The VXX ETN and Volatility Exposure

Tim Husson, PhD, and Craig McCann, PhD[1]

Exposure to the CBOE Volatility Index (VIX) has been available since 2004 in the form of futures and since 2006 in the form of options, but recently new exchange-traded products have offered retail investors an easier way to gain exposure to this popular measure of market sentiment. The most successful of these products so far has been Barclays's VXX ETN, which has grown to a market cap of just under $1.5 billion. However, the VXX ETN has lost more than 90% of its value since its introduction in 2009, compared to a decline of only 60% for the VIX index. This poor relative performance is because the VXX ETN tracks an index of VIX futures contracts that can incur negative roll yield. In this paper we review the VIX index and assess the opportunities and risks associated with investing in the VXX ETN.

I. Introduction

The Chicago Board Options Exchange (CBOE) Volatility Index (VIX) is a measure of "the market expectation of future volatility implied by the S&P 500 stock index options prices."[1] It was originally introduced in a paper by Robert Whaley in 1993 as an average of the implied volatilities of eight near-the-money options contracts on the S&P 100 index. However, in 2003 the VIX was reformulated by the CBOE as a weighted average of S&P 500 options *prices* across a wide variety of strikes.[2] This revised calculation has been shown to be more highly correlated with the realized variance of the S&P 500, and shortly after the revision, futures and options contracts were introduced on the VIX.

The VIX index has earned a reputation as a 'market fear gauge'.[3] The CBOE points out that the VIX index is more properly a measure of 'uncertainty' rather than 'fear'; nonetheless, it attracts considerable attention during periods of market instability or financial uncertainty.[4] This index's reflection of expected future stock market

 Dr. Husson can be reached at 703-890-0743 or timhusson@slcg.com and Dr. McCann can be reached at 703-246-9381 or craigmccann@slcg.com. We thank Belinda Liu at Standard and Poor's for generously providing data on the VIX futures for reconstruction of the VIX Short Term Futures Index.

volatility has made it attractive to investors who want to speculate on, or hedge, future stock market volatility. Moreover, the VIX index has been negatively correlated with the S&P 500 itself. This negative correlation was evident during the 2007-8 financial crisis. Thus adding VIX exposure to an investor's portfolio has been suggested as a source of potential diversification.[5]

The VIX index is simply a calculation and not a directly investable asset; currently the only way to achieve exposure to the VIX index is by trading futures or options contracts written on the VIX. These futures and options contracts are not simple investments for retail investors to trade. Investors who want to invest in futures contracts need to open a margin account, find the right contracts to purchase, and "roll-over" the maturing future contracts into new contracts as they expire. In addition, futures contracts are highly leveraged, marked-to-market daily, and usually only trade in large blocks.[6]

On January 29, 2009 Barclays introduced the iPath S&P 500 VIX Short Term Futures Exchange Traded Note (VXX ETN).[7] The VXX ETN tracks the S&P VIX Short Term Futures Index Total Return (SPVXSTR),[8] which tracks changes in the value of the near-term futures contracts written on the VIX index. Changes in the level of the SPVXSTR Index are generally correlated with changes in the level of the VIX index. The VXX is an ETN and not an ETF, and as such is a senior, unsubordinated, unsecured debt security. As long as Barclays does not default on its obligations, the notes pay investors a return equal to the percentage change in the level of the reference index minus management fees. [9]

The VXX ETN's reference index, SPVXSTR, calculates the return to a portfolio of 1 and 2 month futures contracts that is rebalanced daily to achieve an average maturity of 1 month.[10] While this methodology does achieve high correlation with the spot price of the VIX index, its daily rebalancing has a substantial effect on the changes in the reference index relative to changes in the VIX index. The result is a decline in value of over 90% from January 2009 until the end of 2010, compared to a decline of only 60% for the VIX index during the same time period. This difference is due to the use of a reference index that is calculated from maturing futures contracts rather than the VIX index itself.[11]

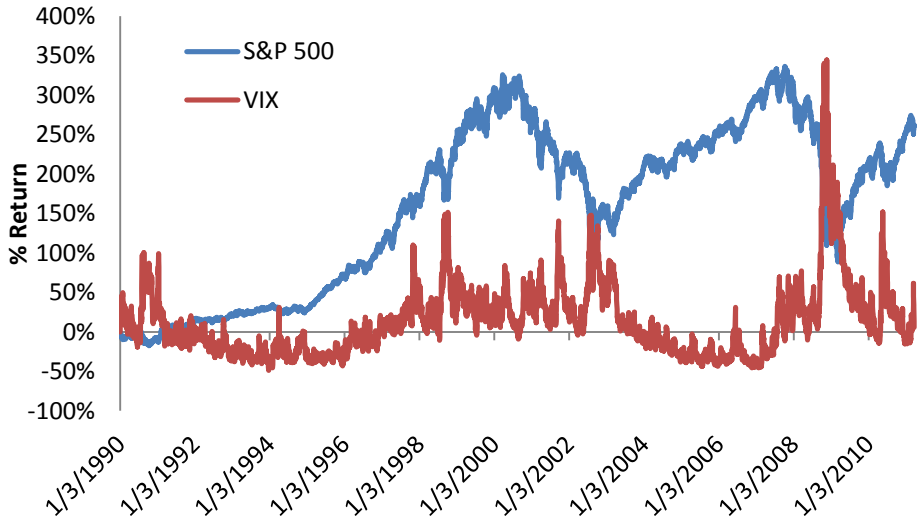
In this paper we review the properties of the VIX index and of the return to the VXX ETN and describe the factors that have contributed to the large difference between returns on the VXX ETN and changes in the level of the VIX index. We describe and discuss the various risks associated with investing in the VXX ETN in order to gain exposure to the changes in the level of the VIX index. We show that the return to the VXX ETN depends in a large part on movements in the futures markets that are complicated to anticipate. We also show that a part of the deviation between the VIX index and the VXX ETN is predictable. Our findings highlight the complexity and the risk of this investment, in particular for unsophisticated investors.

II. The VIX Index and Volatility Exposure

The VIX index is not a tradable asset, it is a calculation that is updated by the CBOE approximately every 15 seconds. The VIX index is designed to capture "the market expectation of future volatility implied by the S&P 500 stock index options prices." [12] It does so by computing the weighted average of S&P 500 options prices across a wide variety of strikes under the assumption that "the price of each option reflect[s] the market's expectation of future volatility."[13]

Figure 1 shows the cumulative historical performance of the VIX index compared to the performance of the S&P 500. The VIX index tends to spike when the S&P 500 drops sharply, and it tends to decline steadily during bull markets.

Figure 1: The VIX Index and S&P 500 Index Daily Cumulative Price Changes
Daily cumulative price changes of the VIX Index and the S&P 500 Index from January 1990 to March 2011.



The VIX index is often interpreted as a measure of stock market risk or general market sentiment[14] – some perceive the VIX index to capture an aspect of Keynes' (1936) 'animal spirits'. During periods of crisis or uncertainty, the volatility of stock markets tends to increase dramatically, which is reflected in abrupt, sharp jumps in the VIX index. For example, during the US government bailouts of banks in October 2008 the VIX index went up by 260% and during the Russian financial crisis of 1998 the VIX index increased by 155%.[15] This well-documented regularity suggests that exposure to the VIX index could be 'catastrophe insurance' (a way of hedging large negative movements in the S&P 500) or a means of betting on disruptive world events. Indeed, this interpretation of the VIX index as a 'market fear gauge' has contributed greatly to the increased attention it has attracted from investors.[16]

Besides being a signal for market sentiment, there is also a clear long-term negative correlation between equity prices and VIX index levels, as shown in Table 1, which reports correlations in the weekly returns of various indexes with the VIX index. While the negative correlation with equities has remained high over the life of the VIX index, there are no clear, consistent correlations with major currencies or interest rates,

making the VIX a potential candidate for diversification in a portfolio with significant exposure to equities.[17]

Table 1: Correlation of VIX Index Price Changes with Other Assets

Correlations of weekly price changes from January 2003 to April 1, 2011. SPVXSTR is the S&P VIX Short Term Futures Index Total Return and is the reference index for the VXX ETN. SPVXSTR is calculated by S&P only from 2006. The VXX ETN was introduced in January 2009.

	VXX US Equity	SPVXSTR Index	EUR Curncy	GBP Curncy	JPY Curncy	US0001M Index	US0012M Index
2003			3.1%	11.0%	-6.5%	-4.6%	-3.4%
2004			0.8%	-7.1%	1.6%	-5.4%	-5.2%
2005			-1.8%	5.0%	13.8%	20.8%	-16.3%
2006		81.0%	-15.9%	-7.6%	14.3%	2.2%	-28.4%
2007		89.9%	-4.4%	-15.7%	-61.0%	6.4%	-25.0%
2008		84.0%	-23.7%	-30.2%	-56.1%	23.6%	9.2%
2009	79.4%	79.3%	-21.3%	-5.4%	-34.1%	0.4%	-19.7%
2010	88.6%	89.7%	-35.8%	-30.1%	-30.9%	53.9%	38.2%
2011	90.0%	91.1%	25.5%	-3.4%	-56.7%	-5.1%	-68.0%

Until 2009 the only way to achieve exposure to the VIX index was through the VIX futures and options markets. These markets, introduced by the CBOE in 2004 and 2006 respectively, have become some of the most liquid markets on the CBOE with, for example, open interests on March 25, 2011 of 182,258 futures contracts and 4,601,688 options contracts.[18] However, due to their complexity, most retail investors are not likely to invest directly in options and futures markets, especially for long term positions that would require rolling over contracts.

To avoid this complexity, the VXX ETN was introduced to offer indirect exposure to the VIX index by tracking changes in the level of a reference index that models the returns to owning a portfolio of VIX futures contracts fully collateralized with treasury securities. The VXX ETN has since become one of the most popular of all exchange-traded products with a market cap of almost $1.5 billion.

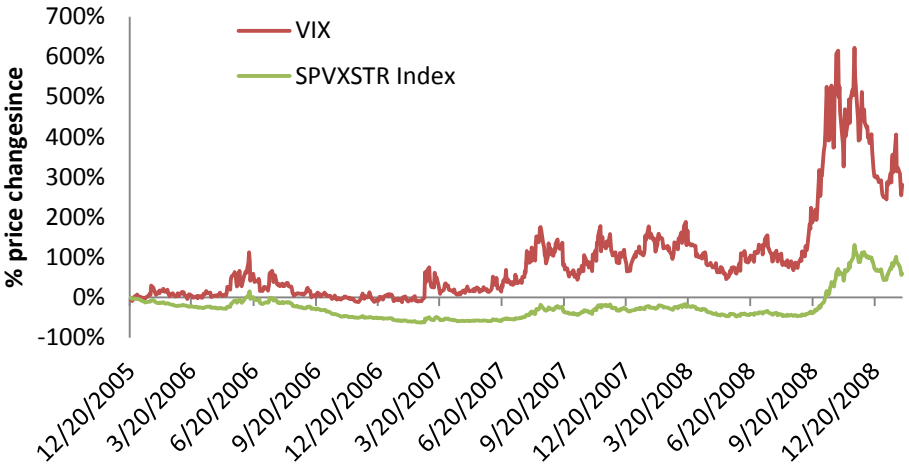
III. Performance of the VXX ETN

In Figure 2 Panel A, we plot the cumulative percentage change in the level of the the VIX index and the SPVXSTR index from December 2005 to the introduction of the VXX ETN in 2009. In Figure 2 Panel B, we plot the cumulative return to the VXX ETN

and the cumulative percentage change in the level of the SPVXSTR index from the VXX's introduction in 2009 to 2011.[19] In both time periods the futures-based methodology underlying the VXX ETN has accumulated a large negative deviation in returns relative to percentage changes in the VIX index despite having a weekly return correlation of 86% with the VIX index. The VXX ETN and SPVXSTR index align in Figure 2 Panel B because the VXX guarantees to pay investors the change in the level of the SPVXSTR index minus fairly modest management fees.

Figure 2: Performance of VXX ETN and its Reference Index SPVXSTR Compared to the Performance of the VIX Index

Panel A: SPVXSTR Index compared to the VIX Index from 2006 to 2008



Panel B: VXX ETN and the SPVXSTR Index compared to the VIX Index from 2009 to 2011

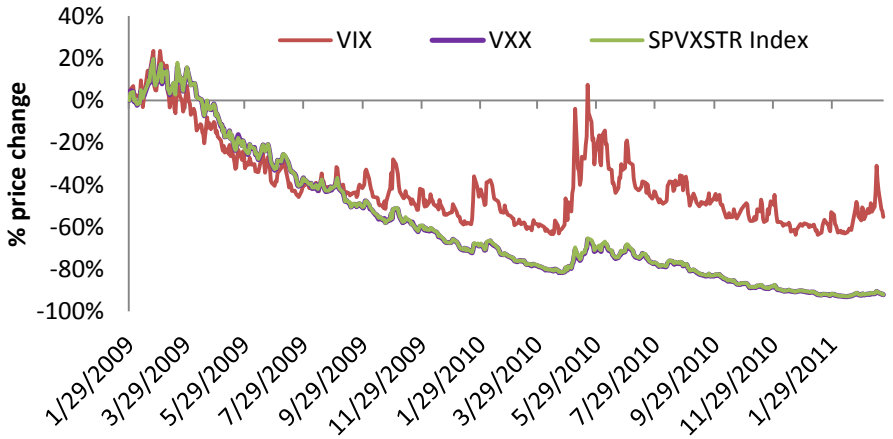


Table 2 lists the correlations and deviations between the weekly returns to the VXX ETN and the changes in the VIX index for 6 month sub-periods. As is clear from the graphs, the deviations are more severe in some periods than in others. It is also important to note that the deviations can also be positive, as in the second period of 2010.

Table 2: Performance of VXX ETN Compared to the VIX Index
Return deviations are the difference in the returns over the entire period.
Correlations are of weekly returns.

Holding period	Return Deviation	Correlation
1/29/2009-6/30/2009	6%	88%
7/1/2009-12/31/2009	-23%	83%
1/1/2010-6/30/2010	-36%	91%
7/1/2010-12/31/2010	14%	82%
1/1/2011-3/1/2011	-3%	84%

The weekly returns to the VXX ETN differ from changes in the VIX index because the VXX ETN's returns are based on the SPVXSTR index of futures prices of the VIX index rather than spot prices of the VIX index. The SPVXSTR index calculates the return to a portfolio that holds a combination of 1- and 2- month futures contracts, and every day it sells a fraction of its holding of 1-month contracts and uses the proceeds to buy 2-month contracts. Once a month, this model portfolio holds only one kind of futures contract, the 2-month contract which becomes the 1-month contract, and the cycle of buying new 2-month futures contracts starts again. If the 1-month contracts are trading at a lower price than the price the portfolio paid when it purchased it as a 2-month contract, and if this difference is lower than the return for the VIX index in that time period, then the daily rebalancing will incur a loss due to selling the 1-month price contracts that were purchased at the higher 2-month price. As this situation has been common in the VIX futures market, the SPVXSTR index and thus the VXX ETN's cumulative returns have gradually accumulated a large deviation compared to cumulative changes in the VIX index.

For example, on July 17, 2009, the portfolio that the SPVXSTR index models would have sold 1/24 of its holdings to buy 2 month contracts at $29 each. These contracts would then be sold on August 20, 2009 at $27.80 per contract. The "roll return" of these contracts was therefore -4.14% ((1 - 27.8)/29) while the VIX index increased

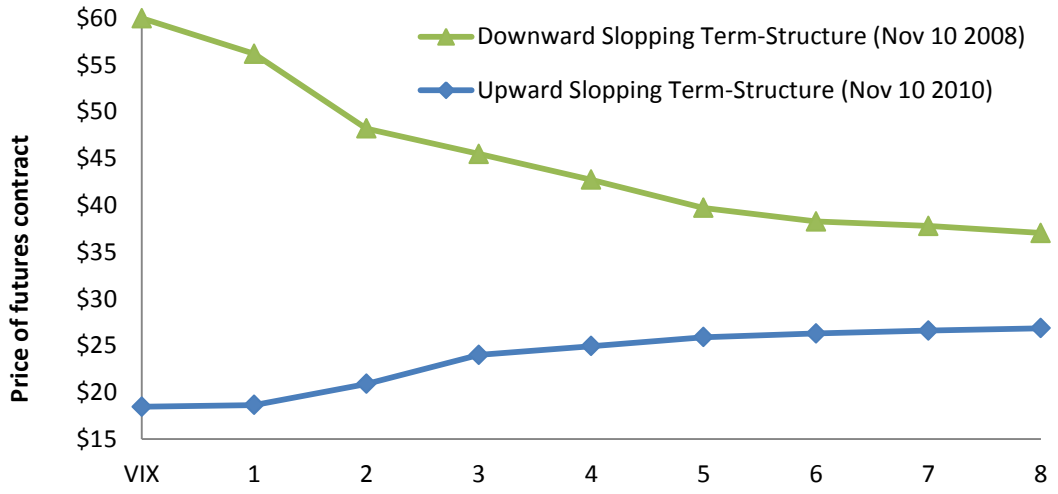
from 24.34 to 25.09 during the same time period, an increase of 3.08%. This difference of 7.22% in returns is the deviation due to the use of futures contracts. In general, if the selling price of an expiring futures contract, which is close to the spot price at maturity, is lower (higher) than the purchase price, the investor will incur a loss (gain). This is referred to as a "roll-over" loss or gain. The expected roll-over loss or gain is correlated with the term structure of the futures market.

IV. VIX Futures Term Structure

The term structure of a futures market is the yield curve of the prices of futures contracts ordered by their time to maturity. An upward (downward) sloping term structure refers to a market condition where the longer-term futures contract is trading at a higher (lower) price than the nearer-term futures contract. The term "backwardation" is often used when referring to a "downward sloping term structure," where the near-term future price is higher than long-term future price.[20] For clarity and tractability, we use the terms "upward sloping term structure" if the longer-term futures price is higher than the near-term futures price and "downward sloping term structure" if the longer-term futures price is lower than the near-term futures price. As an illustration we plot in Figure 3 the term-structure of the VIX future contracts on two separate days, one that had an upward- and one that had a downward-sloping term structure.

Figure 3: Examples of the Term-Structure of the VIX Index Futures Contracts

This graph shows examples of the term structure of the VIX index future contracts. On November 10, 2008 the term-structure was downward sloping, i.e. the price of the second month futures contract was lower than the price of the one month futures contract. On November 10, 2010 the term-structure was upward sloping.



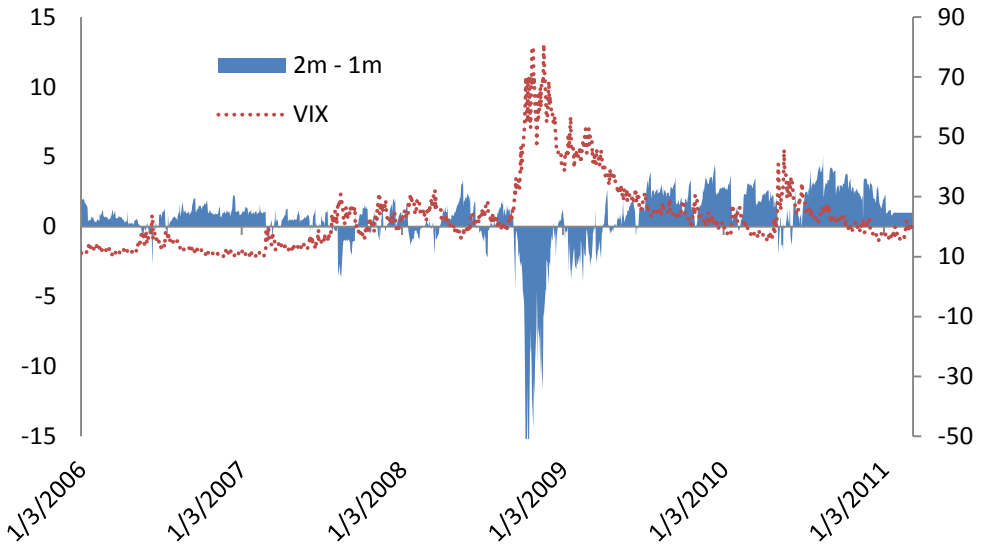
As Gorton and Rouwenhorst (2005) have shown, the term structure of futures prices may contain important information for predicting the expected future spot price and therefore the roll-over return. Erb and Harvey (2006) use the slope of the term structure directly as the measure of roll-over return. However, it is important to note that changes in the yield curve over time, which determine the roll-over return, are different from the term structure of the yield curve, which represents the prices of futures contracts over different maturities at one specific point of time.

The dynamics of the term structure of a futures market will have a potentially important impact on any purchaser of a futures contract, including the exchange traded products that use futures contracts to track an underlying index. The return to such an investment will not only depend on the return to the spot price but also on whether the contract was purchased during a period when the term structure of the futures prices was upward- or downward-sloping.

Following Gorton and Rouwenhorst (2005) and others, Figure 4 plots the term structure of the VIX futures market as defined by the difference in price between the 1 and 2 month VIX futures contracts. Positive (negative) values of the term-structure mean that the term structure was upward-sloping (downward-sloping). The only time the slope was significantly negative was during the financial crisis of 2008-9. During this period, the VXX ETN accumulated a small daily profit compared to the VIX index; however, the majority of the time the VXX ETN incurred a steady loss of value.

The reason for the apparent persistent upward-sloping term-structure in the VIX futures market is not straightforward. In commodities markets, persistent upward-sloping term-structure can be explained by storage costs—investors must be compensated for holding a good (barrels of oil, bushels of wheat, etc.) over a period of time, and this is reflected in a higher futures price.[21] However, the VIX index is an entirely synthetic asset (it is simply a calculated number), thus it is not immediately clear why its term structure should exhibit time persistence.

Figure 4: Term Structure of VIX Futures Contracts Compared to the VIX Index Level
The term structure is defined as the difference between the prices of 2-month and 1-month futures contracts (see Gorton and Rouwenhorst (2005) for example). We report data from January 2006 through March 9, 2011 onwards due to the lack of liquid data, especially for the 2 month futures contracts, before that time[22].



Recent models proposed by Zhu and Lian (2011) and Duan and Yeh (2011) offer a mean-reversion explanation for this behavior, in the sense that investors in the futures market expect volatility to revert to a long-term mean. When the VIX index is above that assumed mean, its term structure will be downward sloping, and when it is below that mean, its term structure will be upward-sloping. This interpretation is especially intuitive during periods of extremely high volatility, such as during financial crises, where it is recognized that market uncertainty will be resolved sometime in the future. In periods of sustained growth, such as the 2010 market rally, the sustained upward-sloping term structure represents an expectation of future market instability, perhaps a bear market. This interpretation is supported by the historical term structure of VIX futures, but it is unclear if this relationship will continue in the future, or what the long-term mean to which the VIX index will revert should be. Since VIX futures date only from 2004 (and are liquid only from about 2006), it is difficult to fully analyze the dynamics of this market.

Table 3: Upward- and Downward-Sloping VIX Futures

Similar to Figure 3, we here report data only from Jan 1, 2006 due to illiquidity effects for earlier contracts. However, it can be noted that on all observable dates from Jan 2004-Jan 2006 the VIX futures market was upward-sloping.

	Trading days	*Days sloped up*	*Days sloped down*	*Upward %*	*Downward %*	*Average slope when positive*	*Average slope when negative*
2006	251	235	16	93.63%	6.37%	0.893	-0.527
2007	251	167	84	66.53%	33.47%	0.736	-0.776
2008	253	87	166	34.39%	65.61%	0.975	-3.750
2009	252	127	125	50.40%	49.60%	1.903	-1.539
2010	252	236	16	93.65%	6.35%	2.396	-0.650
2006-10	1259	852	407	67.67%	32.33%	1.440	-2.120

Table 3 shows the number of days that the VIX futures market has been upward- or downward-sloping. Clearly, since 2006, the dominant regime has been an upward-sloping term structure; however, the most significant downward-slope occurred in 2008 when VIX index levels were remarkably high (see Figure 1). During this period, the slope of the term structure was not only negative, but strongly so. This implies that the roll yield is on average more positive when the term structure is downward-sloping than it is negative when the term structure is upward-sloping.

V. Risks

a. Term Structure Risk

As described in the previous section, a significant risk factor inherent to the VXX ETN is that its reference index, the SPVXSTR index, models a portfolio of rolling VIX futures contracts, and hence its price changes are exposed to the term structure of VIX futures. As shown in Figure 4, the VIX futures market has had long stretches of consistently upward-sloping term structure punctuated by rapid shifts to strongly downward-sloping regimes, making any long or medium term investment involving the VXX ETN subject to a daily loss of value not due to the actual VIX index price changes. Moreover, since the reasons for persistent term structure in the VIX futures market are not clearly understood, it would likely prove exceptionally difficult for an investor to try to time those effects. Indeed, shifts in the term structure can occur abruptly, as they are correlated with unexpected market disruptions.

The roll yield can be easily overlooked by investors because it requires knowledge of and some experience with the term structure of VIX futures. Importantly, when an investor buys the VXX ETN, he or she does not lock in a term structure. Even with an understanding of the history and structure of the VIX futures market, the VXX ETN requires constant monitoring in order to avoid steep losses.

To analyze the persistence of upward- and downward-sloping term structures, we analyze the VIX futures market with a two-state Markov regime switching model.[23] Such a model imposes the condition that there are two distinct states, such as upward or downward-sloping term structures, and can evaluate the likelihood of switching between those states. First, we test whether the spread (log price of second-month futures contract – log price of near-month futures contract) is a unit-root process using an Augmented Dickey-Fuller (ADF) test. The ADF test results reject the unit root process – the spread is a stationary process. The Bayesian Information Criteria (BIC) suggests an ARMA(2,0) process as the optimal number of lags in the time series process to maximize the likelihood estimation. Second, we apply the Markov Regime Switching model to our sample. The results are summarized in Table 4. We use weekly VIX futures market data from February 3, 2006 to March 4, 2011 and find that that the conditional probability of

observing an upward-sloping term structure in the current time period, given an upward-sloping term structure in the prior period, is 96%. Conversely, the conditional probability of observing a downward-sloping term structure in the current period given a downward-sloping term structure in the prior period is only 34%. The expected duration of upward-sloping term structure is approximately 27 weeks, as compared to only 1.5 weeks for downward-sloping.

Table 4: Markov Regime Switching Model Results

	Upward-sloping regime	**Downward-sloping regime**
Transition probability to upward-sloping	96%	66%
Transition probability to downward-sloping	4%	34%
Expected duration	26.7 weeks	1.5 weeks

These results suggest that periods of upward-sloping term structure are highly persistent, whereas downward-sloping term structures tend to be short lived. In the context of the VXX ETN, these results imply that an investment in the VXX ETN will more likely lead to persistent losses due to due to roll yield in the reference index, and that gains from a positive roll during periods of downward-sloping term structure are not likely to last as long. However, as noted above, during periods of a downward slope the gains from the roll yield is larger on average than the losses during an upward slope. Therefore, the extent of roll costs on the value of an investment in the VXX ETN is difficult to forecast, even with specific expectations of future VIX levels.

b. VIX Index Tracking Risk

There are two factors that can impact the return to any portfolio of futures contracts compared to the change of the underlying spot price. The first is the term structure and the second is the correlation between the return to a futures contract, which is the expectation of a price, and the realized return, which is the change of the spot price.

In order to assess the impact of these two risk factors, in Table 5 we decompose these factors in the price changes of the VXX ETN's reference index, the SPVXSTR index. We regress the contemporaneous daily price changes of the SPVXSTR index on the term structure (the difference between the two- and one-month future contracts), the

return to the two-month futures contract, and the daily price changes SPVXSTR tries to track, the VIX index. As we can see, these two factors substantially impact the price changes of the SPVXSTR. Once we incorporate these two risk factors and the changes in the VIX index levels we can explain about 98% of the deviation in returns. The results hold for the VXX ETN return as it delivers the price changes of its reference index minus management fees, and is somewhat weaker as its observation period is shorter.

In addition, we control for the spread between expected equity volatility as reflected in options prices (and thus the VIX index) and realized historical volatility. We use the Standard and Poor's SPARBV index that measures this spread.[24] When we include SPARBV changes in our regression we find that this volatility risk is also reflected in SPVXSTR price changes – when the spread is high, SPVXSTR changes are lower than when this spread is low.

Table 5: Decomposition of SPVXSTR's Price Changes

*This table describes the decomposition of the contemporaneous monthly price changes of the VXX ETN's reference index, the SPVXSTR index, to the two components that may affect them: the term-structure and the return on the VIX futures and VIX index. T-statistics in parentheses, *** indicates significance at 1% level, ** significance at 5% level, and * significance at 10% level.*

	SPVXSTR Index		
	(1)	(2)	(3)
Term Structure	-0.0673***	-0.0252***	-0.0243***
	(0.00682)	(0.00263)	(0.00251)
VIX Return		-0.143***	-0.235***
		(0.0362)	(0.0389)
2M Future Ret		1.199***	1.235***
		(0.0679)	(0.0621)
SPARBV Return			-0.351***
			(0.120)
Constant	0.0370*	-1.067***	-0.658***
	(0.0185)	(0.0509)	(0.119)
Observations	62	62	32
R-squared	0.697	0.977	0.986

Since SPVXSTR is an index that models a portfolio of futures contracts, its price changes are subject to the market's forecasting error for future VIX levels. Estimations of the differences between the realized VIX index level and the futures' prices 1 month prior indicate that the market's ability to predict future movements is not perfect (73%

when adjusted for risk premium[25]). This is also reflected in our regression results, which suggest that the SPVXSTR index is more strongly influenced by movements in the futures market than with movements in the VIX index itself. This represents another risk factor inherent in the reference index of the VXX ETN, as it only *indirectly* achieves exposure to the VIX index.

c. Credit Risk

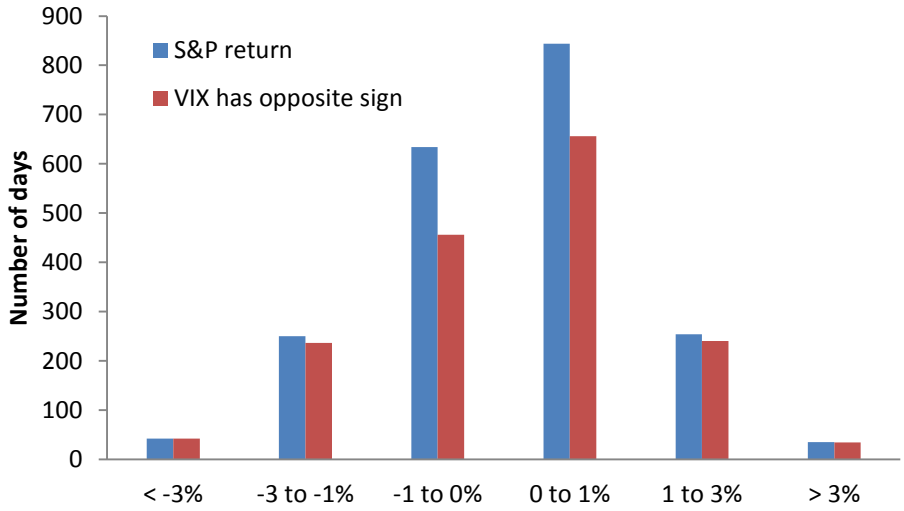
As with all ETNs, the VXX ETN is also subject to the credit risk of the underlying issuer (in this case Barclays). While often ignored in the valuation of derivatives and structured products, credit risk has been an increasingly important input to valuations and strategies since the financial crisis of 2007-8, which proved that even the most reputable and ostensibly protected firms can indeed default on their obligations. For example, the ETNs released by Lehman Brothers that were still outstanding during that firm's bankruptcy lost their entire value. In considering the VXX ETN as an investment vehicle, investors should decrease their expectation of future returns by the relative strength of the issuer's credit, reflected in its CDS swap rates or its debt rating from financial ratings services such as Moody's or Standard & Poor's.

d. Effectiveness as an Equity Hedge

One of the main reasons investors may want to add an exposure to the VIX index in their portfolio is the fact that the VIX index has a negative correlation with the S&P 500, which may contribute to a portfolio diversification. However, as noted by Shu and Zhang (2010), the VIX index appears to show a stronger negative correlation to the S&P 500 index during extraordinarily large daily movements. Figure 5 plots a histogram of daily S&P 500 price changes since January 6, 2003 as well as the number of days the VIX index moved in the opposite direction. On days when the S&P 500 index has high positive or negative movement, the VIX index was highly likely to move in the opposite direction, but on days with smaller absolute returns the VIX index's direction was not always opposite that of the S&P 500. This suggests that the VIX index, and in turn the VXX ETN, functions as an effective hedge on equity returns only during *extreme* equity market movements. While this property may be consistent with a potential role as

catastrophe insurance, the VXX ETN's effectiveness as a long term equity hedge is far less effective during normal market conditions.

Figure 5: Sign of VIX Price Change Compared to that of the S&P 500



e. Predictability

An important question for any potential investor in the VXX ETN is whether the degree to which its return deviates from the VIX index is predictable. In Table 6 we test this question directly, by regressing the monthly price changes of the VXX ETN's reference index, the SPVXSTR index, price changes on observable factors in the previous month. Table 6, column 1 shows the results of regressing the deviation of the monthly price changes of the SPVXSTR with those of the VIX index on the previous month's deviation. While there is no readily apparent relationship, when we also include the lagged price changes of the VIX index and the lagged futures return (column 2), we find a strong positive relationship between the deviation and the previous month's deviation, as well as strong positive contributions from the VIX index and negative contributions from futures market returns. Interestingly, the slope of the term structure (the difference between the second and first month futures contracts) from the previous month does not appear to contribute predictive ability to the deviation (column 3). Overall, these three variables can predict approximately 52% of the variance in the deviation between the VXX ETN's reference index and VIX index price changes.

Table 6: Predictive Regression on Deviation in Price Changes

*T-statistics in parentheses, *** indicates significance at 1% level, ** significance at 5% level, and * significance at 10% level.*

	Deviation SPVXSTR Index		
	(1)	(2)	(3)
Lagged Deviation	-0.119	1.434***	1.523***
	(0.146)	(0.259)	(0.465)
Lagged VIX Return		1.869***	1.970***
		(0.324)	(0.562)
Lagged 2-Month Future Return		-1.982***	-2.076***
		(0.427)	(0.611)
Lagged Term Structure			0.00322
			(0.0135)
Constant	-1.179***	0.529	0.611
	(0.159)	(0.364)	(0.511)
Observations	61	61	61
R-squared	0.014	0.524	0.524

VI. Conclusions

The Volatility Index (VIX) is a calculation by the Chicago Board Options Exchange (CBOE) that is designed to measure the market expectation of future volatility implied by the S&P 500 stock index options prices. Inclusion of exposure to the VIX index in an investor's portfolio can be desirable as a diversification and a hedge. However, exposure to the VIX index can only be achieved by investing in VIX futures and options contracts. Barclays introduced in 2009 the VXX Exchange Traded Note that offers exposure to the return to a reference index that reflects the changes in return to a bundle of 1 and 2 month futures contracts on the VIX index, and thus, indirectly, the VIX index.

The VXX ETN is a complicated and risky investment. Equity volatility is notoriously difficult to predict, and while its negative correlation with equity market movements may seem attractive as a long-term hedge, the fact that the VXX ETN's reference index tracks futures contracts instead of the actual VIX index means that substantial deviations between the two are likely. Investors should understand that the relationship between the VXX ETN and the VIX index is not straightforward, and that the relationship between the VIX and the S&P 500 indexes is also complex. Therefore

the VXX ETN should be considered only by investors who fully understand the term structure of the VIX futures market and who are prepared for the large, sudden movements and prolonged periods of decline characteristic of volatility exposure.

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[1] http://www.cboe.com/micro/VIX/vixwhite.pdf
[2] See Carr and Wu (2006) for a thorough explanation of the old and new VIX calculations.
[3] See for example Whaley (2009)
[4] See the CBOE's explanation at http://www.cboe.com/micro/vix/faq.aspx#2.
[5] Brière, Burgues, and Signori (2010).
[6] Futures contracts are inherently leveraged investments because each contract only requires a small fraction of the contract's notional amount as an initial investment (the initial margin requirement). Chance

(2002) argues that the initial margin requirements for futures contracts are "usually less than 10% of the futures price."

[7] Prospectus and original pricing supplement available at the SEC website: www.sec.gov/Archives/edgar/data/312070/000119312509013753/d424b3.htm

[8] This index is designed to track a portfolio of VIX futures contracts with an average maturity of 1 month, and includes the cost of rebalancing that portfolio daily to maintain that average maturity. Details available at: www2.standardandpoors.com/spf/pdf/index/SP_VIX_Future_Index_Methodology_Web.pdf

[9] See for example Wright, Diavatopoulos, Felton (2010) for an in-depth explanation on ETNs and the differences between ETNs and ETFs.

[10] The SPVXSTR index is a 'total return' index, meaning its notional value includes the interest accrual on a 3-month US Treasury bill.

[11] See for example Guedj, Li, and McCann (2011) for a description of the deviation between commodities spot price return and the return to futures-based commodities ETFs.

[12] http://www.cboe.com/micro/VIX/vixwhite.pdf

[13] See http://www.cboe.com/micro/vix/vixwhite.pdf for a detailed description of the VIX calculation. Although the CBOE revised its original formula in 2003, it still reports both the previous calculation (VXO) and the updated version backfilled to 1990 (VIX).

[14] See Whaley (2009) and Figuerola-Ferretti and Paraskevopoulos (2010).

[15] Return observations from August 28 to October 10, 2008 and July 16 to August 27, 1998.

[16] See for example reviews by Whaley (2000) and Carr and Lee (2009).

[17] See Brière, Burgues, and Signori (2010).

[18] Open interest is the total number of futures or option contracts that are open, i.e., have not been settled, and hence it reflects the size of a market.

[19] On November 9, 2010 the VXX issued a 1-for-4 reverse split and we adjust the price accordingly.

[20] The term "contango" and "backwardation" are used frequently in commodity market literatures, but Hull (2011) defines the following: "When the futures price is below the expected future spot price, the situation is known as normal backwardation; and when the futures price is above the expected future spot price, the situation is known as contango." Hull's definition of backwardation market is defined over a time series, which is a different concept from what we call "downward-sloping term structure" which is defined over a cross-section of futures contracts. He goes on to say, "however, it should be noted that sometimes these terms are used to refer to whether the futures price is below or above the current spot price, rather than the expected spot price."

[21] Alternative explanations for persistence in term structures based on risk premia also exist, see for example Pindyck (2001).

[22] We use the interpolation/extrapolation methods reported by Standard & Poor's to reconstruct missing contract data whenever possible; further missing data has been generously supplied by S&P. Details of these procedures can be found in the SPVXSTR Index Methodology available at: http://www2.standardandpoors.com/spf/pdf/index/SP_VIX_Future_Index_Methodology_Web.pdf

[23] See Hamilton (2008) for a description of regime-switching models. We follow a similar methodology to Fattouh (2009) who uses a Markov Regime Switching model to estimate the transition probability between two states of upward-sloping term structure and downward sloping term structure.

[24] For a description of the index methodology, see: http://www2.standardandpoors.com/spf/pdf/index/SP_Volatility_Arbitrage_Index_Methodology_Web.pdf

[25] Nossman and Wilhelmsson (2009).