Performance Analysis of Shanghai Stock Exchange iVX Index and Its Potential for Risk Management

by

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Abstract

This paper examines the efficiency of the iVX index in capturing the volatility of SSE50 ETF over the next 30 days. By comparing iVX with three other volatility measures of China's stock market, CVX, VXFXI, and the GARCH (1, 1) model estimation on SSE50 ETF returns, the paper concludes that iVX outperforms all the three volatility measures in reflecting the volatility of SSE50 ETF over the next 30-day period.

This paper further explores the asymmetric relationship between the iVX and SSE50 ETF returns, and demonstrates that there exists a one-day lag in iVX change to react to the shock of SSE50 ETF. The paper shows that if the one-day lag in iVX change is taken into account, iVX is observed to have a bigger change when there is a large decrease in the ETF return than where there is a large increase. In addition, this paper observes quadratic effects in the SSE50 ETF returns, and shows that there is a diminishing marginal effect of positive ETF returns on the iVX change, in contrast to an increasing marginal effect of negative ETF returns on the iVX change.

Combining the previous results, this paper finally concludes that iVX index serves as a good reference to the stock market volatility over 30 days. And if China lists products on the iVX index, those products have the potential for being used to hedge against the risks from investors' positions in the stock market. Furthermore, the paper also concludes that when the iVX index tends to increase with the SSE50 ETF for a long time, it may be the warning sign of bubbles in the market, so that investors need to be aware that a sharp decrease in the stock market can occur.

Keywords: iVX · SSE50 ETF returns · Asymmetric relationship · Risk management

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1. Introduction

In the United States, the Chicago Board Options Exchange (CBOE) Market Volatility Index, or VIX, is frequently used as a reference to the future stock market volatility. On January 19th, 1993, CBOE officially launched the real-time reporting of VIX. This index, now well known as the "fear index", reflects investors' expectations on the volatility of the S&P 500 Index over the next 30-day period. The components of the VIX calculation are near- and next-term S&P 500 index put and call options with more than 23 days and less than 37 days to expiration[1]. The VIX index is quoted in percentage points. When VIX level is low, it implies that investors expect low turbulence in the stock market over the next 30 days, so investors can also expect low risks for their investment portfolios. On the contrary, a high VIX reading suggests that investors perceive potential shocks in the market, and expect that the market would move sharply in either upward or downward direction. VIX is a useful index, as when the stock market is expected to increase or drop rapidly, investors can get the warning signal from a huge increase of VIX level, thus being prepared for the increasing of risks in the stock market.

In China, before the year 2015, the only two available volatility indices introduced in the market are China Volatility Index (CVX) published by China Financial Futures Exchange (CFFE) and China ETF Volatility Index (VXFXI) published by CBOE. The problem with the two indices is that they have limited strength in reflecting the expected turbulence of the stock market in mainland China, because they are calculated by using trading prices of options that are not traded in mainland China. CVX is calculated based on virtual options online and VXFXI is calculated based on the information of over-the-counter options listed on the Stock Exchange of

[1] *CBOE VIX Whitepaper*, pg.5, VIX Calculation

Hong Kong Ltd. (SEHK). Thus, before 2015, investors in mainland China didn't have a good volatility measure to reflect the expected volatility in the stock market.

In February 2015, China launched its first and only listed exchange-traded equity option, the SSE50 ETF option, on the Shanghai Stock Exchange (SSE). The listing of the ETF options in 2015 led to the establishment of the iVX index later in the same year. The iVX index now has a real-time reporting on the SSE website. It is calculated by using the trading prices of the near- and next-term SSE50 ETF put and call options. The launch of iVX provides the investors as well as the Chinese government a new volatility measure of the stock market.

2. The Broad Questions

Shanghai Stock Exchange claimed in its recent releasing statement that iVX would be used as an important index to predict the volatility of the stock market. It will also serve as an effective reference for the government and financial institutions to make better decisions in the market. However, whether iVX can perform well in capturing China's stock volatility remains questionable. SSE recently released calculation process of the iVX index, and it can be observed that the same formula used in the CBOE VIX model is applied to iVX. But since the underlying data sources of the two indices are different - iVX uses the trading prices of SSE50 ETF options, while VIX uses the trading prices of S&P 500 index options - the implications of the index reading can be greatly influenced. To some extent, SSE50 ETF options in China are similar with the S&P 500 index options in America, in that they are both European Style index options and their underlying indices are both strong indicators of the overall stock market. However, there are still a lot of differences between the two options. For example, unlike S&P 500 index options, in which one contract represents the claim for 100 shares of the S&P 500 index, in

SSE50 ETF options, one contract can claim for 10,000 shares of the SSE50 ETF[2]. The expiration sequential cycle for the SSE50 ETF options is the following: the current month, the following month and the last months of the next two quarters[3], which is also different from the expiration cycle of the S&P 500 index options. The exact expiration day for SSE50 ETF option contracts is the fourth Wednesday of the expiration month. Investors are only allowed to trade the ETF options three times a day: 9:15 a.m. - 9:25 a.m., 9:30 a.m. -11:30 a.m. and 13:00 p.m. - 15:00 p.m. Those time slots are also the only available time for investors to exercise the options. The unique trading rules of the ETF options may cause the issue that the iVX level cannot efficiently reflect the implied volatility in the market.

In addition, China has imposed a pricing boundary on both the stock trading and option trading, which can also affect the mechanism behind the iVX model, if it directly applies the VIX calculation formula. The percentage increase and decrease of the option price is strictly limited to 10% for a single trading day. Once the maximum percentage has been reached, the trading for that option will be closed immediately. This price boundary is also imposed on every stock listed on the Shanghai Stock Exchange. Therefore, people's anticipation of the market movements may not be fully embedded into either the SSE50 ETF data or the ETF options' data on the exact trading day. From this perspective, it can be argued that the liquidity of the ETF and the ETF options are limited, so a lag may occur between people's expectations of the market volatility and the market implementations. This can also greatly reduce the effectiveness of iVX.

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[2] On Nov. 29th, 2016, SSE50 ETF gave out cash dividends. Therefore, the number of shares per contract for ETF options that expire in December 2016, January 2017, March 2017 and June 2017 temporarily changed into 10220. This is calculated by: (old shares * ending price of ETF on Nov. 28th, 2016)/ (ending price of ETF on Nov. 28th, 2016 - dividends per share) = (10000 * 2.460)/ (2.460 - 0.053) = 10220.

[3] *SSE50 ETF Options Basic Term*, pg.1. Note: the first option contracts released in February 2015 were different. They expired in March, April, June and September, respectively.

Hence, this paper first focuses on evaluating the efficiency of the SSE iVX index in reflecting the stock volatility over the next 30 days. After examining iVX's efficiency, this paper also discusses about whether iVX has the potential use in the risk management. In the United States, products using the VIX index as the underlying asset are considered as suitable hedging products against the risks in the stock market. Previous studies on the relationship between VIX and the S&P 500 index show that in general, VIX moves inversely with SPX. Furthermore, statistical results show that there exists an asymmetric relationship between VIX and SPX[4], meaning that VIX has a bigger change when there is a large decrease in the SPX return than where there is a large increase in the SPX return. The inverse movement and the asymmetric relationship between VIX and SPX generated the potential use of VIX for hedging purposes, so this paper further examines whether iVX has a similar relationship with the SSE50 ETF to explore the potential use of iVX in risk management. Consequently, the following three questions are explored in this thesis:

(a) Does iVX perform well in capturing the volatility of SSE50 ETF over the next 30 days?

(b) Is there an asymmetric relationship between iVX and SSE50 ETF return?

(c) How can the investors in mainland China use iVX for risk management purposes?

3. The Methodology

This research mainly focuses on statistical computations and regression models. To answer the three broad questions, the paper is divided into two parts.

In the first section, this paper examines whether iVX can better capture SSE50 ETF's realized volatility over the next 30 days than the existing indicators of stock market volatility. The paper compared the performance of iVX with the performances of three other volatility

[4] *Relationships Between Implied Volatility Indexes and Stock Index Returns*, pg.2

measures, CFFE CVX, CBOE VXFXI, and the conditional volatility model from the ARCH/GARCH class models, namely the GARCH (p, q) model. Following the methods used in Abhijeet Chandra and M. Thenmozhi's paper, "On Asymmetric Relationship of India Volatility Index (India VIX) with Stock Market Return and Risk Management", the paper regresses the four volatility indices with the realized volatility of SSE50 ETF returns. In this study, we employ two traditional measures of unconditional realized volatility that were frequently referred to in financial literatures, the realized variance[5] and the standard deviation of daily SSE50 ETF returns over 30 days. To compare among the eight models, three criteria[6] are applied to measure which one of the four volatility indices can better capture SSE50 ETF's realized volatility over the next 30 days. The criteria in this study include root mean square error (RMSE), mean absolute error (MAE), and the metric Chris Tofallis discussed about in his paper in 2015, the log of the accuracy ratio[7], which is more superior to one of the commonly used criteria - mean absolute percent error (MAPE), especially for heteroscedastic data[8].

In the second section, this paper further studies the relationship of iVX with the positive and negative SSE50 ETF returns to examine whether there is an asymmetric relationship between the two. The paper reports ten extreme ETF returns, together with the corresponding iVX level on the same day to see how much iVX changed when strong turbulences occurred in the stock market. The iVX levels on the following trading day are also listed in the same table to identify whether there is a lag between people's expectations of the market volatility and the market implementations due to the unique price boundary in stock and option trading in

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[5] RVOL = $\sum_{i=1}^{n} {r_i}^2$, where n is the number of trading days in a month

[6] The first two criteria were mentioned in Abhijeet Chandra and M. Thenmozhi's 2015 paper

[7] calculated by $\frac{1}{n}\Sigma\,(\ln Q)^2$, where Q = $\frac{\text{Predicted Value}}{\text{True Value}}$

[8] *A better measure of relative prediction accuracy for model selection and model estimation*, pg. 9

mainland China. Then, following the regression model used by Pierre Giot in his paper published in 2015, “The Relationships Between Implied Volatility Indexes and Stock Index Returns", this paper applies the same model on the iVX change and the ETF returns:

$$r_{\mathrm{iVX,t}} = \beta_0^+ D_t^+ + \beta_0^- D_t^- + \beta_1^+ r_{\mathrm{ETF,t}} D_t^+ + \beta_1^- r_{\mathrm{ETF,t}} D_t^- + \varepsilon_{\mathrm{t}}$$

Where $r_{\mathrm{iVX,t}}$ represents the change in iVX on day t,

$r_{\mathrm{ETF,t}}$ represents the change in SSE50 ETF returns on day t,

D_t^+ is a dummy variable that equals 0 when the ETF has negative return on day t, and equals 1 when the ETF has negative return on day t, D_t^- = 1 - D_t^+.

Moreover, the paper also takes a one-day lag of iVX into consideration and applies a new model on the iVX change and the ETF returns:

$$r_{\mathrm{iVX,t}} = \beta_0^+ D_{t-1}^+ + \beta_0^- D_{t-1}^- + \beta_1^+ r_{\mathrm{ETF,t-1}} D_{t-1}^+ + \beta_1^- r_{\mathrm{ETF,t-1}} D_{t-1}^- + \varepsilon_{\mathrm{t}}$$

This paper further explores the quadratic effect in the SSE50 ETF returns by adding quadratic terms of the ETF returns into the model:

$$r_{\mathrm{iVX,t}} = \beta_0^+ D_{t-1}^+ + \beta_0^- D_{t-1}^- + \beta_1^+ r_{\mathrm{ETF,t-1}} D_{t-1}^+ + \beta_1^- r_{\mathrm{ETF,t-1}} D_{t-1}^- + \beta_2^+ r_{\mathrm{ETF,t-1}}^2 D_{t-1}^+ + \beta_2^- r_{\mathrm{ETF,t-1}}^2 D_{t-1}^- + \varepsilon_{\mathrm{t}}.$$

Finally, combining all the results, this paper offers the potential use of the iVX index in risk management field.

4. Data and Measurement of Variables

This paper uses the daily closing values with non-overlapping observations for the period spanning from Feb. 9th, 2015 through Feb. 28th, 2017 on the following variables:

- iVX Index

  The SSE iVX index is launched by Shanghai Stock Exchange in February 2015 and now has a real-time reporting on the SSE website. It is calculated using the trading prices of the nearand next-term SSE50 ETF put and call options, and using the same formulas as calculating the CBOE VIX. Therefore, iVX is supposed to work in the same way as the CBOE VIX. When iVX level is low, it implies that investors expect low turbulence in the stock market over the next 30 days, while a high iVX level suggests that investors perceive potential shocks in the market, and expect that the market would move sharply in either upward or downward direction. The iVX index is currently still under a test run, and SSE claimed that iVX would be used as an important index to predict the volatility of the stock market in the future.

- <u>SSE50 ETF</u>

  SSE50 ETF is an exchange-traded fund that tracks the SSE50 index, so that they have similar performances. SSE50 index selects 50 blue chip company stocks that are traded at the Shanghai Stock Exchange with the most liquidity. Also, those companies chosen are the most influential companies in their respective industry. Therefore, although the SSE50 index only contains the information of 50 stocks, it is still considered as a strong indicator of the market. The SSE50 ETF, which closely tracks the index's performances, also has the strong reflection power of the overall stock market performance.

- <u>CVX Index</u>

  The CVX index was released by China Financial Futures Exchange (CFFE) in January 2014, one year before the publish of the SSE iVX index. CVX is calculated based on the simulated online trading data of options on the Shanghai Composite Index (SCI) 300. The CSI 300 Index is a free-float weighted index that consists of 300 A-share stocks listed on the Shanghai or Shenzhen Stock Exchanges. The SCI 300 options takes the SCI 300 Index as the underlying asset, but those options are virtual options for investors to practice online option trading. In other words, people cannot gain or lose real money by trading the SCI 300 options. Ever since its release in 2014, the index keeps being updated daily by CFFE as an indicator of the stock market volatility, so it makes a comparable volatility measure to the iVX index.

- VXFXI Index

  The VXFXI index was released by CBOE in March 2011. It is the first volatility index introduced to reflect the stock volatility in China. VXFXI is calculated using the trading data of options on the iShares Trust FTSE China 25 Index Fund, which are over-the-counter options traded on the Stock Exchange of Hong Kong Ltd. (SEHK). The Fund, which is also called Xinhua China 25 Index Fund, seeks investment results that correspond generally to the price and yield performance, before fees and expenses, of the Xinhua FTSE China 25 Index. The Fund's portfolio of sectors include Financials, Telecommunication, Oil & gas, Technology and Consumer goods. Xinhua FTSE China 25 Index (the underlying index of the fund) is composed using the company shares listed on SEHK of 25 companies in mainland China that are closely followed by international investors. The VXFXI index was released four years before the publish of the SSE iVX, and it also keeps being updated daily by CBOE until today, so I chose it to be another comparable volatility measure to the iVX index.

- GARCH (p, q) model - GARCH (1, 1) model

  GARCH (p, q) model is the conditional volatility model from the ARCH/GARCH class models, and it is a frequently used model to estimate the implied volatility of indices. Empirical evidence supports that a simple GARCH (1,1) process can be fitted adequately in many time financial series (Sharma et al. 1996). Hence, in this study, I employed a GARCH

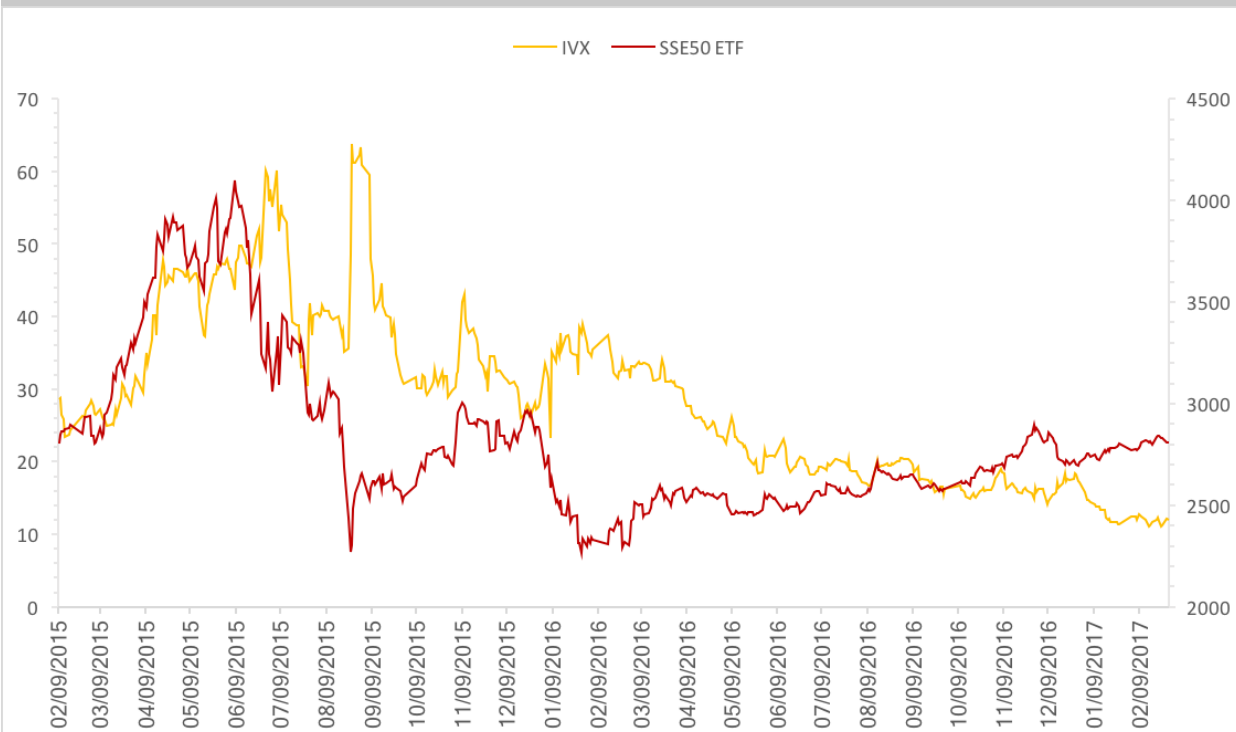
(1,1) model to the SSE50 ETF daily returns, and used the results I get as the third comparable measure to the iVX index.

5. Data Analysis

Overall behavior of iVX and SSE50 ETF

The graph of iVX and SSE50 ETF is plotted below in Figure 1. From the plot, it can be observed that iVX behaved differently in the following two sub-periods: Feb. 9th, 2015 to Jun. 18th, 2015 and Jun. 19th, 2015 to Feb. 28th, 2017. In the first sub-period from Feb. 9th, 2015 to Jun. 18th, 2015, iVX tended to move along with the ETF[9], while in the second sub-period from Jun. 19th, 2015 to Feb. 28th, 2017, iVX moved inversely with the ETF, which is very similar with the performance of the CBOE VIX related to the S&P 500 Index.

Figure 1: Movement of SSE iVX and SSE50 ETF



[9] The explanation for this abnormal phenomenon will be covered in later sections.

The descriptive statistics of the SSE iVX and the SSE50 ETF are reported in Table 1. The statistics of iVX shows that its average level in the sample period is 28.84%. The statistics of SSE50 ETF shows that the ETF maintains a nearly zero average return[10] during the sample period, with the standard deviation of its daily return reaching 1.9 %. Both the iVX and the SSE50 ETF are skewed to the right, while the ETF return is skewed to the left.

Table 1: Descriptive Statistics of Indices

	SSE iVX	SSE50 ETF	SSE50 ETF Return
(a) Descriptive statistics			
Mean	28.839291	2830.413804	0.000003
Median	28.049050	2717.974600	0.000456
Maximum	63.788600	4099.057700	0.075471
Minimum	11.062700	2266.844700	-0.098521
Range	52.725900	1832.213000	0.173992
Standard Deviation	11.780581	400.369255	0.019040
Skewness	0.597355	1.421947	-0.871737
Kurtosis	-0.265160	1.307272	5.451551
Top decile	46.029700	3,553.515700	0.020493
Bottom decile	15.668700	2,470.828800	-0.016823
Observations	498	498	498
(b) Correlation between indices			
SSE iVX	1.000000		
SSE50 ETF	0.507727***	1.000000	
SSE50 ETF Return	-0.022375	0.070671*	1.000000

** Significant at 12 % Level* **** Significant at 1 % Level*

[10] In this paper, all the returns/changes are calculated by taking the log difference, so that the series can be more stable.

First Section: Compare iVX with other volatility measures

The daily closing data of CVX and VXFXI are directly collected from the WIND database. The paper builds the conditional volatility measure, the GARCH (1, 1) model, on the daily ETF returns to get the volatility estimations. It first tests the stationarity of the ETF returns using an augmented Dickey–Fuller test and then tests the ARCH effect of the ETF returns by using a Lagrange Multiplier test. The ADF test result is shown in Table 2, and the LM test result is shown in Table 3.

Table 2: Dickey-Fuller Test Result for Unit Root

		---------------- Interpolated Dickey-Fuller -----------------		
	Test Statistic	1% Critical Value	5% Critical Value	10% Critical Value
Z(t)	-14.167	-3.457	-2.879	-2.570

MacKinnon approximate p-value for Z(t) = 0.0000

Table 3: LM Test Result for Autoregressive Conditional Heteroscedasticity (ARCH)

lags(p)	chi2	df	Prob > chi2
1	28.817	1	0.0000

H_0: No ARCH effects vs. H_1: ARCH(p) disturbance

Judging from the ADF test result, the p-value is 0.000, so we can reject the null hypothesis at 5% as well as at 1% level of significance. This shows that the SSE50 ETF return series is stationary. The LM test of the ETF return series reports a p-value of 0.000, which is well below 0.05, so we reject the null hypothesis of no ARCH (1) effects. Therefore, this paper further estimates the ARCH (1) parameter by specifying arch (1).

The paper then employs the GARCH (1, 1) model on the SSE50 ETF return series, and the result is reported in Table 4. From the result, we can observe that both α and β are significant at 1% confidence level. Also, $\alpha + \beta$ is significantly less than 1, which implies that the volatility is mean reverting. Given the values of α and β from the GARCH (1,1) results, the estimation model of the SSE50 ETF volatility is built as the following:

$$\begin{cases} r_{SSE,t} = 0.0003 + \varepsilon_t & (1) \\ {\sigma_t}^2 = 0.239\, {\varepsilon_{t-1}}^2 + 0.757\, {\sigma_{t-1}}^2 & (2) \end{cases}$$

Table 4: GARCH (1,1) of SSE50 ETF Return

	Coefficient	Standard Error	z	P > |z|
Constant	0.0003075	0.0007143	0.43	0.667
α	0.2392172***	0.0520113	4.60	0.000
β	0.7570530***	0.0873708	8.66	0.000

**** Significant at 1 % Level*

The statistics of the three comparable volatility indices, CVX, VXFXI and the GARCH (1, 1) prediction are reported in Table 5.

Table 5: Descriptive Statistics of Three Volatility Estimates

	GARCH (1,1) Volatility Estimates	CFFE CVX	CBOE VXFXI
Mean	0.000343	35.809197	28.549335
Maximum	0.003212	110.580000	58.400000
Minimum	0.000071	10.590000	17.090000
Range	0.003141	99.990000	41.310000
Standard Deviation	0.000351	14.462595	6.732292
Skewness	4.927539	0.966731	1.040550
Kurtosis	32.82088	1.177661	1.504851
Observations	498	498	481[11]

[11] Note: The underlying asset of CBOE VXFXI is options traded in Stock Exchange of Hong Kong Ltd., where the trading dates are different from those of mainland China. Therefore, I processed the VXFXI data, so that only those prices on mainland China trading days are kept. This is the reason why only I only have 481 VXFXI observations, which is different from other indices.

To calculate the realized volatility of the SSE50 ETF returns over the 30 days, this paper employs two common measures that are frequently used in financial literatures, the realized variance (RVOL = $\sum_{i=1}^{n} r_i{}^2$, where n is the number of trading days in a month) and the standard deviation of daily SSE50 ETF returns. The statistics of the two measures of realized volatility are reported in Table 6.

Table 6: Descriptive Statistics of Two Realized Volatility Measures

	Realized Variance (RVOL)	SD of Daily SSE50 ETF Returns
Mean	0.006310	0.016163
Maximum	0.039018	0.049060
Minimum	0.000194	0.003432
Range	0.038824	0.045628
Standard Deviation	0.008139	0.010567
Skewness	2.104538	1.154330
Kurtosis	4.077846	0.757642
Observations	481	481

This paper then regresses each of the volatility indices with each of the proxies of the ETF realized volatility, so there are eight regression models in total. The results are reported in Table 7. Statistical results show that iVX has the strongest explanatory power in terms of the realized volatility of the SSE50 ETF over the next 30-day period, as the Adjusted R-squares are the highest from the models that use iVX as the independent variable, reaching 44.95% and 60.49% respectively for realized variance and the standard deviation of daily SSE50 ETF returns.

Table 7: Performance of iVX and other volatility measures in capturing realized volatility

Dependent variable	Constant	β	Adj. R-square	F-statistic
(a) Independent variable: SSE iVX				
Realized Variance (RVOL)	-0.0076762 (0.0007575) [0.000]	0.0004746 (0.0000239) [0.000]	0.4495	392.87
SD of Daily SSE50 ETF Returns	-0.00489 (0.0008331) [0.000]	0.0007143 (0.0000263) [0.000]	0.6049	735.75
(b) Independent variable: GARCH (1,1) Volatility Estimates				
Realized Variance (RVOL)	0.0037184 (0.0004924) [0.000]	7.464893 (0.9897457) [0.000]	0.1045	56.89
SD of Daily SSE50 ETF Returns	0.0123497 (0.0006286) [0.000]	10.9663 (1.263553) [0.000]	0.1343	75.32
(c) Independent variable: CFFE CVX				
Realized Variance (RVOL)	-0.0030162 (0.0008827) [0.001]	0.0002589 (0.0000227) [0.000]	0.2114	129.69
SD of Daily SSE50 ETF Returns	0.0010103 (0.0010546) [0.339]	0.0004206 (0.0000272) [0.000]	0.3323	239.85
(d) Independent variable: CBOE VXFXI				
Realized Variance (RVOL)	-0.0042417 (0.0016333) [0.010]	0.0003654 (0.0000551) [0.000]	0.0847	43.92
SD of Daily SSE50 ETF Returns	-0.0032247 (0.002012) [0.110]	0.0006705 (0.0000679) [0.000]	0.1722	97.49

Standard errors and p-values are reported in () and [] respectively

This paper further evaluates the eight regression models by applying three criteria to measure which one of the four volatility indices can better capture SSE50 ETF's realized volatility over the next 30 days. The criteria in this study include RMSE, MAE, and the log of the accuracy ratio: $\frac{1}{n}\Sigma(\ln Q)^2$, where $Q = \frac{\text{Predicted Value}}{\text{True Value}}$. The last criterion was introduced by Chris Tofallis in his paper in 2015. Tofallis proved that this metric is more superior to one of the commonly used criteria - mean absolute percent error (MAPE), especially for heteroscedastic data. Since the SSE50 ETF returns are time series data, which normally suffers from heteroscedasticity, the log of the accuracy ratio is a more appropriate criterion in this study than MAPE. The results of the three criteria are listed in Table 8.

Table 8: Performance Comparison of Different Volatility Measures

	SSE iVX	GARCH (1,1) Volatility Estimates	CFFE CVX	CBOE VXFXI
(a) Root Mean Square Error (RMSE)				
Realized Variance (RVOL)	0.00604	0.00771	0.00723	0.00783
SD of Daily SSE50 ETF Returns	0.00664	0.00984	0.00864	0.00964
(b) Mean Absolute Error (MAE)				
Realized Variance (RVOL)	0.00379	0.00519	0.00469	0.00538
SD of Daily SSE50 ETF Returns	0.00454	0.00761	0.00639	0.00738
(c) $\frac{1}{n}\Sigma(\ln Q)^2$, where $Q = \frac{\text{Predicted Value}}{\text{True Value}}$				
Realized Variance (RVOL)	0.94818	1.87542	1.23158	1.73043
SD of Daily SSE50 ETF Returns	3.17318	4.26289	3.75381	4.09869

Judging from the results shown in Table 8, This paper concludes that iVX index outperformed all three other volatility measures in reflecting SSE50 ETF's realized volatility over the next 30 days, as the models using iVX as the independent variable have the least forecast errors under all three criteria.

Second Section: Analyze iVX change in terms of positive and negative SSE50 ETF returns

Table 9: Extreme ETF Returns and iVX Changes

(a) Ten highest one-day ETF percentage gains

Date	ETF Return (%)	iVX Change (%)	Closing iVX	iVX Change $_{t+1}$ (%)	Closing iVX $_{t+1}$
2015-08-27	7.547%	-4.234%	61.144	0.032%	61.164
2015-06-30	6.911%	-1.480%	59.206	-5.727%	55.911
2015-07-09	6.388%	6.801%	55.341	-2.411%	54.023
2015-07-06	6.293%	8.558%	60.078	-9.129%	54.837
2015-12-02	4.730%	-3.864%	32.452	0.241%	32.530
2015-06-08	4.576%	-6.514%	43.660	8.532%	47.549
2015-08-10	4.447%	-0.103%	40.750	-1.404%	40.182
2015-11-04	4.259%	0.793%	30.249	6.130%	32.161
2015-06-01	4.185%	-0.158%	47.216	0.831%	47.611
2015-04-16	4.169%	-7.160%	37.361	10.675%	41.570
Average	5.351%	-0.736%	46.746	0.777%	46.754

(b) Ten highest one-day ETF percentage losses

Date	ETF Return (%)	iVX Change (%)	Closing iVX	iVX Change $_{t+1}$ (%)	Closing iVX $_{t+1}$
2015-08-24	-9.852%	1.146%	35.608	30.564%	48.338
2015-07-27	-9.474%	-8.445%	30.409	26.202%	39.518
2015-07-08	-7.510%	-5.885%	51.703	6.801%	55.341
2015-06-26	-7.301%	1.381%	48.084	22.289%	60.089
2015-08-25	-7.263%	30.564%	48.338	27.736%	63.789
2015-05-28	-6.808%	-0.593%	46.632	1.403%	47.291
2016-01-04	-6.412%	17.931%	33.439	-3.840%	32.179
2016-01-07	-6.096%	-30.052%	23.330	41.179%	35.217
2015-08-18	-5.749%	-2.500%	39.073	-4.318%	37.421
2016-01-26	-5.669%	-8.175%	32.016	18.351%	38.465
Average	-7.213%	-0.463%	38.863	16.637%	45.765

This paper reports ten extreme values of both the positive and negative ETF returns in Table 9 to see how iVX reacted to the shocks in the stock market. It also includes the iVX change of the next trading day. From the above table, we have an interesting observation that there seems to be a lag in the iVX change, which means than the iVX reacts to the market shock after one trading day. In terms of the ten extreme negative returns in the SSE50 ETF, a sharp increase in iVX only occurred on the next trading day.

To further prove that the one-day lag exists in iVX change exists, this paper builds and runs the following two models, which separates the positive and negative ETF returns:

[The model doesn't include the lag] $r_{\mathrm{iVX,t}} = \beta_0^+ D_t^+ + \beta_0^- D_t^- + \beta_1^+ r_{\mathrm{ETF,t}} D_t^+ + \beta_1^- r_{\mathrm{ETF,t}} D_t^- + \varepsilon_{\mathrm{t}}$

[The model includes the lag] $r_{\mathrm{iVX,t}} = \beta_0^+ D_{t-1}^+ + \beta_0^- D_{t-1}^- + \beta_1^+ r_{\mathrm{ETF,t-1}} D_{t-1}^+ + \beta_1^- r_{\mathrm{ETF,t-1}} D_{t-1}^- + \varepsilon_{\mathrm{t}}$

The regression results of the two models are presented in Table 10.

Statistical results show that if the one-day lag in the value of iVX change is not taken into consideration, all the parameters are non-significant, meaning that iVX is independent of the positive and negative ETF returns, which cannot be the case since iVX uses the ETF options as its underlying data source. Also, a negative Adjusted R-square is reported in this model. If we take the lag in the iVX change into regression model, it can be observed that there exists a significant relationship between $r_{\mathrm{iVX,t}}$ and both the positive and negative ETF returns on day t -1. This one-day lag in iVX change to react on the shocks occurred on SSE50 ETF is expected, as I mentioned previously that the Chinese government has price boundaries on both stock and option trading. Stocks and options will be forced to stop trading after a 10% of increase or decrease in the prices, which may delay people's fear of high volatility to the next day. Another reason for this one day lag could be the limited trading hours of the SSE50 ETF options. As was introduced, the investors only have three time periods a day to trade or exercise options, which greatly affects the liquidity of the options.

From the results in table 10, it can also be clearly observed that an asymmetric relationship of iVX with the SSE50 ETF return exists, if the model includes the one-day time lag in iVX change, as β_1^- has a higher absolute value than β_1^+. This shows that iVX has a bigger change when there is a large decrease in the ETF return than when there is a large increase, which is very similar with the performance of CBOE VIX in terms of the S&P 500 index.

Table 10: Results from the two regression models

(a) Model 1 without a one-day time lag in iVX Change

β_0^+	β_0^-	β_1^+	β_1^-	β_2^+	β_2^-	R^2	N
-0.007055	-0.001982	0.390821	-0.080779				
(0.003747)	(0.004480)	(0.26163)	(0.424369)	-	-	0.0054	498
[0.060]	[0.658]	[0.136]	[0.849]				

(b) Model 2 with a one-day time lag in iVX Change

β_0^+	β_0^-	β_1^+	β_1^-	β_2^+	β_2^-	R^2	N
-0.009106	-0.020454	0.562092	-1.575357				
(0.003817)	(0.00474)	(0.285672)	(0.489958)	-	-	0.1147	497
[0.017]	[0.000]	[0.050]	[0.001]				
-0.018238	0.001778	2.168596	2.113935	-32.66405	54.20504		
(0.004013)	(0.004597)	(0.612490)	(0.588377)	(11.21598)	(6.18278)	0.2181	497
[0.000]	[0.699]	[0.000]	[0.000]	[0.004]	[0.000]		

White's heteroscedastic consistent standard errors are given in (), p values are given in []. N is the number of observations.

Finally, the paper adds the quadratic terms of the positive and negative ETF returns into the model, to find out if the size of the ETF returns can have an influence on the change of iVX. The results are also reported in Table 10. The regression results show that there is a diminishing rate of return for greater positive ETF returns, and an increasing rate of return for greater negative ETF returns, which means that for extreme ETF returns, iVX will change more in terms of negative ETF returns. This further indicates that the asymmetric relationship between the iVX index and the SSE50 ETF returns is strengthened at extreme ETF returns.

The potential of iVX in risk management

From the results in the previous two sections, it can be concluded that iVX index serves as a good reference to the stock market volatility over 30 days. In fact, compared to the only two other existing volatility indices, CVX and VXFXI, as well as the traditional volatility estimation model, the GARCH (1, 1) model, iVX performs better than all three of the volatility measures. Since the paper identifies an asymmetric relationship between the iVX index and the SSE50 ETF returns, which is further strengthened at extreme ETF returns, iVX has the potential to be used in risk management field. If China lists products on the iVX index in the future, those products can be used to hedge against the risks from investors' positions in the stock market.

In addition, the paper mentions previously that in the sub-period from Feb. 9th, 2015 to Jun. 18th, 2015, iVX tended to move along with the SSE50 ETF, especially when ETF increases, iVX also increases. A big event in the stock market around this period is that starting from Jun. 12th, 2015, the China's stock crash occurred. The Shanghai Composite Index, an index of 1,073 stocks (A shares and B shares) that are traded at the Shanghai Stock Exchange, dropped from 5000 to 3000 in 3.5 months. Combined the abnormal phenomenon of iVX with this big event in the China's stock market, it can be concluded that when the iVX index tends to move with the SSE50 ETF for a long time, it may be the warning sign of bubbles in the market, so that investors need to be aware that a sharp decrease in the stock market can occur. The reason behind this can be that when iVX increases with the ETF, it may suggest that investors are panic about the high risks in the stock even if the ETF has a positive return, which is a signal for bubbles in the market.

6. Conclusions

This paper concludes that among the four different volatility measures, SSE iVX, CFE CVX, CBOE VIFXI, and GARCH (1,1) estimate of the ETF return series, iVX has the best performance in capturing the volatility of SSE50 ETF over 30 days.

This paper also shows that there exists a one-day lag in iVX change to react on the shocks occurred on SSE50 ETF. And if this one-day lag in iVX change is taken into account, statistical results from the regression models show that there exists an asymmetric relationship between iVX and SSE50 ETF return. It can be observed that iVX has a bigger change when there is a large decrease in the ETF return than when there is a large increase, which is very similar with the performance of CBOE VIX in terms of the S&P 500 index. In addition, quadratic effects exist in the SSE50 ETF returns. The paper shows a diminishing marginal effect of positive ETF return on the iVX change, and an increasing marginal effect of negative ETF return on the iVX change, which further indicates that an asymmetric relationship exists between iVX and the SSE50 ETF returns.

Finally, combining the previous results, this paper concludes that iVX index serves as a good reference to the stock market volatility over 30 days. And if China lists products on the iVX index in the future, those products have a strong potential for being used to hedge against the risks from investors' positions in the stock market. Furthermore, the paper also concludes that when the iVX index tends to increase with the SSE50 ETF for a long time, it may be the warning sign of bubbles in the market, so that investors need to be aware that a sharp decrease in the stock market can occur.

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