility, negative risk-neutral skewness, and slightly positive risk-neutral excess kurtosis, on average, the magnitude of which changes with the maturity. We find that US traders buy OTM put options to hedge against market crashes in China just as they do in the United States. These recommendations will help build a sound FXI option pricing model motivated by empirical characteristics.

ACKNOWLEDGMENTS

We are grateful to Bob Webb (editor) for his encouragement. We would also like to acknowledge helpful comments and suggestions from Ming Yan William Cheung (our ICFOD discussant), Jose Da Fonseca, Sergey Isaenko (our NZFM discussant), Duminda Kuruppuarachchi, Zhangxin (Frank) Liu, Zheyao (Terry) Pan, and seminar participants at the seventh 7th Conference on Futures and Other Derivatives (ICFOD 2018) in Shanghai and 2018 New Zealand Finance Meeting (NZFM) in Queenstown. Jianhui Li is particularly grateful to Xinfeng (Edwin) Ruan for his research support. She appreciates having interesting discussions with Pakorn (Beam) Aschakulporn, Wei Guo, and Tian (Tin) Yue during their regular group meetings. She also appreciates receiving the Publishing Bursary and Alan MacGregor Prize offered by the University of Otago. Jin E. Zhang has been supported by an establishment grant from the University of Otago and the National Natural Science Foundation of China grant (Project No. 71771199).

ORCID

Jianhui Li http://orcid.org/0000-0001-8073-1505
Sebastian A. Gehricke http://orcid.org/0000-0002-3251-9275

REFERENCES

An, B.-J., Ang, A., Bali, T. G., & Cakici, N. (2014). The joint cross section of stocks and options. *Journal of Finance*, *69*, 2279–2337.
Ang, A., Hodrick, R. J., Xing, Y., & Zhang, X. (2006). The cross-section of volatility and expected returns. *Journal of Finance*, *61*, 259–299.
Bakshi, G., Cao, C., & Chen, Z. (1997). Empirical performance of alternative option pricing models. *Journal of Finance*, *52*, 2003–2049.

Bakshi, G., Kapadia, N., & Madan, D. (2003). Stock return characteristics, skew laws, and the differential pricing of individual equity options. *Review of Financial Studies*, *16*, 101–143.

Bali, T. G., Hu, J., & Murray, S., (2017). *Option implied volatility, skewness, and kurtosis and the cross-section of expected stock returns*. Available at SSRN 2322945.

Barndorff-Nielsen, O. E., & Shephard, N. (2004). Power and bipower variation with stochastic volatility and jumps. *Journal of Financial Econometrics*, *2*, 1–37.

Bates, D. S. (1996). Jumps and stochastic volatility: Exchange rate processes implicit in Deutsche mark options. *Review of Financial Studies*, *9*, 69–107.

Black, F., & Scholes, M. (1973). The pricing of options and corporate liabilities. *Journal of Political Economy*, *81*, 637–654.

Bollen, N. P. B, & Whaley, R. E. (2004). Does net buying pressure affect the shape of implied volatility functions? *Journal of Finance*, *59*, 711–753.

Carr, P., & Wu, L. (2003). The finite moment log stable process and option pricing. *Journal of Finance*, *58*, 753–777.

Chang, B. Y., Christoffersen, P., & Jacobs, K. (2013). Market skewness risk and the cross section of stock returns. *Journal of Financial Economics*, *107*, 46–68.

Chang, E. C., Luo, X., Shi, L., & Zhang, J. E. (2013). Is warrant really a derivative? Evidence from the Chinese warrant market. *Journal of Financial Markets*, *16*, 165–193.

Chatrath, A., Miao, H., Ramchander, S., & Wang, T. (2016). An examination of the flow characteristics of crude oil: Evidence from risk-neutral moments. *Energy Economics*, *54*, 213–223.

Conrad, J., Dittmar, R. F., & Ghysels, E. (2013). Ex ante skewness and expected stock returns. *Journal of Finance*, *68*, 85–124.

Cont, R., & Da Fonseca, J. (2002). Dynamics of implied volatility surfaces. *Quantitative Finance*, *2*, 45–60.

Corrado, C. J., & Su, T. (1997). Implied volatility skews and stock index skewness and kurtosis implied by S&P 500 index option prices. *Journal of Derivatives*, *4*, 8–19.

Cox, J. C., Ross, S. A., & Rubinstein, M. (1979). Option pricing: A simplified approach. *Journal of Financial Economics*, *7*, 229–263.

Cremers, M., Halling, M., & Weinbaum, D. (2015). Aggregate jump and volatility risk in the cross-section of stock returns. *Journal of Finance*, *70*, 577–614.

Cremers, M., & Weinbaum, D. (2010). Deviations from put-call parity and stock return predictability. *Journal of Financial and Quantitative Analysis*, *45*, 335–367.

DeMiguel, V., Plyakha, Y., Uppal, R., & Vilkov, G. (2013). Improving portfolio selection using option-implied volatility and skewness. *Journal of Financial and Quantitative Analysis*, *48*, 1813–1845.

Dennis, P., & Mayhew, S. (2002). Risk-neutral skewness: Evidence from stock options. *Journal of Financial and Quantitative Analysis*, *37*, 471–493.

Dennis, P., Mayhew, S., & Stivers, C. (2006). Stock returns, implied volatility innovations, and the asymmetric volatility phenomenon. *Journal of Financial and Quantitative Analysis*, *41*, 381–406.

Doran, J. S, Fodor, A., & Jiang, D. (2013). Call-put implied volatility spreads and option returns. *Review of Asset Pricing Studies*, *3*, 258–290.

Doran, J. S, & Krieger, K. (2010). Implications for asset returns in the implied volatility skew. *Financial Analysts Journal*, *66*, 65–76.

Dueker, M. J. (1997). Markov switching in garch processes and mean-reverting stock-market volatility. *Journal of Business and Economic Statistics*, *15*, 26–34.

Fajardo, J. (2017). A new factor to explain implied volatility smirk. *Applied Economics*, *49*, 4026–4034.

Forde, M., & Jacquier, A. (2009). Small-time asymptotics for implied volatility under the Heston model. *International Journal of Theoretical and Applied Finance*, *12*, 861–876.

Forde, M., Jacquier, A., & Lee, R. (2012). The small-time smile and term structure of implied volatility under the Heston model. *SIAM Journal on Financial Mathematics*, *3*, 690–708.

Foresi, S., & Wu, L. (2005). Crash-o-phobia: A domestic fear or a worldwide concern? *Journal of Derivatives*, *13*, 8–21.

Fouque, J.-P., Papanicolaou, G., & Sircar, K. R. (2000). Mean-reverting stochastic volatility. *International Journal of Theoretical and Applied Finance*, *3*, 101–142.

Garleanu, N., Pedersen, L. H., & Poteshman, A. M. (2009). Demand-based option pricing. *Review of Financial Studies*, *22*, 4259–4299.

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

Hansen, P. R., & Timmermann, A. (2012). *Choice of sample split in out-of-sample forecast evaluation*. Working paper, Stanford University.

Hentschel, L. (2003). Errors in implied volatility estimation. *Journal of Financial and Quantitative analysis*, *38*, 779–810.

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

Higgs, H., & Worthington, A. (2008). Stochastic price modeling of high volatility, mean-reverting, spike-prone commodities: The Australian wholesale spot electricity market. *Energy Economics*, *30*, 3172–3185.

Huang, X., Liu, J., Zhang, X., & Zhu, Y. (2018). Volatility premium and term structure of china blue-chip index options. *Emerging Markets Finance and Trade*, (forthcoming).

Jiang, G. J., & Tian, Y. S. (2005). The model-free implied volatility and its information content. *Review of Financial Studies*, *18*, 1305–1342.

Lee, C. F., Chen, G.-M., & Rui, O. M. (2001). Stock returns and volatility on China's stock markets. *Journal of Financial Research*, *24*, 523–543.

Mellow, C. (2018). *China finds a slower, steadier growth path*. Barron's. https://www.barrons.com/articles/china-finds-a-slower-steadier-growth-path-1528473832

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

Pena, I., Rubio, G., & Serna, G. (1999). Why do we smile? On the determinants of the implied volatility function. *Journal of Banking and Finance*, *23*, 1151–1179.

Rapach, D. E, Strauss, J. K., & Zhou, G. (2010). Out-of-sample equity premium prediction: Combination forecasts and links to the real economy. *Review of Financial Studies*, *23*, 821–862.

Ruan, X., & Zhang, J. E. (2018). Risk-neutral moments in the crude oil market. *Energy Economics*, *72*, 583–600.

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

Shiu, Y.-M., Pan, G.-G., Lin, S.-H., & Wu, T.-C. (2010). Impact of net buying pressure on changes in implied volatility: Before and after the onset of the subprime crisis. *Journal of Derivatives*, *17*, 54–66.

Skiadopoulos, G., Hodges, S., & Clewlow, L. (2000). The dynamics of the S&P 500 implied volatility surface. *Review of Derivatives Research*, *3*, 263–282.

Stein, E. M., & Stein, J. C. (1991). Stock price distributions with stochastic volatility: An analytic approach. *Review of Financial Studies*, *4*, 727–752.

Vasquez, A. (2017). Equity volatility term structures and the cross section of option returns. *Journal of Financial and Quantitative Analysis*, *52*, 2727–2754.

Venema, K. (2018). Options trader targets new lows for big-cap Chinese stocks. *Schaeffer's Investment Research*. https://www.schaeffersresearch.com/content/options/2018/07/13/options-trader-targets-new-lows-for-big-cap-chinese-stocks

Welch, I., & Goyal, A. (2007). A comprehensive look at the empirical performance of equity premium prediction. *Review of Financial Studies*, *21*, 1455–1508.

Wu, T. L. (2011). *A comprehensive study of the Chinese warrants bubble* (Working Paper). Available at SSRN 1991522.

Xing, Y., Zhang, X., & Zhao, R. (2010). What does the individual option volatility smirk tell us about future equity returns? *Journal of Financial and Quantitative Analysis*, *45*, 641–662.

Xiong, W., & Yu, J. (2011). The Chinese warrants bubble. *American Economic Review*, *101*, 2723–2753.

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

Zhang, J. E., Chang, E. C., & Zhao H. (2019). Market excess returns, variance and the third cumulant, *International Review of Finance*, (forthcoming).

Zhang, J. E, & Xiang, Y. (2008). The implied volatility smirk. *Quantitative Finance*, *8*, 263–284.

Zhou, X., Zhang, W., & Zhang, J. (2012). Volatility spillovers between the Chinese and world equity markets. *Pacific-Basin Finance Journal*, *20*, 247–270.

How to cite this article: Li J, Gehricke SA, Zhang JE. How do US options traders "smirk" on China? Evidence from FXI options. *J Futures Markets*. 2019;39:1450–1470. https://doi.org/10.1002/fut.22005