The VIX Futures Basis: Evidence and Trading Strategies

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Abstract

This study demonstrates that the VIX futures basis does not have significant forecast power for the change in the VIX spot index from 2006 through 2011 but does have forecast power for subsequent VIX futures returns. The study then demonstrates the profitability of shorting VIX futures contracts when the basis is in contango and buying VIX futures contracts when the basis is in backwardation with the market exposure of these positions hedged with mini-S&P 500 futures positions. The results indicate that these trading strategies are highly profitable and robust to transaction costs, out of sample hedge ratio forecasts and risk management rules. Overall, the analysis supports the view that the VIX futures basis does not accurately reflect the mean-reverting properties of the VIX spot index but rather reflects a risk premium that can be harvested.

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Volatility has become a widely accepted asset class since the introduction of the VIX futures contract in 2004. The popularity of the VIX futures contract stems from its hedging properties, which owe to its reliably negative correlation with equity returns and its usefulness as insurance against tail risk.[1] Szado (2010) and Alexander and Korovilas (2011) examine the impact of adding long VIX futures positions to equity portfolios and find that while long VIX futures positions are drags on equity portfolio returns during normal periods, they provide substantial benefits during steep equity market selloffs. The losses on long VIX futures positions during normal periods result in part from VIX futures rolling down an upward sloped futures curve. This phenomenon suggests the profitability of short VIX futures positions when the VIX curve is upward sloped.

Other studies, such as Zhang and Zhu (2006), Zhang et al. (2010) and Dupoyet et al. (2011), focus on modeling the VIX futures curve. These studies assume that volatility follows a mean reverting process, which implies that the basis reflects the risk-neutral expected path of volatility.[2] Accordingly, when the VIX futures curve is upward sloped (in contango), the VIX is expected to rise because it is low relative to long run levels, as reflected by higher VIX futures prices.[3] Likewise, when the VIX futures curve is inverted (in backwardation), the VIX is expected to fall because it is above its long run levels, as reflected by lower VIX futures prices. Thus,

[1] Tail risk hedging refers to hedging against extreme adverse market moves and was championed by Taleb (2007), who claims that such events are far more frequent than market participants generally believe. Tail risk insurance became extremely popular in the aftermath of the large equity market declines associated with the financial panic that began in 2008.

[2] Because the VIX index is not readily tradable, the basis is not determined by cash and carry and reverse cash and carry arbitrage as is typically the case for most financial futures contracts.

[3] For expositional ease this study refers to the VIX spot price as the VIX and the relationship between the VIX and VIX futures prices as the VIX futures curve. This study also adopts the conventions of describing VIX futures trading above the VIX as contango, a positive basis or an upward sloped VIX futures curve. Likewise, this study describes VIX futures trading below the VIX as backwardation, a negative basis or an inverted VIX futures curve.

contango and backwardation reflect risk-neutral expected VIX increases and decreases, respectively, and the steepness of the curve in either case reflects the speed of mean-reversion. The recent empirical evidence on the forecast power of models calibrated to the VIX futures curve indicates satisfactory out of sample forecast power for the one-day ahead VIX futures curve.

Research that examines the forecast power of the VIX futures basis for future VIX prices in a regression framework, such as Mixon (2007) and Nossman and Wilhelmsson (2009), indicates insignificant forecast power unless the basis is adjusted for a time-varying volatility risk premium. This risk premium owes to the usefulness of long VIX futures positions as hedges for equity positions, which causes the basis to be more upward sloping than rational expectations would dictate.

This study examines trading opportunities presented by the VIX futures curve's lack of forecast power for the subsequent VIX change. The study first assesses the forecast power of the VIX futures basis from 2006 through 2011 and is consistent with the findings of previous studies that the basis does not have predictive power for VIX changes. This lack of forecast power suggests that the VIX futures basis forecasts VIX futures returns, which is confirmed.[4] This finding is similar to those of Erb and Harvey (2006) and Gorton and Rouwenhorst (2006), who demonstrate more generally that the basis has profound effects on commodity futures index returns. These authors show that when futures markets are in backwardation, investors benefit from buying futures contracts at discounts to spot prices given that backwardated markets are not associated with commodity spot prices falling.[5] Likewise, an implication of this finding is that

[4] For example, if the front futures contract is trading well above the spot price and the spot price at the settlement of the futures contract is expected to be unchanged because the basis has no forecast power, the futures price must converge to the unchanged spot price at the settlement of the futures contract and hence would tend to fall on average. Whether the tendency of futures prices to decline under these circumstances is statistically significant is another issue.

[5] A parallel literature exists in the foreign currency literature where this phenomenon is referred to as the carry trade (see Darvas (2009) and Burnside et al. (2011)). The trade involves borrowing in a low yielding currency and lending in a high yielding currency without hedging foreign currency risk in order to take advantage of the yield differential in light of the tendency of the higher yielding currency not to depreciate. This strategy is also similar to riding the yield curve in bond

when the curve is in contango, short futures positions benefit from selling futures contracts at premiums to spot prices. Of course, futures positions that benefit from the roll are exposed to risks associated with the level of the futures curve. Similarly, VIX futures positions that take advantage of the basis or the roll have similar risks associated with the VIX futures curve rising or falling. However, the present study shows that much of this risk is associated with equity prices rising or falling owing to the strong tendency of the VIX to move inversely to equity returns and as a result can be hedged.

This study demonstrates that selling (buying) VIX futures contracts when the basis is in contango (backwardation) and hedging market exposure with short (long) S&P futures positions is highly profitable and robust to both conservative assumptions about transaction costs and the use of out of sample forecasts to set up hedge ratios. The results also indicate that risk-reward tradeoffs are either robust to or are enhanced by risk management techniques.

The study proceeds as follows: the first section provides background information on VIX futures contracts and presents preliminary information about the data. The second section focuses on tests of the forecast power of the VIX futures basis for both VIX changes and VIX futures price changes. The third section simulates trading strategies and the fourth section discusses the implications of the findings.

I. Background on the VIX Futures Contract

The Chicago Board Options Exchange (CBOE) introduced the Volatility Index (VIX) in 1993 to provide a measure of the implied volatility of 30-day, at the money S&P 100 index

markets, where in a steep yield curve environment investors who buy longer duration bonds benefit from the relatively higher yield, which is not systematically offset by capital losses because steep yield curves are not associated systematically with rising interest rates.

options. The current methodology for calculating the VIX was introduced in 2003 and is based on more heavily traded S&P 500 index options and provides a measure of 30-day implied volatility in a model-free framework consistent with the pricing of volatility swaps. The VIX is interpolated from the mid-points of the bid-ask spreads of options from the two front month contracts until the front contract has five days until expiration, at which point options from the second and third contracts are used. The VIX is calculated as a weighted average of the prices of options that are out of the money relative to the forward value of the S&P 500 index and have bid quotes above zero. While the VIX is a useful indicator of the changing demand for the limited risk associated with being long S&P 500 index call options or equivalently for hedging long stock portfolios with S&P 500 index put options as opposed to just being long the S&P 500 index, the spot VIX is not readily tradable. This is because while the VIX theoretically could be replicated by a basket of options, doing so would be prohibitively expensive because of the large number of options that would have to be bought and traded on an ongoing basis to maintain the 30-day interpolated maturity of the VIX.

The CBOE introduced VIX futures contracts in March 2004 to facilitate volatility trading and to encourage investors to use volatility to hedge equity portfolios owing to the strong negative correlation between equity returns and implied volatility.[6] In light of the popularity of VIX futures contracts, the CBOE introduced VIX options in 2006 and Barclays introduced the first volatility exchange traded note (ticker symbol—VXX) in January 2009, in light of expected strong retail investor demand for a volatility instrument.[7]

[6] For example, Akoundi and Haugh (2010) show that the correlation between US large cap stocks and the VIX was -.65 with monthly data from March 2006 through April 2010.

[7] The VXX provides exposure to a combination of the first two VIX futures contracts; each day, a portion of the exposure to the first VIX future is rolled to the second. When the VIX future is in contango, this roll can produce a significant headwind and not surprisingly, the VXX has attracted its share of negative publicity. From its launch through the end of the first quarter of 2012 the VXX lost 96 percent of its value, owing to losses from contango but also because the VXX was launched when implied volatility was extremely high. Nevertheless, average daily trading volume in 2011 was 27.7

The data examined in this study are from January 2006 through the end of December 2011. The sample period begins in January 2006 because of gaps in VIX futures trading activity prior to then. The study focuses on the front two VIX futures contracts because liquidity falls off and quoted bid-ask spreads rise substantially beyond the front two futures contracts. Because this study examines trading strategies, it is extremely important to make sure that transaction costs associated with bid-ask spreads are reflected accurately and that the data are synchronous. The VIX futures data used in this study are from CQG Market Data and include all bid and ask quotes, trades and sizes of each throughout the trading day. The closing VIX futures quotes used in this study are constructed from what appeared on trading screens from 3:00 to 3:15 pm (CST) and specifically are the first quote during this time interval with a bid-ask spread no greater than 10 cents.[8] In the absence of such a quote, the final bid-ask quote of the day is used. This procedure is consistent with the assumption made later that trades are executed and full bid-ask spreads are paid at the first opportunity after 3:00 pm CST when bid-ask spreads are no more than 0.10 points**,** or in the absence of such opportunities at the reported bid-ask spreads at the close.[9] The VIX (spot index values) and the front rollover adjusted mini-S&P 500 futures prices are taken from Pi Trading, which provides one-minute open, high, low, and close data during the trading day. The VIX index values and the mini-S&P 500 futures prices used in the study are the averages of the

million shares, with an average daily market value of $927 million. The success of the VXX attracted followers and over twenty volatility ETNs were created subsequently to give investors various exposures to volatility.

[8] Regular trading hours for the VIX futures contract are from 8:30 AM to 3:15 PM CST, while extended hours trading begins at 7:00 AM CST.

[9] As can be seen in table 1, bid-ask spreads over the sample period are typically 5 cents and are only occasionally greater than 10 cents. We originally used closing data from Bloomberg, which included both closing VIX futures prices as well as closing bid and ask quotes but found that the closing bid-ask spreads occasionally were much wider, despite CQG data showing a lot of activity with tight bid-ask spreads in the last minutes of the trading day. The sometimes wide bid-ask spread quotes recorded at the close of trading by Bloomberg likely reflects traders occasionally pulling their quotes at the very end of the trading day.

open and closing values during the minute in which the above conditions for VIX futures contracts hold.[10]

Table 1 provides a statistical summary of the data examined in this study, including the VIX, the mid-point and bid-ask spread of the front two VIX futures contracts, the basis of the two VIX futures contracts, defined as the levels of each of the front two VIX futures contract prices minus the VIX, and the price of the front mini-S&P 500 futures contract. The table shows the levels and daily first differences of these variables (percent change in the case of the S&P 500 futures contract) and for each provides the mean, standard deviation, maximum and minimum values, cutoffs for the top and bottom deciles, as well as skewness and kurtosis coefficients.

The VIX averages 23.70 percent over the sample period from 2006 through 2011, while the means of the two front VIX futures contracts are higher at 23.84 and 24.36 percent. The peak and trough of the VIX are 81.11 and 9.88 percent. Not surprisingly, the range of VIX futures contracts is compressed relative to that of the VIX, consistent with a tendency of VIX futures prices to be lower than the VIX when the VIX is at extremely high levels and above the VIX when the VIX is at extremely low levels. For example, the peak and trough prices of the front VIX futures contract are 69.04 and 10.30 percent, respectively. The basis of the front VIX futures contract averages 14 basis points with the cutoffs for the top and bottom deciles at 201 and -140 basis points, respectively. The basis of the second VIX futures contract averages 66 basis points with cutoffs for the top and bottom deciles at 420 and -276 basis points, respectively. Thus, the VIX term structure varies substantially over the sample period, despite the fact that on average it is upward sloping. The table also shows that the bid-ask spreads at the close average .062 and .068 futures points for the front and second futures contract, although there are instances when bid-ask

[10] For example, if the first bid-ask spread less than or equal to 10 cents occurs for the front VIX futures at 3:07 pm CST on a given day, the bid and ask of the VIX futures price is matched with the average of the open and close of both the VIX spot index and the mini-S&P 500 futures price at 3:07 pm CST. Thus, the VIX futures basis is measured synchronously, as are the prices of mini-S&P 500 futures contracts that are used to hedge VIX futures positions.

spreads at the close are very wide with the maximum values at roughly a full point for both contracts. Nevertheless, the cutoff for the top decile of bid-ask spreads is .10 futures point, which is worth $100 per contract, as one VIX futures point is worth $1,000. The table also shows that VIX changes are more volatile than VIX futures price changes with a standard deviation of 2.24 percentage points for the VIX versus 1.49 and .99 for the front and second VIX futures contract. These standard deviations are associated with occasionally very large changes in the VIX and VIX futures prices—the largest front VIX futures increases and decreases are 7.71 and -11.49 points, with top and bottom decile cutoffs at 1.51 and -1.33 points. Finally, as expected VIX and VIX futures changes are skewed to the right.

Table 2 provides further information on the VIX futures basis during different volatility regimes and demonstrates a strong tendency of the basis to be in contango when volatility is low and in backwardation when volatility is high. When the VIX is less than 20, the front and second VIX futures bases are in contango 78 and 91 percent of the time and the bases average 64 and 182 basis points, respectively. By contrast, when the VIX is between 40 and 50 percent, the front and second VIX futures bases are in contango only 46 and 32 percent of the time and the bases average -102 and -280 basis points, respectively. This evidence underscores the fact that while the basis for the front two futures contracts is in contango roughly 2/3 to 3/4 of the time, the basis fluctuates substantially over the sample period according to the different volatility regimes and backwardation is not infrequent.

The relationship between the basis and the level of the VIX can also be seen in Figure 1, which shows the daily roll, which is defined as the spread between the price of the front VIX futures contract that has more than ten business days until settlement and the VIX, scaled by the number of business days until the front VIX futures contract settles. The figure further underscores the fact that the basis tends to go into backwardation when the VIX spikes. The figure

also demonstrates that while backwardation was most prominent during the height of the financial crisis, it also occurred frequently throughout the sample period.

II. The Predictive Power of the Basis

This section examines the predictive power of the VIX futures basis for subsequent VIX and VIX futures price changes. Studies, such as Mixon (2007) and Nossman and Wilhelmsson (2009), demonstrate that the VIX basis has insignificant forecast power for VIX changes unless a risk premium that stems from the usefulness of long VIX futures positions as hedges against equity price declines is included. Mixon (2007) models the risk premium as a linear function of volatility, while Nossman and Wilhelmsson (2009) model the risk premium in a constant elasticity of variance framework that allows for jumps. Both studies demonstrate that the VIX basis does not have significant predictive power for the subsequent change in the VIX unless a risk premium is included.

The purpose of the present study differs from these two studies. The issue here is to determine whether the VIX futures basis can be exploited by trading strategies, which is linked to whether the VIX futures basis has predictive power for subsequent VIX changes**.** This can be seen most readily with an example: suppose that the VIX futures basis is in contango with the one month VIX futures price at 22 percent and the VIX at 20 percent. If the basis has unbiased forecast power for the VIX, the VIX on average should rise from 20 to 22 percent over the next month, which would imply no systematic tendency for VIX futures prices to change and hence no VIX futures trading strategy. However, if the basis does not have forecast power for the VIX, an unchanged VIX is a reasonable forecast using only this information. Since on settlement dates VIX futures must converge to the VIX**,** the implication would be that in this example the VIX

futures price on average would fall from 22 to 20 percent and would suggest shorting the VIX futures contract.[11] Therefore, the absence of forecast power of the VIX futures basis for subsequent VIX changes suggests short VIX futures trades when the basis is in contango and long VIX futures trades when the basis is in backwardation.

The forecast power of the basis for the subsequent change in the VIX is examined by estimating the following equations, where the data are from the last trading day of each month of the front VIX futures contract.

$$VIX^{S}_{t+1} - VIX^{S}_{t} = \alpha_0 + \alpha_1[VIX^{F}_{t} - VIX^{S}_{t}] + u_t \quad (1)$$

$$VIX^{F}_{t+1} - VIX^{F}_{t} = B_0 + B_1[VIX^{F}_{t} - VIX^{S}_{t}] + u_t \quad (2)$$

One month VIX and VIX futures price changes are regressed on a constant and on the lagged VIX futures basis, defined as the spread between the price of the VIX futures contract that settles in one month and the VIX. If the basis has significant forecast power for VIX changes, the estimated α_1 coefficient in equation 1 should be significantly positive. On the other hand, if the basis reflects a risk premium rather than expectations about future VIX changes, the β_1 coefficient in equation 2 should be significantly negative. In this case, as the basis becomes more positively sloped the VIX futures price tends to fall more as it rolls down a more steeply sloped curve and as the basis becomes more negatively sloped the VIX futures price tends to rise more as it rolls up a more steeply sloped inverted curve. To determine whether the forecast power of the basis owes

[11] VIX futures contracts are cash settled on Wednesdays that are 30 days before the Fridays on which SPX options settle, with the settlement values based on opening prices of 30-day options. Pavlova and Daigler (2008) demonstrate that this settlement procedure often results in meaningful deviations between the VIX and VIX futures prices just before settlement. For the purposes of the trading strategies later examined in this study, VIX and VIX futures prices need not converge completely at settlement, because positions are initiated only in VIX futures contracts that settle in a minimum of 10 business days and are held at most for 5 business days.

more to when the basis is in contango or backwardation, equations 1 and 2 are also estimated separately conditional on the basis being in contango or in backwardation. Once more if the basis has forecast power for VIX changes, the slope coefficients for the basis should be significantly positive when the basis is either in contango or backwardation. If the basis has forecast power for VIX futures changes the slope coefficient should be significantly negative when the basis is either in contango or backwardation.

Table 3 shows the estimation results for these equations over the sample period from January 2006 through December 2011. The results indicate that the basis does not have significant forecast power for VIX changes. This finding continues to hold when the equation is estimated separately when the basis is in contango and in backwardation. By contrast, the basis has substantial predictive power for subsequent VIX futures price changes. The estimation results indicate that a one percentage point positive (negative) basis is associated with a highly statistically significant 79 basis point VIX futures price decrease (increase) over the next month. This coefficient estimate is not significantly different from -1, which along with the statistically insignificant intercept term estimate indicates that subsequent VIX futures price changes move one for one with the VIX futures basis. The VIX futures basis also has significant forecast power for subsequent VIX futures prices both when the basis is in contango and in backwardation. The results indicate that when in contango, a basis of one percentage point is associated with a statistically significant 1.12 percent decrease in VIX futures prices over the next month. Likewise, the results indicate that a backwardated curve is associated with a statistically significant (at the 10 percent level) increase in VIX futures prices over the next month. Thus, the evidence is consistent with the VIX futures basis reflecting how much the VIX futures contract is going to either roll up or down the curve rather than predicting the subsequent VIX change. The finding that the basis has substantial forecast power for subsequent VIX futures price changes suggests the possibility

that profitable trading strategies could be designed based on the basis being in contango or in backwardation by more than some threshold. At the same time, the regressions explain only about 10 percent of the variation of VIX futures price changes, which also suggest that such trades would have a considerable amount of market exposure, in light of the strong negative correlation between VIX futures prices and equity prices. In the next section we examine the profitability of these trading strategies and explore whether risk-reward tradeoffs are enhanced by hedging VIX futures positions with S&P futures positions.

III. VIX Futures Trading Strategies

The previous section demonstrates that the basis has little forecast power for subsequent VIX changes but has substantial forecast power for subsequent VIX futures price changes. This section examines the profitability of shorting VIX futures when the basis is in contango and buying VIX futures when the basis is in backwardation. While these trading strategies take advantage of the roll by selling VIX futures at a premium to the VIX and buying VIX futures at a discount to the VIX, they are exposed to the potentially substantial risks associated with adverse moves in the VIX futures curve. For example, traders who are short VIX futures contracts face substantial losses if the VIX curve spikes, but because such spikes typically are associated with sharp equity market selloffs, it is possible that much of this risk could be hedged by shorting mini-S&P 500 futures contracts. Likewise, traders who are long VIX futures contracts face the risk that the VIX curve plummets, but because such events typically are associated with rallying equity markets, it is possible that much of this risk could be hedged by buying mini-S&P 500 futures contracts. Thus, by hedging risks associated with changes in the overall level of the VIX

futures curve, it may be possible to earn the roll embedded in the VIX futures basis with more favorable risk-return tradeoffs.

The trading simulations examine the profitability of hedged and unhedged VIX futures positions where the size of the mini-S&P futures hedge is based on out of sample estimates of optimal hedge ratios. The hedge ratios are constructed from regressions of VIX futures price changes on a constant and on contemporaneous percentage changes of the front mini-S&P 500 futures contract both alone and multiplied by the number of days that the VIX futures contract is from settlement, as shown below.

$$\Delta VIX^{F}_{t} = \beta_0 + \beta_1 * SPRET_t + \beta_2 * [SPRET_t * TTS_t] + \mu_{t.} \quad (3)$$

The latter independent variable owes to the empirical evidence that the reaction of VIX futures prices to equity returns is more subdued for longer-dated VIX futures contracts, consistent with the mean reverting tendencies of the VIX demonstrated by Zhang and Zhu (2006), Zhang et al (2010) and Dupoyet et al (2011). Because our trading simulations assume that traders buy or sell the nearest VIX futures contract that settles in 10 or more business days, VIX futures price changes in equation 3 are based on the same contracts and are adjusted for breaks between contracts. The β_1 coefficient should be significantly negative in light of the tendency of VIX futures prices to move inversely to equity returns. The β_2 coefficient should be significantly positive if the reaction of VIX futures prices to equity returns is more subdued the further contracts are from settlement. This equation is estimated first for 2006 and these estimates are used to set up hedge ratios for 2007. One year of data is then added to the estimation period and these estimates are used to set up hedge ratios for 2008. This process is continued for each year

through 2011. For the sake of illustration, the estimates of equation 3 from 2006 through 2010 that determine hedge ratios for 2011 trades are

$$\Delta VIX^{F}_{t} = \underset{(.024)}{-.024} \quad \underset{(.051)}{-.714} * SPRET_{t} \quad + \underset{(.002)}{.0127} * [SPRET_{t+1} * TTS_{t}]$$

$$RBAR^{2} = .43, \ DW = 2.27, \ NOBS = 1258,$$

where standard errors are shown in parentheses. These estimates are fairly similar for the other estimation periods and indicate that contemporaneous positive (negative) S&P futures returns are associated with declines (increases) in the price of the front VIX futures contract. The estimates also indicate that the response of the VIX to a one percent increase or decrease in S&P futures returns is decreased by .06 for each week the relevant VIX futures contract is from settlement. Together the estimates indicate that a one percent increase (decrease) in S&P futures returns is associated with a .59 percentage point decrease (increase) in VIX futures prices for contracts that have 10 days until settlement.

The hedge ratio--the number of mini-S&P futures contracts to buy or sell per VIX futures position--is constructed using the out of sample parameter estimates from equation 3 to obtain the fitted gain or loss on one VIX futures contract for an assumed one percent mini-S&P futures price change and the associated gain or loss per mini-S&P futures contract. We then solve for the number of mini-S&P futures contracts that offset the fitted gains and losses on one VIX futures contract. The value of a one point VIX futures price change is $1,000 and the gain or loss for an arbitrarily assumed one percent mini-S&P futures price change is equal to .01 times the lagged value of the mini-S&P futures contract times $50 (the value of one mini-S&P futures point). The formula for the hedge ratio is

$$HR_t = [\beta_1 * 1000 + \beta_2 * TTS_{t-1} * 1000]/[.01 * ES_{t-1} * 50] . \quad (4)$$

The average hedge ratio is roughly one mini-S&P futures contract per VIX futures contract, and the range of the hedge ratio from 1/2 and 2 contracts owes mostly to fluctuations in the number of business days to settlement of relevant VIX futures contracts and the level of S&P futures prices.[12]

The simulations examine the profitability of shorting or buying VIX futures contracts when the VIX futures basis is in contango or backwardation, respectively, and the efficiency of hedging market risk with mini-S&P futures positions. The simulations then examine the impact of modifying entry rules and then introducing exit rules based on risk management strategies. All trading simulations examine the profitability of shorting or buying the front VIX futures contract that has at least ten business days until settlement when the magnitude of the daily roll is greater in magnitude than .10 VIX futures point ($100) per day.[13] The daily roll is defined as the difference between the front VIX futures price and the VIX, divided by the number of business days until the VIX futures contract settles, and measures potential profits assuming that the basis declines linearly until settlement.

The trading simulations incorporate conservative assumptions about transaction costs, which are assumed to be incurred both at the outset and the termination of trades. VIX futures positions are entered and exited in the last 15 minutes of the trading day at the first instance that the bid-ask spread is no greater than .10, and in the absence of such opportunities, at the final

[12] More specifically, the fitted gain or loss on a VIX futures contract for a one percent change in S&P futures prices is equal to $\beta_1*1000 + \beta_2*TTS_{t-1}*1000$. The gain or loss on one mini-S&P futures contract for a one percent price change is equal to $.01*ES_{t-1}*50$. The hedge ratio is determined by solving for the number of futures contracts needed to buy or sell to have expected offsetting gains and losses.

[13] Simulations were also run using +/-.15 daily roll thresholds for entering trades and the unreported results show somewhat fewer but more profitable trades.

bid-ask spread recorded at the close.[14] The simulations assume that full bid-ask spreads are paid on VIX futures contracts--sales and purchases of VIX futures contracts are executed at the bid and ask, respectively. Mini-S&P futures hedges are assumed to be entered at the average of the opening and closing price of the minute that VIX futures positions are entered. Bid-ask spread costs of mini-S&P futures contracts are assumed to be one-half of the minimum 1/4 point tick size of mini-S&P futures contracts or $6.25, which are assumed to be paid upon both entering and exiting positions. In addition, round trip futures brokerage charges of $3 per contract are assumed.[15] Total round trip transaction costs associated with both bid-ask spreads and brokerage fees average roughly $60 per trade. Hedge ratios are determined at the outset of trades and are not adjusted during trades.

The statistical significance of the means of the P&Ls from particular trading strategies against the null hypothesis that the means of the P&Ls are not better than random is tested as follows. We randomly select with replacement entry days for the same number of trades that are executed for each strategy (assumed here to be n). We then calculate the P&Ls for each of the n random trades assuming that trades are held for durations equal to the average duration of the actual trades and calculate the mean P&L of the n simulated trades. This procedure is repeated 10,000 times and the P-values are calculated based on the percentage of times that the means of the 10,000 trials are better than the actual results.[16] Thus, for the 82 short VIX futures 5-day trades shown in Table 4, the P-values reflect the percentage of times that randomly selecting the entry points for 82 short VIX futures trades lasting 5 business days resulted in higher mean

[14] The basis and whether entry conditions are triggered are determined at this point, where the mid-point of VIX futures prices are compared to the average of the open and close of the VIX for the minute that the first bid-ask spread of the VIX futures not greater than .10 is observed or at the close.

[15] Indivisibilities in the number of mini-S&P futures contracts are not considered here in light of the possibility that the number of VIX futures contracts trades could be increased to minimize divisibility issues.

[16] These randomization strategies are similar to those performed by Lo et al. (2000), who compare the conditional distributions of stock returns after technical patterns occur to randomly selected unconditional distributions. A similar approach is also taken by Batchelor and Kwan (2007), who examine the market timing ability of technical analysts in German bond markets and compare their results to randomly shuffled trading positions.

returns than the actual mean return.[17] P-values are calculated in this manner for the overall P&L, the unhedged P&L and the P&L of mini-S&P hedges.

The first set of trading simulations assume that short VIX futures positions are entered when the VIX futures basis is in contango and the daily roll exceeds .10 VIX futures points and that long VIX futures positions are entered when the VIX futures basis is in backwardation and the daily roll is less than -.10 VIX futures points. These simulations also assume that trades are exited at the end of 5 business days and that transaction costs associated with exiting positions are incurred. After exits, trades are entered at the end of the next day that entry conditions are triggered. The assumption that trades are exited after 5 days both provides a sense of the profitability of trades after 5 business days and serves as a base case for later examining the impact of exit rules based on risk management strategies.

Table 4 reports the P&L on hedged VIX futures positions, unhedged VIX futures positions and mini-S&P futures hedges. The table also shows the P&L from the roll, which breaks out and accumulates the daily gains earned on the roll while trades are open.[18] Transaction costs associated with bid-ask spreads and brokerage fees are apportioned to each of these positions and included in the P&Ls. The table shows the means, associated p-values and cutoffs for the top and bottom deciles. The table also reports semi-standard deviations and Sortino ratios rather than standard deviations and Sharpe ratios owing to the frequently non-normal P&L distributions.[19]

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[17] Later when strategies include stop loss or take profit orders that cause trades to be exited in 3 or 4 days on average, the simulations assume again that the same number of trades are entered randomly and exited in 3 or 4 days.

[18] The roll measures the profit earned assuming that the basis decays linearly until settlement. Thus, if the basis equals 2 points with 10 business days to expiration, the daily roll is 0.20, or $200 per futures contract. The Roll P&L reported in the tables reflects the accumulated values of the daily roll while trades are open, with the daily roll recalculated each day that trades are open.

[19] The Sortino Ratios are calculated with the minimum acceptable profit set equal to zero and hence are equal to the mean profit scaled by the semi-standard deviation, where for the latter gains are set to zero and are included in semi-standard deviation calculations.

The results indicate that shorting VIX futures contracts and hedging when the basis is sufficiently in contango is highly profitable. Mean profits after transaction costs are a highly statistically significant $539 with a win to loss ratio of roughly 2:1 for the 82 trades. The losses are manageable, as the bottom 10 percent cutoff for the P&L is -$814. The results also indicate that average profits on hedged positions are in line with the average $549 P&L from the roll, and hence the roll accounts for the profits. Profits without hedges average a highly statistically significant $656 as the average loss on hedges is $116 per trade. However, the bottom decile P&L cutoff for unhedged trades is -$1,903 versus -$814 for hedged trades, and downside volatility is about 50% higher for the unhedged trades.[20] The greater downside volatility more than offsets the higher mean returns of unhedged trades, resulting in a higher Sortino ratio for hedged trades than for unhedged trades (0.75 vs. 0.59).

The results also indicate that buying VIX futures contracts and hedging with long mini-S&P futures contracts when the VIX futures curve is in backwardation is extremely profitable. The average P&L over 5 business days is a highly statistically significant $908, with winners outpacing losers by a roughly 2:1 margin for the 42 trades. Because the VIX and overall market volatility tends to be higher when the VIX futures curve is in backwardation, long VIX futures trades have almost 3 times the downside volatility of short VIX futures trades. In this higher volatility environment, hedging reduces downside volatility by about 30% and improves the bottom decile P&L cutoff to -$2,809 from -$4,453, but also reduces average profits by $132. The lower downside volatility of hedged trades leads to a better Sortino ratio of 0.53 for hedged trades versus 0.42 for unhedged trades. Similar to short VIX futures trades, average profits on long VIX futures trades are very close to average profits from the roll. Overall, these results

[20] Unreported correlations between the P&Ls of VIX futures positions and mini-S&P futures positions are -.8 and thus while adding mini-S&P futures positions to VIX futures positions results in an additional source of variability, the reliably negative correlations and the stability of the estimated hedge ratios result in considerably lower volatilities for hedged versus unhedged trades.

indicate that hedging improves downside risk adjusted returns and that the profitability of hedged VIX futures trades can be attributed to the roll rather than to subsequent changes in implied volatility levels.

Figure 2 shows the outcomes and the timing of short and long VIX futures trades over the sample period. The figure demonstrates that opportunities to buy and short VIX futures contracts are fairly well spread over the sample period, but more concentrated in the middle of the 2007 through 2011 sample period. The figure also shows two large winning trades (one long and one short) and one large losing long trade. Unreported results indicate that both long and short trades remain significantly profitable when the largest winning trades for both long and short trades are trimmed from the distribution.[21]

The stability of the profitability of hedged short and long VIX futures trades is also reflected in Figure 3, which shows the cumulative gains over the 2007 through 2011 period, assuming that each trade is for one VIX futures contract and the corresponding mini-S&P 500 futures hedge. The figure shows cumulative earnings of $82,000, as well as an absence of meaningful drawdowns and strong performance during the financial panic.[22] One way to gain perspective on the potential returns on equity associated with these trading strategies is to compare earnings to both margin requirements and to multiples of margin requirements. The minimum initial margin requirement for one VIX futures contract and one mini-S&P futures contract (the average size of hedges) at the time of the writing of this paper was $6,900 and $4,375, respectively. Thus, traders fully margined at the outset could have enjoyed 53 percent

[21] The very large $11,200 gain shown in figure 2 occurred on a long VIX future trade entered on November 13, 2008 and exited five business days later on November 20, 2008. During this period the relevant VIX futures contract rose 17 points, while the mini-S&P futures contract fell 91 points. Because the hedge ratio was 1.3 mini-S&P futures contracts per VIX futures contract, the roughly $5,900 loss on the mini-S&P futures contract (91 *$50 * 1.3 contracts) was more than offset by the roughly $17,000 gain on the VIX futures contract. The daily roll contributed roughly $3,000 to the gain on the trade as the VIX futures curve remained steeply inverted during the trade.

[22] Regressions of the ex-post hedged P&Ls on contemporaneous mini-S&P futures percent price changes indicate that the profitability of short VIX futures strategies was uncorrelated with equity returns, while the profitability of long VIX futures strategies was negatively correlated with equity returns.

annual compound returns on these trades over the 5 year period, not including returns from investing margin account funds. However, such returns are an extreme upper bound for possible returns given that few traders employ such leverage.[23] A more realistic assumption that traders employing this strategy initially have equity equal to 5 times the required margin results in 20 percent annually compounded returns.

The general tendency of the VIX futures basis to be in contango when the VIX is low and to be in backwardation when the VIX is high is borne out by the (unreported) 21 percent median level of the VIX at the outset of short trades and the 34 percent median level of the VIX at the outset of long trades. The next simulations examine whether the level of the VIX at trade inception has an impact on profitability by adding to the previous entry rules the condition that the VIX at the outset of trades is above or below these median levels.[24] Thus, short trades are entered when the daily roll is greater than .1 VIX futures point and either (i) the VIX is greater than 21 percent or (ii) the VIX is below 21 percent. Long trades are entered when the daily roll is less than -.10 VIX futures point and either (i) the VIX is greater than 34 percent or (ii) the VIX is less than 34 percent. The simulations again assume that trades are exited after 5 business days.

The results in Table 5 indicate that short trades are far more profitable when the VIX is higher. When the VIX is above 21 percent, mean profits are a highly statistically significant $976 compared to $539 without conditioning on the level of the VIX, as reported in Table 4. Winners outpace losers by a roughly 4:1 margin for the 43 trades and the top and bottom P&L decile cutoffs are $2,750 and -$522, respectively. The results also indicate that hedging continues to be a noticeable drag on overall profitability as hedging losses average $281, and

[23] Figures 2 and 3 also suggest that heavily margined traders would not have received margin calls. The cumulative earnings on trades over time would have substantially lowered leverage because of the assumption that each trade involves buying or selling one VIX futures contract.

[24] The trades in table 5 do not exactly aggregate to those in table 4 because the timing of entering and exiting trades after 5 business days varies with additional entry conditions. We use the median rather than the mean level of the VIX to make the number of trades apportioned by the level of the VIX to be close to each other although similar results occur when we use the mean.

thus unhedged profits average a highly statistically significant $1,258. However, not hedging increases downside volatility by about 50% and worsens the lowest decile cutoff for profits from -$522 to -$2,083. A notable difference from the previous results is that average profits are no longer completely accounted for by the daily roll with roughly 1/3 of the profits coming from VIX futures falling in excess of the declines built in to the roll.

By contrast, profitability is substantially lower when short VIX futures trades are also conditioned on the VIX being below 21 percent. In this case, the P&L averages only $305, although mean profits remain statistically significant but on average are less than the mean profits earned on the roll. These trades also lose much less on mini-S&P futures hedges, as equity futures prices tend to move less in the low volatility market environment. These results suggest that when the VIX is low and the basis is in contango, traders are reluctant to allow VIX futures prices to fall much further. Finally, the more attractive risk adjusted profits when the curve is in contango and when the VIX is relatively high is supported by the much higher Sortino ratios of trades conditioned on above average versus below average levels of the VIX (1.15 vs. 0.62).

The results for long VIX futures trades indicate that when the VIX is above 34 percent, average profits are a highly statistically significant $1,277. These profits owe more to the favorably skewed profits, as the top and bottom decile cutoffs are $6,965 and -$2,809, respectively, while the ratio of winning to losing trades is not much better than 1:1. Although the profitability of unhedged trades is highly statistically significant and slightly greater than hedged trades, they have somewhat higher downside volatilities than hedged trades. The results also indicate that against the backdrop of these trades--inverted VIX futures curves and relatively high volatility--S&P futures prices surprisingly are little changed on balance and VIX futures price increases are about in line with the daily roll.

Entering long VIX futures trades only when the VIX is below 34 percent also results in favorable outcomes as the mean $959 profit is highly statistically significant. Although these mean profits are lower than when the VIX is above 34 percent, the ratio of winners to losers is now better than 2:1 and downside volatility is about 50% lower. This leads to better risk-reward tradeoffs as Sortino ratios are higher for long VIX futures trades when volatility is below rather than above average (0.99 vs. 0.68). The results also indicate that unhedged trades are highly significantly profitable with mean profits of $1,222. However, once more the absence of hedging results in downside volatilities that are roughly 50% higher and the cutoff for the bottom decile of profits is 75 percent lower than for the hedged trades.

Overall, the results for the trading rules examined so far indicate that shorting or buying VIX futures contracts on a hedged basis offers favorable risk return tradeoffs with typically highly favorable ratios of winners to losers and manageable losses. Downside risk-adjusted profits on short trades are substantially lower when the VIX at the outset of trades is low although profits are significantly positive, while downside risk-adjusted profits for long trades are greater when the VIX at the outset is low although the difference is less pronounced.

The baseline simulations in Table 4 assume that trades are exited at the end of 5 business days. The next simulations focus on the impact of risk management strategies that can trigger earlier exits. Entry conditions are the same as in the first set of simulations--short trades are entered when the basis is in contango and the daily roll is greater than .10 VIX futures point and long trades are entered when the basis is in backwardation and the daily roll is less than -.10 VIX futures point. The first risk management strategy is based on the common sense idea that trades should be exited when the conditions for being in them no longer exist. These simulations assume that short VIX futures trades are exited when the daily roll falls below .05 point and that

long VIX futures trades are exited when the daily roll rises above -.05. If these exit conditions are not triggered, trades are exited at the end of 5 business days.[25]

The second risk management rule involves stop loss orders, which attempt to limit the extent of large losses by exiting individual trades when losses reach predetermined levels. Stop loss orders are commonly used by futures traders for a variety of reasons; one is to enforce discipline on losing trades. In addition, stop loss orders are similar to momentum trades and can be based on views that market movements that cause large losses are likely to continue, which makes quickly cutting losses a preferred strategy. The stop loss orders here assume that trades are exited at the close when losses net of transaction costs are greater than $500.[26] In addition to shedding light on whether stop loss orders enhance VIX futures trading strategies, they also provide information about whether the trading strategies examined in this study would have been feasible for traders who are unwilling to ride out potentially large losing trades.

The final risk management strategy involves take gain orders, which stipulate exiting trades when gains exceed a certain level. The take gain orders examined in this study are symmetric to stop loss orders, and exit trades at the close when profits net of transaction costs exceed $500. While take gain orders may cause potentially large winners to be exited prematurely, they ensure that meaningful unrealized profits are not given back. Take gain orders also can be justified if traders believe that profits of hedged VIX futures positions mean revert when they exceed certain levels.

Table 6 shows the results for hedged short VIX futures trades entered when the basis is in contango and the daily roll is greater than .10 VIX futures points, and exited when (a) the daily

[25] Simulations run with exit strategies triggered by the daily roll going below zero for short trades and above zero for long trades resulted in relatively few early exits and are not reported.

[26] The rationale for using net losses rather than gross losses for stop loss orders is that the roughly $60 average transaction cost per trade owing to bid-ask spreads and brokerage costs are effectively incurred as soon as trades are opened, which would cause the effective tightness of stop loss orders to change over the duration of trades if they included transaction costs. The same rationale holds for take gain orders, which also stipulated net of transaction costs.

roll is less than .05 VIX futures points, (b) net losses are greater than $500, or (c) net gains are greater than $500. If exit rules are not triggered, trades are closed at the end of 5 business days. The results are improved by exiting short VIX futures trades when the condition for entering them no longer holds. The highly statistically significant mean profit of $594 surpasses the baseline $539 average profit, downside volatility drops to $548 from $716, and the Sortino ratio rises to 1.08 from 0.75.[27] This exit rule also lowers the average duration of trades to 4.3 business days, with 22 of the 84 trades exited early.

The stop loss rule for short VIX futures trades results in slightly lower but highly statistically significant mean profits relative to the baseline trades. The lower mean is offset by lower downside volatilities, resulting in an unchanged Sortino Ratio of 0.75. However, the cutoff for the lowest decile of profits is worse with stop loss rules (-$1,030 versus -$814) and the ratio of winning to losing trades falls from 67 percent to 59 percent. The stop loss orders also cause the average duration of trades to decline to 4.2 days, as 23 of the 90 trades are exited before 5 business days. While the outcomes of short VIX futures trades are not changed greatly with stop loss orders, the results more importantly demonstrate that large unrealized losses did not occur frequently with these trades and thus riding out potentially large losing positions was not required to earn the profits associated with these trades.[28] While the results do not make the use of stop loss orders compelling, the decision to employ stop loss orders ultimately rests on the aversion of traders to suffering potentially large losses.

[27] Statistical significance of the mean P&Ls for trades with variable durations owing to exit rules are performed by randomly drawing from all possible entry days the same number of trades and assuming that trades are held for the same rounded integer number of days as the average durations of trades with the specific exit rules. This process is repeated 10,000 times and significance levels are determined from the histogram of mean results. For example, the statistical significance of the mean P&L of short trades with exit rules based on the roll is determined by randomly selecting 84 entry days with replacement and calculating mean profits assuming that these randomly entered trades are held for 4 days. This procedure is repeated 10,000 times to determine the probability of getting the actual results under the assumption that trades are selected randomly and held on average for a duration close to the average duration of the actual trades.

[28] When stop loss levels of $1,000 are used, mean profits are $567 and only 9 of 83 trades are exited early. The average duration of trades is 4.7 days and hence this level for stop loss orders was not frequently binding.

The third risk management strategy of exiting trades at the close if profits exceed $500 or in 5 business days is clearly counterproductive. Mean profits per trade are statistically significant but drop from $539 to $307 and downside volatility is little improved, leading to a low Sortino ratio of .44. Not surprisingly, the ratio of winners to losers spikes to almost 3:1, as the average duration of trades falls to 3.1 business days, with 50 of the 116 trades exited because the take gain level is hit. Another major impact of this rule is that the cutoff for the upper decile of profits falls to $1,191 from $1,788. As mentioned above, take profit rules involve balancing the realization of profits with potentially foregoing larger winners.[29] Our results indicate that they cause trades to be exited prematurely, which hurts profitability. In summary, the findings indicate that closing short VIX futures trades when the initial conditions for being in them no longer exist substantially enhances the risk-reward tradeoffs. Stop loss orders have a negligible effect on risk reward tradeoffs, while take gain orders substantially worsen the risk-reward tradeoffs of short VIX futures trades relative to the benchmark 5 day exit strategies.

Table 7 shows the results for hedged long VIX futures trades entered when the basis is in backwardation and the daily roll is below -.10 VIX futures points and exited when (a) the daily roll is greater than -.05 VIX futures points, (b) losses (net of transaction costs) are greater than $500 and (c) net gains are greater than $500. Again, trades are closed at the end of 5 business days if these exit rules are not triggered. The results again are improved by exiting trades when the rationale for being in them no longer exists. Although the mean profit per trade declines to a statistically significant $808 from $908, downside volatility falls to $1,164 from $1,702, resulting in an improved Sortino ratio of 0.69 versus 0.53 for the baseline trades. In addition, the bottom decile cutoff is more favorable (-$1,716 vs. -$2,809). Finally, this exit rule causes the average duration of trades to drop to 3.4 business days with 24 of 47 trades exited early.

[29] When take gain levels of $1,000 are used, mean profits are $473 and 35 of 95 trades are exited before 5 business days and the average duration of trades is 4.2 days.

As stated earlier, long VIX futures trades tend to occur during periods of greater market volatility relative to short VIX futures trades and not surprisingly $500 stop loss and take gain orders affect long VIX futures trades more than short VIX futures trades. With the $500 stop loss rule, mean profits per trade compared to the baseline trades drop from $908 to $531, although mean profits remain statistically significant. The lower average profitability is only partly offset by lower downside volatility ($1,311 vs. $1,702) and consequently stop loss orders produce a deterioration of the Sortino Ratio from 0.53 to 0.41. Of the 54 trades, 29 are stopped out and fewer than half of the trades are now profitable. However, the size of the largest losses is reduced as the cutoff for the lowest decile of profits is -$2,223 versus -$2,809. Hedging reduces mean profits by an average of $348, which is much more than with the other simulations. Unreported results indicate that the same trading simulations run without mini-S&P futures hedges and with $500 stop loss orders result in highly statistically significant mean profits of $1,012.[30] These results suggest that stop loss orders could be an effective substitute for hedging long VIX futures trades, notwithstanding the evidence indicating that they do not have a major impact on the risk-reward tradeoffs of hedged long VIX futures trades.[31]

When take gain exit rules are employed, the mean profit per trade is $777 and is statistically significant. However, because mean returns are lower and downside volatility is about unchanged, the resulting Sortino Ratio is lower than the benchmark case (0.47 vs. 0.53). In addition, the take gain level is frequently reached as the average duration of trades falls to 2.6 days, with 49 of the 66 trades exited before 5 business days and with the ratio of winning to losing trades improving to 5:1. Overall, the risk-reward tradeoffs of long VIX futures trades are

[30] Unlike the other simulations, the unhedged P&Ls with stop loss and take gain rules do not reflect the results of unhedged trading strategies because the exit rules are specified in terms of hedged losses and gains.

[31] When stop loss levels of $1,000 for long VIX futures trades are used, mean profits are $518 and 22 of 52 trades are exited early, which causes the average duration of trades to fall to 3.5 days. When take gain levels of $1,000 for long VIX futures trades are used, mean profits are $499 and 29 of the 58 trades are exited early, which causes the average duration of trades to be 3.4 days.

enhanced by exit strategies based on closing trades when the rationale for being in them no longer holds, while stop loss and take gain orders have small adverse effects on the results.

IV. Conclusion

This study examines trading opportunities in VIX futures contracts that stem from the evidence that the VIX futures basis does not have significant forecast power for the VIX. This finding suggests that the VIX futures basis should have predictive power for VIX futures price changes. The rationale is that if no tendency exists for the VIX to be either higher or lower when the VIX futures basis is in contango or backwardation, respectively, convergence of VIX futures prices to a VIX that on average is unchanged should result in VIX futures prices falling when the basis is in contango and rising when the basis is in backwardation. Empirical evidence is consistent with this view as the VIX futures basis has substantial forecast power for subsequent VIX futures price changes. Hence, a positive basis suggests that VIX futures roll down the VIX futures curve, while a negative basis indicates the VIX futures roll up the VIX futures curve. This evidence is consistent with the poor performance of VIX related products in recent years, which has been attributed largely to the substantial built-in losses from rolling long VIX futures positions in a typically upward sloped VIX futures curve environment. This evidence also is consistent with the more general findings that the slopes of commodity futures curves are major factors in the profitability of long-only commodity futures indexes.

This study then examines whether the roll can be captured by trading strategies, which involve shorting the front VIX futures contract when the VIX futures curve is sufficiently in contango and buying the VIX futures contract when the VIX futures curve is sufficiently in backwardation. While these positions are exposed to the risk that the VIX futures curve moves

sharply higher or lower, much of this risk is associated with decreases and increases in equity prices and can be hedged. The trading strategies hedge this risk by matching short VIX futures and short mini-S&P futures positions and long VIX futures and long mini-S&P futures positions, with hedge ratios determined using out of sample estimates of the tendency of VIX futures prices to move inversely to mini-S&P futures returns. In addition, the simulations assume that traders pay full bid-ask spreads on VIX futures contracts when both entering and exiting positions as well as other transaction costs.

The basic trading strategies involve shorting one front VIX futures contract when the VIX futures basis is in contango and the associated daily roll exceeds 0.10 VIX futures points and buying one front VIX futures contract when the basis is in backwardation and the daily roll is greater in magnitude than -0.10 VIX futures points and holding for 5 business days. These strategies produce statistically significant $539 and $908 profits per contract for short and long trades, respectively, and highly favorable downside risk-reward tradeoffs. The findings also indicate that mean profits remain both highly statistically significant and are greater without mini-S&P futures hedges, although hedging reduces downside volatility and substantially improves Sortino ratios. Also, short and long trades both remain significantly profitable when they are partitioned on the basis of the level of the VIX at the outset of trades.

The study then examines the impact of risk management rules that can cause trades to be exited earlier than 5 business days. The first rule involves exiting trades when the original reason for being in them--the favorable roll owing to the VIX futures curve being sufficiently in contango or backwardation--no longer exists. The other two rules involve $500 stop loss orders and $500 take gain orders. Exit rules triggered when the initial conditions for being in both short and long VIX futures trades no longer exist substantially increase Sortino Ratios. In addition to enhancing performance, these strategies are logical compared to stop loss and take gain orders,

which can be arbitrary if not grounded in views or evidence about the mean-reverting tendencies of the P&L. The evidence also suggests that while stop loss orders do not improve risk-reward tradeoffs for either short or long VIX futures trades, they do not substantially degrade performance either. What is more important is that this finding indicates that the trading strategies examined in this study could have been employed profitably by traders averse to maintaining trades in the face of even fairly modest unrealized losses. The results also indicate that take gain orders are not a good exit strategy, as they tend to result in exiting winning trades prematurely.

Overall, the results are consistent with the lack of forecast power of the basis in many commodity and financial futures markets. In the case of VIX futures, the popularity of "tail risk" insurance during the sample period likely put a strong bid in VIX futures prices, which may have caused their prices to be higher and the VIX futures curve to be steeper than otherwise. While this phenomenon could be partly responsible for the profitability of short VIX futures positions, this study also demonstrates ample opportunities to profit from buying VIX futures when the VIX futures curve was inverted. Interesting questions for future research include whether our findings can be extended to other volatility products and whether the roll in other futures contracts can be exploited and the market risk hedged as in this study.

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Table 1. Daily summary statistics for the VIX, the mid-points and bid-ask spreads of the front and second VIX futures, the basis of the front and second VIX futures and the rollover-adjusted mini-S&P 500 futures price from 2006-2011. The basis equals the VIX futures price minus the VIX. Each observation is taken after 3:00 pm CST at the first instance the bid-ask spread for the VIX future is 0.10 or less. The levels for the VIX and mini-S&P 500 futures are the average of the open and close for the minute at which the VIX futures prices are taken. The top panel displays the levels, while the bottom panel displays the daily first differences and daily percent changes of the mini-S&P futures contract.

	VIX	Front VIX Futures	2nd VIX Futures	Bid-Ask Front VIX Futures	Bid-Ask 2nd VIX Futures	Front VIX Basis	2nd VIX Basis	Mini-S&P Futures
Levels								
Mean	23.70	23.84	24.36	0.062	0.068	0.144	0.658	1201.14
Std. Deviation	11.39	10.362	9.146			2.349	4.229	207.63
Maximum	81.11	69.04	59.16	1.00	0.99	4.885	6.715	1536.00
Minimum	9.88	10.30	11.78	0.00	0.00	-22.150	-35.210	610.50
Top Decile	39.10	37.58	35.75	0.10	0.10	2.005	4.195	1443.75
Bottom Decile	11.99	12.40	13.21	0.03	0.04	-1.395	-2.755	857.75
Skewness	1.71	1.399	1.024	--	--	-3.970	-3.544	-0.619
Kurtosis	3.737	2.319	1.253	--	--	24.886	18.691	-0.406
1st Differences								
Mean	0.0064	0.0065	0.0062	--	--	0.00006	0.00015	-0.00003
Std. Deviation	2.239	1.490	0.994	--	--	1.367	1.620	0.0155
Maximum	15.300	7.710	6.405	--	--	8.355	12.960	0.1305
Minimum	-16.300	-11.485	-7.610	--	--	-20.94	-21.335	-0.1145
Top Decile	2.000	1.505	1.035	--	--	1.115	1.305	0.0147
Bottom Decile	-1.910	-1.330	-0.925	--	--	-1.000	-1.285	-0.0150
Skewness	0.534	0.328	0.429	--	--	-2.865	-1.359	-0.1945
Kurtosis	10.964	7.387	7.241	--	--	46.715	30.743	11.058

Table 2. The VIX basis by volatility regime. The table shows the basis, scaled by the VIX, and the frequency of contango and backwardation for the front and second VIX futures contract when the VIX is at various levels.

			First VIX Future			Second VIX Future		
	OBS	**VIX**	**Basis & % of VIX**	**OBS & % in Contango**	**OBS& % in Backwardation**	**Basis & % of VIX**	**OBS & % in Contango**	**OBS & % in Backwardation**
All OBS	1493	23.70	0.144 0.6%	1017 68.1%	476 31.9%	0.658 2.8%	1119 74.9%	374 25.1%
VIX<=20	644	15.01	0.635 4.2%	505 78.4%	139 21.6%	1.822 12.1%	588 91.3%	56 8.7%
20<VIX<=30	559	24.10	0.625 2.6%	394 70.5%	165 29.5%	1.816 7.5%	439 78.5%	120 21.5%
30<VIX<=40	152	34.04	-0.810 -2.4%	76 50.0%	76 50.0%	-1.610 -4.7%	65 42.8%	87 57.2%
40<VIX<=50	81	44.22	-1.019 -2.3%	37 45.7%	44 54.3%	-2.800 -6.3%	26 32.1%	55 67.9%
VIX>50	57	61.23	-5.918 -9.7%	5 8.8%	52 91.2%	-12.880 -21.0%	1 1.8%	56 98.2%

Table 3. The forecast power of the VIX futures basis for one month VIX and the nearest VIX futures price changes taken on the last day of trading each month from January 2006 through December 2011. The VIX futures basis is defined as the difference between the price of the VIX futures contract that has roughly one month to settlement and the VIX index. The VIX futures price change is measured from the contract that has one month to settlement at month t until it settles in month t+1. Regressions are also run separately when the VIX futures basis is in contango (+) and in backwardation (-). Standard errors are shown in parentheses and one, two and three asterisks denote statistical significance at the 10, 5 and 1 percent levels, respectively.

Dependent Variable		$VIX^{S}_{t+1} - VIX^{S}_{t}$			$VIX^{F}_{t+1} - VIX^{F}_{t}$		
Constant		-.016 (.791)	1.36 (1.26)	-3.74 (3.17)	.019 (.779)	1.22 (1.24)	-3.81 (3.10)
$[VIX^{F}_{t} - VIX^{S}_{t}]$		.231 (.279)			-.791*** (.276)		
$[VIX^{F}_{t} - VIX^{S}_{t}]^{+}$			-.178 (.549)			-1.12** (.542)	
$[VIX^{F}_{t} - VIX^{S}_{t}]^{-}$				-.483 (.779)			-1.54* (.76)
$RBAR^2$		-.005	-.018	-.040	.095	.058	.162
DW		1.99	2.05	1.64	2.00	2.02	1.60
NOBS		71	53	18	71	53	18

Table 4. Profits from shorting or buying one front VIX futures contract with at least ten days until settlement when the daily roll at the outset is greater than .10 or less than -.10 VIX futures points. The table shows the P&L on hedged and unhedged VIX futures positions and the P&L on the S&P futures hedge. The Roll P&L accumulates the profits on the daily roll, calculated each day as the difference between the front VIX futures contract and the VIX, divided by the number of business days until settlement. Transaction costs for both entering and exiting positions are included for each of the P&L categories and assume that quoted bid-ask spreads are paid on VIX futures contracts and that bid-ask spreads equal to one half of the minimum 1/4 point tick are paid on mini-S&P futures contracts. $3 round trip brokerage fees per contract are assumed. Trades are entered and exited at the close and are held for 5 business days. The sample period is from January 2007 through December 2011.

	Hedged P&L	Unhedged P&L	S&P Hedge P&L	Roll P&L
Short Trades 5 day exits				
Mean	$539	$656	-$116	$549
P-value	.007	.015	.244	<.001
Semi Std Dev	716	1,111	930	--
90% fractile	1,788	2,797	1,174	871
10% fractile	-814	-1,903	-1,497	214
Winners/Losers	55/27	53/29	33/49	--
Sortino Ratio	.75	.59	-.12	--
Long Trades 5 day exits				
Mean	$908	$1,040	-$132	$1,066
P-value	.001	.009	.364	<.001
Semi Std Dev	1,702	2,473	2,588	--
90% fractile	4,449	8,532	3,151	2,664
10% fractile	-2,809	-4,453	-4,458	37
Winners/Losers	27/15	22/20	24/18	--
Sortino Ratio	.53	.42	-.05	--

Table 5. The effect of the level of the VIX on the profits from shorting or buying one front VIX futures contract with at least ten days until settlement when the daily roll at the outset is greater than .10 or less than -.10 VIX futures points. The trading rules also include as entry conditions for short trades that the VIX is either above or below its 21 percent median level and for long trades that the VIX is either above or below its 34 percent median level of the previously examined short and long trades, respectively. The table shows the P&L on hedged and unhedged VIX futures positions and the P&L on the S&P futures hedge. The Roll P&L accumulates the profits on the daily roll, calculated each day as the difference between the front VIX futures contract and the VIX, divided by the number of business days until settlement. Transaction costs for both entering and exiting positions are included for each of the P&L categories and assume that quoted bid-ask spreads are paid on VIX futures contracts and that bid-ask spreads equal to one half of the minimum 1/4 point tick are paid on mini-S&P futures contracts. $3 round trip brokerage fees per contract are assumed. Trades are entered and exited at the close and are held for 5 business days. The sample period is from January 2007 through December 2011.

	Hedged P&L	Unhedged P&L	S&P Hedge P&L	Roll P&L
Short Trades: if VIX is > 21				
Mean	$976	$1,258	-$281	$623
P-value	.001	.002	.125	<.001
Semi Std. Dev	848	1,289	1,184	--
90% fractile	2,750	4,247	1,238	979
10% fractile	-522	-2,083	-1,744	253
Winners/Losers	34/9	32/11	18/25	--
SortinoRatio	1.15	.98	-.24	--
Short Trades: if VIX is <21				
Mean	$305	$326	-$22	$524
P-value	.002	.002	.447	<.001
Semi-Std. Dev	490	713	514	--
90% fractile	1,396	1,697	784	879
10% fractile	-814	-1,303	-898	214
Winners/Losers	25/17	26/16	15/27	--
Sortino Ratio	.62	.46	-.04	--
Long Trades: if VIX is >34				
Mean	$1,277	$1,360	-$83	$1,528
P-value	.001	.017	.436	<.001
Semi Std. Dev	1,883	2,390	1,720	--
90% fractile	6,965	7,257	2,103	4,086
10% fractile	-2,809	-2,443	-3,463	141
Winners/Losers	14/11	17/8	14/11	--
Sortino Ratio	.68	.57	-.05	__
Long Trades: if VIX is < 34				
Mean	$959	$1,222	-$263	$727
P-value	.007	.023	.250	<.001
Semi Std Dev	969	1,514	1,469	--
90% fractile	4,806	6,647	1,899	1,727
10% fractile	-1,742	-3,053	-2,411	37
Winners/Losers	17/7	14/10	12/12	--
Sortino Ratio	.99	.81	-.18	--

Table 6. The effect of risk management strategies on the profits from shorting one front VIX futures contract with at least ten days until settlement when the daily roll is greater than .10 VIX futures points. The risk management strategies cause trades to be exited when 1) the daily roll falls below .05 VIX futures points, 2) losses net of transaction costs on trades are greater than $500, or 3) the net gains on trades are greater than $500. Trades are closed after 5 business days if these exit rules are not triggered. The table shows the P&L on hedged and unhedged VIX futures positions and the P&L on the S&P futures hedge. The Roll P&L accumulates the profits on the daily roll, calculated each day as the difference between the front VIX futures contract and the VIX, divided by the number of business days until settlement. Transaction costs for both entering and exiting positions are included for each of the P&L categories and assume that quoted bid-ask spreads are paid on VIX futures contracts and that bid-ask spreads equal to one half of the minimum 1/4 point tick are paid on mini-S&P futures contracts. $3 round trip brokerage fees per contract are assumed. Trades are entered and exited at the close and are held for 5 business days. The sample period is from January 2007 through December 2011.

Short Trades if Daily Roll > .10 VIX futures points

	Hedged P&L	Unhedged P&L	S&P Hedge P&L	Roll P&L
Exit if daily roll < .05 or in 5 days				
Mean	$594	$718	-$124	$536
P-value	<.001	.004	.209	<.001
Semi Std Dev	548	880	908	--
90% fractile	2,120	3,147	1,174	876
10% fractile	-814	-1,743	-1,496	144
Winners/Losers	55/29	56/28	37/47	--
Avg. Days in Trades	4.3	--	--	--
Sortino Ratio	1.08	.82	-.14	--
Exit if net loss > $500 or in 5 days				
Mean	$489	$518	-$29	$481
P-value	.004	.021	.400	<.001
Semi Std Dev	650	1,080	806	--
90% fractile	2,136	3,072	1,235	872
10% fractile	-1,030	-1,941	-1,522	81
Winners/Losers	53/37	54/36	53/37	--
Avg. Days in Trades	4.2	--	--	--
Sortino Ratio	.75	.48	-.04	--
Exit if net gain > $500 or in 5 days				
Mean	$307	$223	$84	$322
P-value	.008	.101	.277	<.001
Semi Std Dev	701	1,097	653	--
90% fractile	1,191	1,647	1,570	700
10% fractile	-1,087	-1,903	-1,002	61
Winners/Losers	86/30	81/35	50/66	--
Avg. Days in Trades	3.1	--	--	--
Sortino Ratio	.44	.20	.13	--

Table 7. The effect of risk management strategies on the profits from buying one front VIX futures contract with at least ten days until settlement when the daily roll is less than -.10 VIX futures points. The risk management strategies cause trades to be exited when 1) the daily roll rises above -.05 VIX futures points, 2) losses net of transaction costs on trades are greater than $500, or 3) net gains on trades are greater than $500. Trades are closed after 5 business days if exit rules are not triggered. The table shows the P&L on hedged and unhedged VIX futures positions and the P&L on the S&P futures hedge. The Roll P&L accumulates the profits on the daily roll, calculated each day as the difference between the front VIX futures contract and the VIX, divided by the number of business days until settlement. Transaction costs for both entering and exiting positions are included for each of the P&L categories and assume that quoted bid-ask spreads are paid on VIX futures contracts and that bid-ask spreads equal to one half of the minimum 1/4 point tick are paid on mini-S&P futures contracts. $3 round trip brokerage fees per contract are assumed. Trades are entered and exited at the close and are held for 5 business days. The sample period is from January 2007 through December 2011.

Long Trades if Daily Roll < -.10 VIX futures points

	Hedged P&L	Unhedged P&L	S&P Hedge P&L	Roll P&L
Exit if daily roll > -.05 or in 5 days				
Mean	$808	$1,030	-$223	$978
P-value	<.001	.001	.203	<.001
Semi Std. Dev	1,164	1,901	2,445	--
90% fractile	4,449	8,532	3,151	2,664
10% fractile	-1,716	-4,103	-4,458	61
Winners/Losers	25/22	25/22	27/20	--
Avg. Days in Trades	3.4	--	--	--
Sortino Ratio	.69	.54	-.09	--
Exit if net loss > $500 or in 5 days				
Mean	$531	$878	-$348	$836
P-value	.003	.002	.523	<.001
Semi Std. Dev	1,311	1,520	2,338	--
90% fractile	4,373	7,097	1,671	2,256
10% fractile	-2,223	-2,823	-3,534	60
Winners/Losers	23/31	18/36	29/25	--
Avg. Days in Trades	3.2	--	--	--
Sortino Ratio	.41	.58	-.15	--
Exit if net gain > $500 or in 5 days				
Mean	$777	$634	$142	$467
P-value	< .001	.008	.149	<.001
Semi Std. Dev	1,655	2,587	1,227	--
90% fractile	3,883	5,117	2,277	1,159
10% fractile	-3,050	-3,273	-2,313	61
Winners/Losers	54/12	44/22	35/31	--
Avg. Days in Trades	2.6	--	--	--
Sortino Ratio	.47	.25	.12	--

Figure 1. The VIX and the daily roll from 2007 through 2011, where the daily roll is the difference between the price of the front VIX futures contract that has at least 10 days to settlement and the VIX, scaled by the number of business days until settlement .

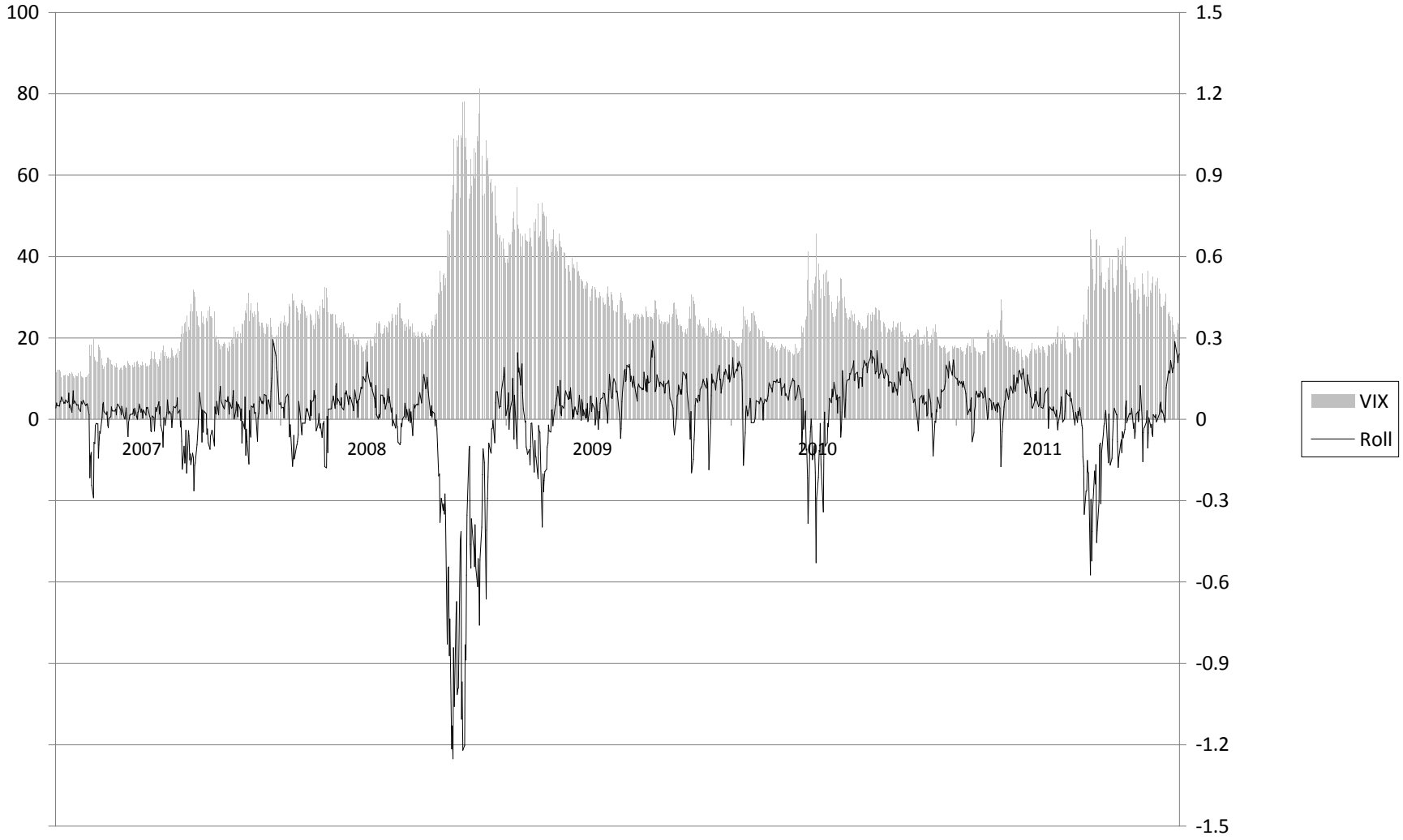

Figure 2. The P&L after transactions costs on short and long VIX futures trades (1 contract) hedged by mini-S&P futures contracts when the daily roll is greater than .10 VIX futures point or less than -.10 VIX futures point, where the daily roll is the difference between the price of the front VIX futures contract that has at least 10 days to settlement and the VIX, scaled by the number of business days until settlement.

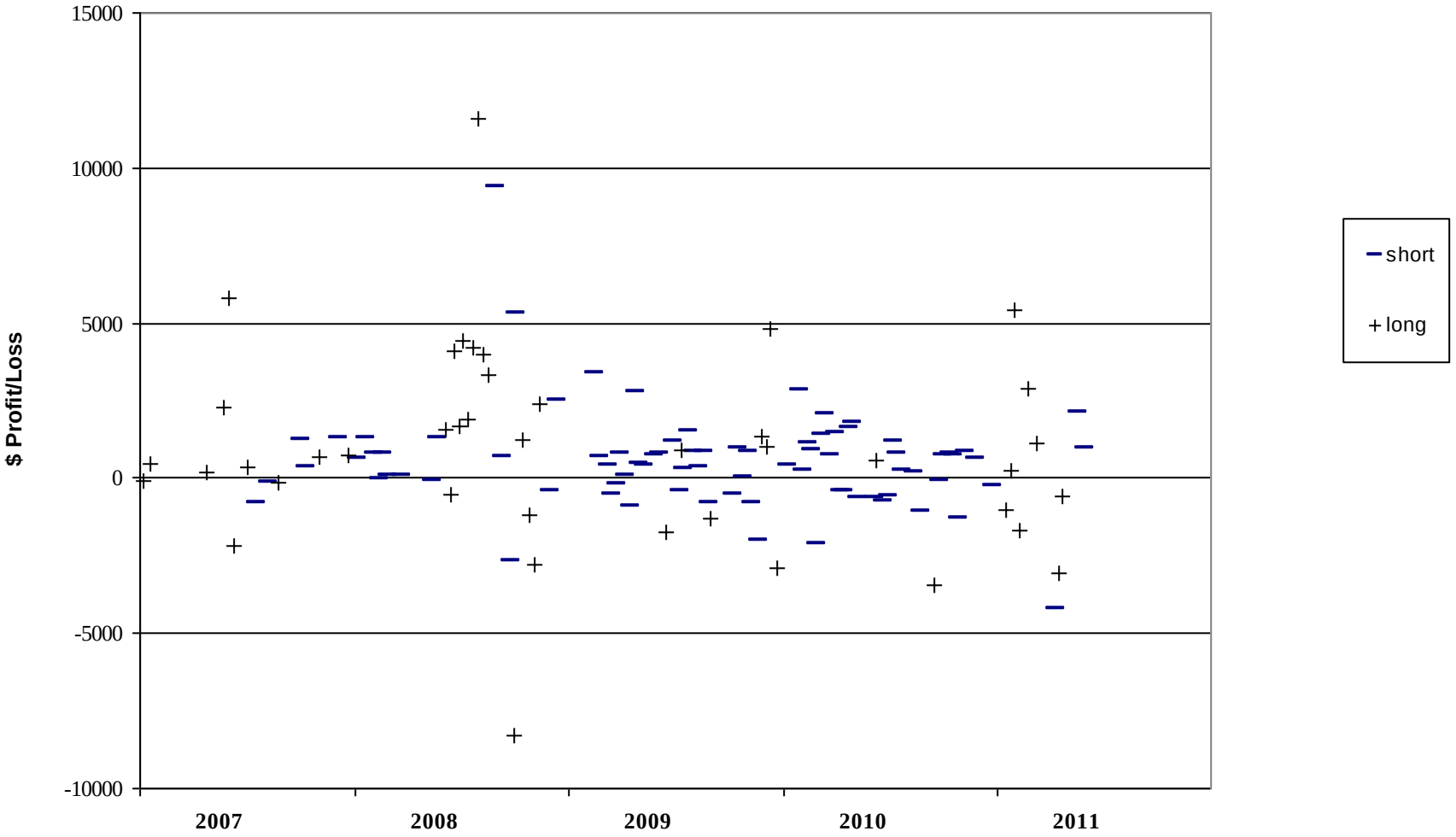

Figure 3. The cumulative P&L after transactions costs on short and long VIX futures trades (1 contract) hedged by mini-S&P futures contracts when the daily roll is greater than .10 VIX futures point or less than -.10 VIX futures point, where the daily roll is the difference between the price of the front VIX futures contract that has at least 10 days to settlement and the VIX, scaled by the number of business days until settlement.