The VIX and VXN volatility measures: Fear gauges or forecasts?

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Practical applications

Should an alert trader/investor sell options (and hedge) when the VIX (or VXN) rises? If the rise in the VIX reflects mainly investor fear, then the sale of options is potentially profitable. If, however, the rise in the VIX reflects an increase in anticipated volatility, then such selling of options is not potentially profitable.

The authors' research indicates that prior to August 1998, the VIX reflected fear and potential profits existed. Thereafter, however, neither the VIX nor the VXN seem to have reflected fear. Therefore, selling options when the VIX and VXN rise does not appear to be a profitable strategy.

Abstract

This paper examines the behaviour of the 'VXO', previously called the 'VIX', and 'VXN' measures of the volatility implied by stock index options. From the mid-1990s to the end of 2002, the volatility measures seem to reflect both sentiment associated with market declines ('fear') and imminent actual volatility. There is a stark difference between the early and late parts of that time interval, however. Prior to the Russian default in August 1998, the volatility measures do not forecast imminent stock index volatility; the VXO in this early period seems to be reflective of investor fear. In the interval after the Russian default, however, both the VXO and the VXN reflect future volatility rather than investor fear.

INTRODUCTION

The VIX, the implied volatility of 30-day options on the S&P, has gained popularity as an indicator of investor fearfulness about future declines in stock prices.[1] Some market participants claim that, when stocks prices decline, investors become afraid of

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holding stocks, and their fears are reflected in a higher VIX. Indeed, it has become common for financial commentators to refer to the VIX as the 'fear gauge'. An alternative viewpoint, rooted in the theory of options, is that the VIX forecasts the imminent volatility in the S&P.

Whether or not the VIX is a fear gauge has implications for market efficiency and for whether certain types of trading strategies involving options on stock indexes are profitable. For example, if investor fear raises option premiums, there might be profitable opportunities to sell index options (and hedge them) at such times. In contrast, if expected volatility is raising option premiums, and if volatility does turn out to be high, selling and hedging index options when the VIX/VXN rise would not end up being profitable. Yet, the literature to date does not contain any careful tests of the relative validity of the two viewpoints.

This paper investigates the extent to which the VXO — the new label for the original VIX — and VXN forecast future stock market volatility versus the extent to which they reflect market participants' short-term fears. (Until late 2003, the 'VIX' corresponded to options on the S&P100; since then, it has been redefined to apply to options on the S&P500 and reflects a new methodology; at that time, the new name 'VXO' was assigned to the implied volatility on the S&P100 as originally specified.) The plan of the paper is as follows: the next section discusses the background of the issue; the following section presents the model and empirical results; in the next section the results are discussed. The final section concludes.

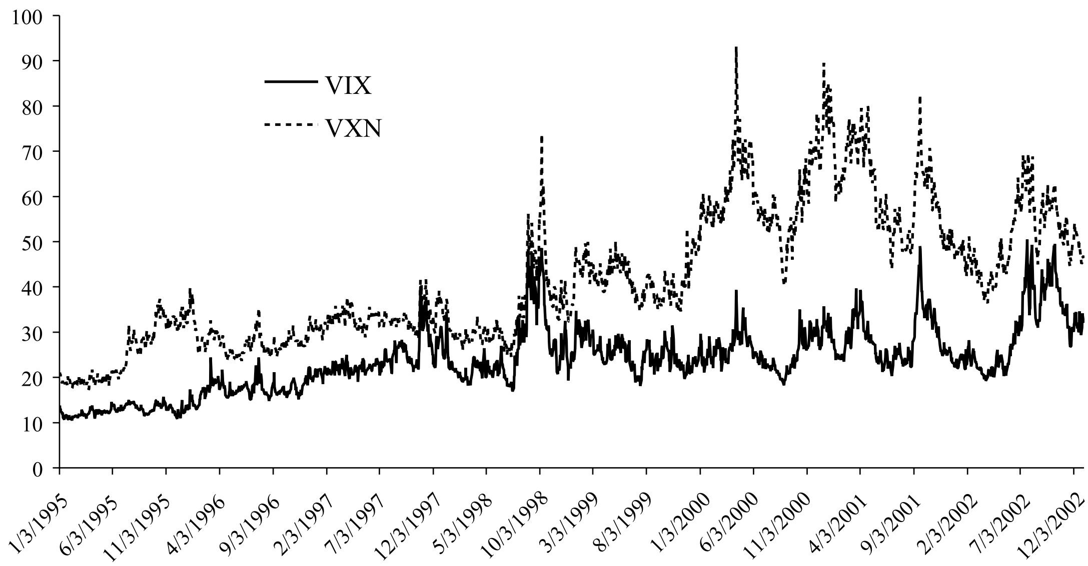
BACKGROUND

The VXO, which has been calculated by the Chicago Board Options Exchange (CBOE) since 1993, reflects the volatility implicit in 30-day options on the S&P100, an index of 100 large cap stocks. S&P100 puts and calls which have strike prices close to the money and which have fewer than 30 calendar days or somewhat more than 30 calendar days to expiration are each used to obtain an implied volatility.[2] The implied volatility estimates from the different options whose strike is close to the money and expiration dates are close to 30 days are combined to compute an average 'implied volatility' that approximates the 30 day mark.

Some years later, the CBOE began to compute a volatility measure for the Nasdaq-100, using a similar methodology. That new measure, called the 'VXN', was calculated back to 1995. Figure 1 shows the VXO and VXN since 1995.

There are two quite different perspectives on these volatility measures. The typical academic perspective is that market participants have a forecast of future volatility for the underlying stock index. They insert that forecast of future volatility (as well as the strike price of the option, the current level of the S&P, its dividend yield, the risk-free rate and the time to expiration) into a model such as Black-Scholes to derive an option value that corresponds to that expected volatility. The higher the inserted volatility, the

Figure 1: VXO and VXN since 1995



higher will be the calculated value of an option on that stock index. From this perspective, high option premiums in the market reflect the fact that market participants are anticipating high volatility for that stock index over the option's life.

Fleming *et al.*[3] investigate whether the implied volatility predicts future volatility over the 1987–93 time interval. They find that the VIX does have some predictive power, although it is a biased estimator of future volatility. Fleming[4] also finds some predictive power in the VIX, and Christensen and Prabhala[5] find both predictive power and unbiasedness, using an instrumental variables approach that is designed to circumvent the measurement problems inherent in the VIX computations.

The alternative interpretation of the VXO and the VXN is that they reflect investor concern about the stock market rather than an estimate of future volatility. For this interpretation, the implicit argument is something like the following: people rush in to buy options when they are nervous. Put options on the S&P100, for example, protect against the downside on a portfolio of large cap stocks. That protection against downside risk is more desirable when stockholders are worried. Call options provide upside possibilities but do not have the downside risk associated with owning stocks. Therefore, call options are also more desirable when investors are worried. The extra demand for both puts and calls at times of investor fear bids up their prices. If the price of an option rises, other inputs to the model (time to expiration, dividends, interest rates and stock index level) being unchanged, then the volatility that is calculated as implicit in the option premium must be higher.

Option theoreticians would respond to this argument by noting that, if rational traders were willing to supply additional quantities of options at 'fair' prices, ie fair volatilities, the price of options would not be bid up much, despite the greater demand by fearful investors. Those traders who sell overly expensive options could hedge their short options positions with stock baskets, exchange-traded funds or index futures, rehedging when necessary; or they could sell both puts and calls to achieve a delta-neutral position in the underlying index, adjusting their options positions as necessary to stay delta- neutral.[6] Traders who sell high-priced options could earn the difference between the overly high market value of these options and the fair price, minus the transactions costs of the options trading and associated hedging and rehedging. From this perspective, a sizeable fear impact could indicate that (a) the transactions costs are very large and/or (b) the suppliers of these index options require substantially higher returns for writing a greater quantity of options.

Fleming *et al.*[3], Simons[7] and Whaley[8] examine whether the VIX measures 'fear'. Fleming *et al.* correlate daily changes in the VIX with stock market returns. They find a strong *contemporaneous* negative correlation (−0.61 for their non- crash sample) — when stock prices fall, the VIX tends to increase. Lagged values of stock returns, however, have no effect on the VIX. Simons[7] claims that each 1 per cent fall in the S&P100 produces a 4.73 per cent rise in the VIX. Whaley[8] tests weekly changes in the VIX against weekly percentage changes in the S&P100. He finds that rises in the VIX are associated with declines in the S&P100: each 1 percentage point rise in the VIX is associated with a reduction of the S&P100 by about 0.7 per cent.

Although all these articles address the issue of the relationship of the VIX to other market measures, and the Fleming *et al.*[3] article carefully considers many alternatives, none of these articles explicitly addresses the question of which explanation of the VIX is better — 'fear' or forecast — or whether they both have some merit.

This paper explores the two alternative explanations more directly, using a dataset that covers the 1993–2002 time interval for the VXO, and 1995–2002 for the VXN.

THE MODEL AND EMPIRICAL FINDINGS

The model

The model used to test the role of 'fear' versus anticipated volatility is

$$V_t = a_0 + a_1 {*} ASD_t + a_2 {*} FEAR_{t-1} + a_3 {*} DUM901_t$$

where the variables are constructed as follows.

- V represents either the VXO or the VXN: The daily close of the VXO and VXN on the first day of each month was obtained from the CBOE.[9] In most cases, 30 days of subsequent volatility occurred within the same calendar month.
- Actual volatility (*ASD*): S&P100 and

NDX daily closes were obtained from the Yahoo Finance website (historical data), and the annualised volatility for day 2 to the end of each month was calculated. (The price ratio of the index on each day to the previous one was calculated, the logs of these price ratios computed, and then the standard deviation for each month calculated. Finally, the daily standard deviation was annualised so that ASD measures actual volatility over the month in the same annual units as the VXO or VXN.) The days used in calculating the actual volatility for each month are (roughly) the same as the 30 calendar days represented by VXO (VXN) on the first day of the month — since the volatility measures represent implied volatility on options with 30 days of life.[10]

— *FEAR1*: 'Fear' cannot be measured directly, but stock market declines can be observed. As a rough measure of 'investor sentiment', the percentage changes in the S&P100 (NDX) in the five-day period prior to each VXO (VXN) observation are calculated. Note that the lagged change is used in order to avoid the contemporaneous causality issue.[11]

— *FEAR2*: Here, the five-day percentage change in the S&P100(NDX) is used only if it is negative; positive numbers are replaced with zeroes. The reasoning is that the size of a positive change in stock prices is less likely to affect *FEAR* than is the size of a decline.

— *DUM901*: This variable is one for September 2001 and zero for all other months. The volatility in September 2001 could not have been predicted on the first of that month, when the VXO and VXN readings were taken (except by the terrorists and their associates).

The characteristics of the data are shown in Table 1, which includes the mean and standard deviation over the whole time interval as well as sub- periods representing the interval prior to the Russian default and the interval after it.

A positive coefficient is expected on *ASD*: if the VXO/VXN reflects anticipated volatility and anticipated volatility is a good forecast of actual volatility, the coefficient should be positive. A negative coefficient is expected on the *FEAR* variables — declines in the SP100 (NDX) should raise the VXO (VXN) according to the fear gauge hypothesis. *DUM901* should have a negative coefficient to offset the actual volatility in September 2001, which is on the right- hand side of the equation. (Recall that actual volatility was higher than could have been anticipated on 1st September, 2001, when the VXO for that month, on the left-hand side of the regression equation, was recorded.)

VXO empirical results

Table 2 shows the regressions relating to the VXO. The regressions for the overall time interval 1993–2002 were estimated using AR(1), as there is significant first-order autocorrelation of the residuals. For that time period, the VXO is significantly negatively related to the *FEAR* measures as shown in regressions 1–3 and 5 in the upper panel of the table In regression 3 with *FEAR2* (the variable that

Table 1: Descriptive statistics

					Entire period						
VXO (01/93–12/02)						*VXN (01/95–12/02)*					
	VXO	*S&P100*	*ASD*	*FEAR1*	*FEAR2*	*Statistics*	*VXN*	*NDX*	*ASD*	*FEAR1*	*FEAR2*
Observations	120	2520*	120	120	120	Observations	96	2015*	96	96	96
Mean	21.41	451.54	16.60	0.0007	–0.0082	Mean	41.21	1543.66	35.32	–0.0018	–0.0166
St. dev.	7.72	193.03	8.28	0.0249	0.0161	St. dev.	14.85	994.73	16.26	0.0417	0.0278
					Pre-Russian default						
VXO (01/93–07/98)						*VXN (01/95–07/98)*					
	VXO	*S&P100*	*ASD*	*FEAR1*	*FEAR2*	*Statistics*	*VXN*	*NDX*	*ASD*	*FEAR1*	*FEAR2*
Observations	67	1410*	67	67	67	Observations	43	905*	43	43	43
Mean	16.59	309.56	11.77	0.0026	–0.0049	Mean	28.49	804.52	23.26	0.0037	–0.0087
St. dev.	4.80	107.30	4.84	0.0159	0.0096	St. dev.	4.65	264.73	6.40	0.0249	0.0117
					After Russian default						
VXO (11/98–12/02)						*VXN (11/98–12/02)*					
	VXO	*S&P100*	*ASD*	*FEAR1*	*FEAR2*	*Statistics*	*VXN*	*NDX*	*ASD*	*FEAR1*	*FEAR2*
Observations	50	1046*	50	50	50	Observations	50	1046*	50	50	50
Mean	26.90	639.30	22.42	0.0019	–0.0092	Mean	51.89	2197.43	45.12	–0.0017	–0.0195
St. dev	5.50	107.55	7.41	0.0275	0.0122	St. dev.	12.02	970.46	15.66	0.0458	0.0271

*Daily observations

is zero for positive market moves), the coefficient of -0.9485 indicates that a 5 per cent decline in the market over the previous five days tends to raise the VXO by about 5 percentage points, eg from 20 per cent to 25 per cent.

Over the 1993–2002 time interval, the VXO (the implied volatility for the next 30 days), is also significantly related to ASD (the actual volatility over those 30 days): in Equation (3), its coefficient of 0.1211 (significant at the 5 per cent level) indicates that the VXO forecasts about 0.12 of each 1 percentage point of volatility increase. The September 2001 dummy is also significant.

The 1993–2002 time interval contains some difficult months for the financial markets, including the Russian default in August 1998 and the failure of Long Term Capital Management shortly thereafter, as well as the aftermath to September 11th, 2001. Because the interval connected with the Russian default may be a major influence on the overall results, two separate sub-periods are defined, one prior to the Russian default, from January 1993 to July 1998, and a second subsequent to it, from December. 1998 to December 2002.[12] The dummy variable, *DUM901*, should deal with the volatility that occurred after the markets reopened in mid-September 2001.

In the pre-default time interval, the data showed significant first- order autocorrelation of the residuals in one case and both first-order and second-order autocorrelation in three cases. With the autocorrelation corrections, the results are as follows: with both explanatory variables included, only FEAR is significant in explaining the VXO (panel B). In regression 2, the coefficient of FEAR2 is 1.4076 which implies that a 5 per cent decline in the market over the previous five days would tend to produce about a 7 percentage point rise in the VXO, eg from 20 per cent to 27 per cent. The rise in the VXO represents a rise in the cost of 30 day at- the-money call option on the S&P100 from 13.17 to 17.76, assuming that the index is 575, the risk- free rate is 1.75 per cent, and the dividend yield is 1.60 per cent. (A 30-day put under those assumptions would rise from 13.10 to 17.69.)

The post-default time period produces very different results: only actual future volatility is significant (see panel C). According to regression 4, which excludes the insignificant fear variables, the VXO reflects 0.16 of each additional 1 percentage point of future volatility.

Readers of the previous empirical literature on this topic should note that most researchers testing the VXO's forecast ability would regress the actual volatility on the VXO. The coefficient that would be obtained by running a simple regression with ASD on the left is the coefficient obtained from running a simple regression of VXO on ASD multiplied by the ratio of the variance of ASD to the variance of the VXO. That ratio is about 1.8.

VXN empirical results

This section turns next to the results for the VXN, the implied volatility of Nasdaq-100 Index (NDX) options. Table 1 illustrates the higher volatility of the NDX

Table 2: The VXO Vs: Future volatility (ASD) and 'fear'

	A. Whole time interval (1993:02–2002:12)									
	Reg. 1		*Reg. 2*		*Reg. 3*		*Reg. 4*		*Reg. 5*	
	ASD, FEAR1		*ASD, Fear2*		*ASD, Fear2, Dummy*		*ASD*		*FEAR2*	
	coef.	*t-stat.*	*coef.*	*t-stat.*	*coef.*	*t-stat.*	*coef.*	*t-stat.*	*coef.*	*t-stat.*
Const	20.9491★★	8.61	20.2824★★	8.73	19.3584★★	8.70	20.2954★★	8.77	21.5974★★	9.00
ASD	0.0716	1.22	0.0715	1.30	0.1211★	2.08	0.1041	1.75		
FEAR1	–0.2887★	–2.57								
FEAR2			–0.8269★★	–4.51	–0.9485★★	–5.02			–0.847★★	–4.67
DUM901					–7.2376★	–2.21				
Rho	0.8325★★	16.00	0.8341★★	16.02	0.8258★★	15.41	0.8176★★	15.18	0.8521★★	17.36
DW	2.0084		2.1464		2.1407		2.0117		2.1122	
R^2	0.7327★★	0.7599★★	0.7696★★	0.7175★★	0.7566★★					
	B. Pre-Russian default (1993:02–1998:07)									
	ASD, FEAR1		*ASD, Fear2*		*ASD, Fear2, Dummy*		*ASD*		*FEAR2*	
	coef.	*t-stat.*	*coef.*	*t-stat.*	*coef.*	*t-stat.*	*coef.*	*t-stat.*	*coef.*	*t-stat.*
Const	18.6627★★	5.03	17.9601★★	5.14			18.5062★★	7.27	17.5451★★	5.49
ASD	–0.0005	–0.01	–0.0272	–0.43			–0.1199	–1.65		
FEAR1	–0.7322★★	5.34								
FEAR2			–1.4076★★	–6.42					–1.4072★★	–6.49
DUM901										
Rho1	0.5314★★	4.32	0.5856★★	4.64			0.8577★★	13.30	0.5734★★	4.70
Rho2	0.3860★★	3.11	.3327★	2.61					.3414★★	2.78
DW	2.1000		2.0737				2.4102		2.0800	
R^2	0.8103★★	0.8348★★					0.6946★★		0.8343★★	

Table 2: (Continued)

	C. Post–Russian default (1998:12–2002:12)									
	ASD, FEAR1		*ASD, Fear2*		*ASD, Fear2, Dummy*		*ASD*		*FEAR2*	
	coef.	*t-stat.*	*coef.*	*t-stat.*	*coef.*	*t-stat.*	*coef.*	*t-stat.*	*coef.*	*t-stat.*
Const	22.9039⋆⋆	9.50	23.4708⋆⋆	9.43	21.8221⋆⋆	8.54	23.4140⋆⋆	9.87	26.8465⋆⋆	13.86
ASD	0.1854⋆	2.25	0.1532⋆	1.90	0.2166⋆⋆	2.46	.1638⋆	2.09		
FEAR1	0.1378	0.81								
FEAR2			–0.2016	–0.53	–0.5849	–1.33			–0.3530	–0.94
DUM901					–7.2408	–1.68				
Rho	0.6361⋆⋆	5.36	0.6511⋆⋆	5.59	0.6544⋆⋆	5.50	0.6481⋆⋆	5.62	0.6950⋆⋆	6.50
DW	1.80		1.74		1.68		1.76		1.62	
R^2	0.5287⋆⋆	0.5239⋆⋆	0.5526⋆⋆	0.5209⋆⋆	0.4861⋆⋆					

⋆⋆Coefficient is greater than zero (*ASD*, Rho) or less than zero (*FEAR* variables, *DUM901*) at 1 per cent significance level or *F* is significant at 1 per cent level.
⋆Coefficient is greater than zero (*ASD*, Rho) or less than zero (*FEAR* variables, *DUM901*) at 5 per cent significance level.
†DW statistic indicates significant positive autocorrelation at the 1 per cent level.

Table 3: The VXN Vs: Future volatility (ASD) and 'fear'

	A. Whole time interval (1995:02–2002:12)									
	Reg. 1		*Reg. 2*		*Reg. 3*		*Reg. 4*		*Reg. 5*	
	ASD, FEAR1		*ASD, Fear2*		*ASD, Fear2, Dummy*		*ASD*		*FEAR2*	
	coef.	*t-stat.*	*coef.*	*t-stat.*	*coef.*	*t-stat.*	*coef.*	*t-stat.*	*coef.*	*t-stat.*
Const	36.33**	7.30	35.5321**	7.32	35.3776**	7.24	36.5073**	7.26	43.2153**	7.07
ASD	0.1892**	3.57	0.1912**	3.62	0.1948**	3.67	0.1850**	3.42		
FEAR1	–0.2564*	–2.30								
FEAR2			–0.4350*	–2.46	–0.4748*	–2.57			–0.4000*	–2.17
DUM901					–3.7563	–0.78				
Rho	0.8631**	16.65	0.8591**	16.29	0.8594**	16.21	0.8601**	16.53	0.8896**	19.36
DW	2.3158		2.3535		2.3466		2.3227		2.1819	
R^2	0.8343**		0.8356**		0.8367**		0.8247**		0.8129**	
	B. Pre–Russian default (1995:02–1998:07)									
	ASD, FEAR1		*ASD, Fear2*		*ASD, Fear2, Dummy*		*ASD*		*FEAR2*	
	coef.	*t-stat.*	*coef.*	*t-stat.*	*coef.*	*t-stat.*	*coef.*	*t-stat.*	*coef.*	*t-stat.*
Const	30.34**	11.60	29.63**	11.37			29.7998**	11.76	28.5272**	14.03
ASD	–0.0453	–0.76	–0.0439	–0.72			–0.032	–0.51		
FEAR1	–0.2875*	–2.19								
FEAR2			–0.5798	–1.90					–0.5601	–1.85
DUM901										
Rho	0.8070**	9.17	0.8024**	8.93			0.7828**	8.46	0.7902**	8.59
DW	2.201		2.2133				2.2728		2.2665	
R^2	0.6728**		0.6635**				0.6317**		0.6589**	

Table 3: (Continued)

	ASD, FEAR1		*ASD, Fear2*		*ASD, Fear2, Dummy*		*ASD*		*FEAR2*	
					C. Post–Russian default (1998:12–2002:12)					
	coef.	*t-stat.*	*coef.*	*t-stat.*	*coef.*	*t-stat.*	*coef.*	*t-stat.*	*coef.*	*t-stat.*
Const	41.2077⋆⋆	9.01	40.1494⋆⋆	8.96	39.8030⋆⋆	8.81	41.7410⋆⋆	9.02	50.7984⋆⋆	11.88
ASD	0.2491⋆⋆	3.25	0.2527⋆⋆	3.32	0.2585⋆⋆	3.36	0.2397⋆⋆	3.12		
FEAR1	–0.2173	–1.22								
FEAR2			–0.4728	–1.53	–0.5556	–1.66			–0.4695	–1.4343
DUM901					–4.4087	–0.67				
Rho	0.6499⋆⋆	5.83	0.6290⋆⋆	5.50	0.6291⋆⋆	5.37	0.6574⋆⋆	6.03	0.7330⋆⋆	7.39
DW	2.19		2.19		2.28		2.24		1.89	
R^2	0.6606⋆⋆		0.6663⋆⋆		0.6696⋆⋆		0.6495⋆⋆		0.5741⋆⋆	

⋆⋆Coefficient is greater than zero (*ASD*, Rho) or less than zero (*FEAR* variables, *DUM901*) at 1 per cent significance level or *F* is significant at 1 per cent level

⋆Coefficient is greater than zero (*ASD*, Rho) or less than zero (*FEAR* variables, *DUM901*) at 5 per cent significance level.

†Significant positive autocorrelation at the 1 per cent level.

compared with the S&P100, as measured by the mean *ASDs* of the two series. For example, from 11/98 to 12/02, NDX volatility is about 45 per cent versus 22 per cent for the S&P100. The implied volatility of NDX options reflects this also — the VXN mean was about 52 per cent, whereas the VXO mean was about 27 per cent over that time interval.

Table 3 shows the estimated relationships for the VXN over the period 1995–2002. The initial OLS regressions indicated significant autocorrelation of the residuals. Consequently, the results of regressions which correct for first-order autocorrelation are shown.

For the 1995–2002 time period as a whole, both future volatility (*ASD*) and *FEAR* are significant (top panel of Table 3). *FEAR2*, which includes only the declines, is significant at a higher probability level (compare reg. 1 and 2). The *FEAR2* coefficient of −0.4350 in regression 2 implies that a 5 per cent decline in the market in the last five days of the previous month would add about 2 percentage points to the volatility index; that coefficient is significant at the 5 per cent level. A 2 percentage point increase in volatility, say from 41 per cent to 43 per cent, would raise the cost of 30-day at-the-money call options from 73.42 to 76.95, assuming an index of 1,544, a risk-free rate of 1.75 per cent and a dividend yield of 0.00 per cent. (A similar put option would rise from 71.21 to 74.73.) Actual volatility, *ASD*, has a coefficient of 0.1912, which is significantly greater than zero at the 1 per cent level. That implies that the VXN tends to rise by 0.2 percentage point in advance of an extra 1 percentage point in imminent volatility over the next 30 days.

The sub-periods tell a somewhat different story. In the pre-default time interval (middle panel of Table 3), neither explanation of the VXN works well: actual volatility and *FEAR2* are not significant (at the 5 per cent level) while *FEAR1* is marginally significant at the 5 per cent level (see regression 1). In the post-default time interval, however, actual volatility is highly significant and has a coefficient of about 0.25: each 1 percentage point increase in actual future volatility is reflected in an increase of.25 percentage point increase in the VXN reading at the beginning of the month. The *FEAR* variables are not significant in this later period. The September 2001 dummy is not significant.

Again, the reader should note that the coefficient of *ASD* when VXN is the dependent variable is different from the coefficient of the VXN if that were the independent variable and ASD were the dependent variable. The ratio of the variances that would be used to convert the coefficient is about 1.7.

DISCUSSION

The results for both volatility measures suggest that they forecast the future volatility of their underlying indexes in recent years, albeit far from perfectly The lack of forecast ability of the VXN in the early years is not that surprising, considering that Nasdaq-100 futures began trading in April 1996. Before then, it would have been cumbersome to hedge options on that index: the trader selling overpriced options would need to purchase or sell the key stocks in the index individually, because there was no single instrument that was highly correlated with the Nasdaq-100. Alternatively, the trader could have combined positions in puts and calls to neutralise exposure to the direction of the NDX. In the latter time interval, the Nasdaq-100 futures contract was available throughout and, from 10th March, 1999, QQQ (now called QQQQ), the exchange-traded fund representing the Nasdaq-100 basket of stocks, was also available.

This may not be the whole explanation, however: the VXO also shows a lack of forecast ability in the early years, and options on the S&P100 could have been fairly easily hedged by using S&P500 futures, since the S&P 100 and the S&P500 are highly correlated. For both measures, the lack of significance of actual future volatility in the pre-default samples may be attributable to the lack of capital devoted to stock index trading/arbitrage in those years or to high transactions costs that impeded arbitrage. Insufficient capital and/or high transactions costs could have reduced the amount of arbitrage and allowed the volatility measures to show sizeable responses to *FEAR*. It is also possible that traders were unable to forecast future volatility in those early years, and so their arbitrage activities were aimed to achieve an inaccurate target.

For the more recent years, our results, which show the significance of actual future volatility in explaining the VXO (VXN), suggest that traders arbitraged some of disparities between the implied volatility and their forecasts of future volatility.

CONCLUDING REMARKS

For the 1993/95 to 2002 time interval as a whole, the VXO and VXN appear to be partly fear gauges, partly forecasts of future volatility. In the period since the Russian default, however, the implied volatility measures significantly reflect future volatility in the underlying stock indexes, as option theory predicts, not 'fear', as measured by recent market declines.

The CBOE has developed a new methodology for calculating the VIX and has decided to use the S&P500 for the new index. The CBOE has also developed a futures contract on a reconstituted VIX. It will be interesting to see how these new trading opportunities affect the behaviour of the new VIX versus actual volatility.

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References and Notes

1 The VIX is frequently called a volatility 'index'. It is not an 'index' with a base year benchmark, however, but a measure of annual standard deviation, in per cent.

2 Implied volatility is calculated as follows: for each option, its strike price, its days to expiration, a Treasury interest rate, the level of the S&P100 and its dividend yield are inserted into a standard option pricing model. Then, an estimate of volatility is inserted to see whether the observed market price of that option is achieved. That particular level of volatility that produces the observed market value of the option is the 'implied volatility' for that option.

3 Fleming, J., Ostdiek, B. and Whaley, R. E.(1995)

'Predicting Stock Market Volatility: A New Measure', *The Journal of Futures Market*, Vol. 15, No. 3, pp. 265–302.

4 Fleming, J. (1998) 'The Quality of Market Volatility Forecasts implied by S&P 100 Index Option Prices', *The Journal of Empirical Finance*', Vol. 5, No. 4, pp. 317–345.

5 Christensen, B. J. and Prabhala, N. R. (1998) 'The Relation between Implied and Realized Volatility', *Journal of Financial Economics*, Nov., pp. 125–150.

6 A 'delta-neutral' position is one whose value does not change when the price of the underlying (eg S&P100) changes.

7 Simons, H. L.(1999) 'Nothing to Fear', *Futures Magazine*, Vol. 36, No. 5, pp. 61–64.

8 Whaley, R. E.(2000) 'The Investor Fear Gauge', *Journal of Portfolio Management*, Vol. 59, No. 1, pp. 12–17.

9 The CBOE's calculation method for the VXO has some flaws. See Christensen and Prabhala[5] for a good discussion of this.

10 There is one VXO observation for each month, and each data point on the S&P100 is used to calculate only one ASD. Thus overlap in the data and the statistical problems stemming from that are avoided.

11 Some would argue that high volatility causes the market to decline — since stockholders are short a put option (to bondholders) rather than the opposite view — that a decline in the market causes options premiums to be bid up. The contemporaneous causality issue is avoided by the construction of the variables.

12 The Russian default influenced the markets during the Aug.–Oct. 1998 time interval. Since AR(1) requires an extra month at the beginning, the first observation of the dependent variable in the post- default time interval is for December 1998.