An Examination of Long-Term Bond iShare Option Selling Strategies

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Abstract

This paper examines volatility trades in Lehman Brothers 20+ Year US Treasury Index iShare (TLT) options from July 2003 through May 2007. The results indicate that implied volatility is persistently above actual volatility and that unconditionally selling front contract strangles and straddles and holding for one month is highly profitable after transactions costs. The paper also demonstrates that the profitability of short-term strategies is enhanced when strangles and straddles are sold when implied volatility is high relative to out of sample time series volatility forecasts. Profitability owes both to winning trades outpacing losing trades by 2:1 margins and to profits of winning trades exceeding losses of losing trades, despite the limited return and unlimited risk profiles of short option strategies. A decomposition of the results indicates that most of the profitability can be attributed to theta gains outpacing gamma losses. Risk management strategies such as stop loss strategies detract from the profitability of short term option selling strategies, while take profit orders have only modest favorable effects on the results. Overall, the results demonstrate that TLT option selling strategies offered attractive risk-return tradeoffs over the sample period.

An Examination of Long-Term Bond iShare Option Selling Trades

Very few studies in recent years have examined the attractiveness of long-term US government bond option selling strategies. Goodman and Ho (1997) find that selling over the counter 3-month options on 10-year US Treasury notes was profitable from 1991 to 1996, owing to implied volatility being higher than actual volatility. However, Bertonazzi and Maloney (2001) find that the implied volatility of US Treasury Bond futures options was an unbiased predictor of subsequent volatility over the period from 1993 to 1999, which suggests that short option strategies would not have been profitable over a somewhat different sample period. Other studies such as Vahamaa, Watzka and Aijo (2005) focus on the effect of macroeconomic announcements on the implied volatility and the implied skewness of Treasury bond futures options, but do not examine trading strategies or the relationship between implied volatility and subsequent actual volatility.[1]

This paper provides evidence on the profitability of option selling strategies in Lehman Brothers 20+ Year US Treasury Index iShares (ticker symbol TLT). This exchange traded fund was introduced by Barclays Global Investors in July 2002 and TLT options were introduced about a year later. This paper examines both unconditional option selling strategies as well as conditional option selling strategies where entries are driven by divergences between implied volatility and volatility forecasts. This study also focuses on the effect of delta hedging and exit rules on risk-return tradeoffs.

The key results are that selling front month strangles and straddles every month and delta hedging until expiration offers attractive risk reward tradeoffs over the sample period from July

[1] By contrast, several studies have demonstrated the attractiveness of equity index option selling strategies, including Coval and Shumway (2001), Bakshi and Kapedia (2003) and Bollen and Whaley (2004).

2003 through May 2007. Simulations also indicate that the performances of short-term strangle and straddle selling strategies is enhanced when TLT implied volatilities are high relative to out of sample time series forecasts of near-term volatility. In addition, the performance of these strategies is weakened by stop loss orders, but is modestly improved by take profit orders.

The paper proceeds as follows: The first section provides background information on TLT options. The second section demonstrates the relative importance of the greeks in determining daily returns on delta-hedged, short option positions. The third section examines the profitability of unconditional strangle and straddle selling strategies where trades are held for one month. The fourth section examines the impact of entry and exit rules on short-term option selling strategies where entries are triggered by differences between implied volatilities and out of sample time series volatility forecasts and trades are exited in either five business days or earlier if stop loss or take profit orders are triggered. The final section summarizes the findings.

I. Background on TLT Options

Since the introduction of options on the Lehman Brothers 20+ Year US Treasury Index iShares (ticker symbol--TLT) in June 2003, TLT options have become the most actively traded options on fixed income exchange traded funds. TLT iShares are structured so that investors receive monthly dividends from the coupons paid on the bonds held by the fund. Because these payouts are substantial and because TLT options are American options, accounting for the effect of dividends on TLT option prices is important. This paper uses a 200-step Cox, Ross and Rubenstein (CRR) binomial model that allows for early exercise to calculate implied volatility and the greeks. The underlying TLT stock price is adjusted for the impact of dividends by subtracting the present value of actual future dividends through expiration. Because evidence indicates that TLT return volatility scales with business days rather than with calendar days, the CRR binomial model is modified as suggested by French (1984) with time expressed in business days when it is multiplied by volatility and time expressed in calendar days when it is multiplied by interest rates.[2] The greeks are calculated based on the usual derivatives of the modified binomial model.

The option data come from ivolatility.com and are comprised of bid and ask closing option quotes. Quoted closing bid-ask spreads are typically 10-15 cents for TLT options trading below \$3 and 15-20 cents for TLT options trading at or above \$3. Observations are omitted from the data set if put-call parity boundary conditions for American options are violated.[3] These two boundary conditions are

$$C_{BID} - P_{ASK} > S - D - X \tag{1}$$

$$C_{ASK} - P_{BID} < S - Xe^{-rt} , \tag{2}$$

where C and P are closing call and put option quotes taken at either the bid or the ask, S is the closing TLT price, D is the present value of actual dividends, X is the strike price and r is the interpolated Treasury bill rate for the relevant horizon. In addition, option quotes are omitted when option prices are less than their intrinsic values.

[2] This specification is supported by the finding that during the sample period the Friday close to Monday close annualized standard deviation of TLT returns is 6.2 percent, whereas the standard deviation of close to close TLT returns on consecutive days during the business week is actually higher at 7.7 percent. The finding that volatility is on average lower over the three days from the Friday to Monday close likely reflects the tendency for Monday to be a light day for economic announcements.

[3] See Hull (2005) for the intuition concerning these boundary conditions.

The actual volatility of TLT returns is calculated using intraday squared TLT log returns. This approach was developed by Anderson, Bollerslev, Diebold and Labys (2003), who show that aggregating frequently sampled intraday volatility results in realized volatility measures that are far more efficient than traditional estimators. In addition, realized volatility is an observed rather than a latent variable and standard time series techniques can be used to forecast realized volatility.

Realized volatility is constructed as follows: Thirty minute return intervals are chosen because they are frequent enough to provide efficient measures of volatility without being contaminated by microstructure effects.[4] These thirteen 30-minute squared returns during the trading day from 9:30 am to 4:00 pm EST are summed to form a measure of intraday volatility from the open to the close of regular trading hours, where R is the log difference of TLT prices over 30-minute intervals.

$$\sigma_t = \text{Realized trading hours} = \sqrt{\sum_{d=1}^{13} R_d^2}\,, \qquad (3)$$

Because the analysis of this paper requires a volatility measure that incorporates overnight volatility, the suggestion of Martens (2002) is followed and close to close measures of realized volatility are constructed by grossing up the realized volatility from the open to close of each trading day by the sample period ratios of the average daily close to close volatility to the average daily open to close volatility as shown below.

[4] Anderson et al. (2003) examine the tradeoff between the benefits of greater precision from more frequently sampled intraday intervals and the distortions from microstructure effects and find that 10 to 15 minute intervals are optimal for equities. In this paper, 30 minute intervals are preferable, as the volatility signature plots suggest that realized volatilities from shorter intervals are unrealistically high and affected by microstructure effects.

$$\sigma_{t \text{ Realized close-to-close}} = \sigma_{t \text{ Realized trading hours}} * \frac{\sigma_{avg-daily-close-to-close}}{\sigma_{\text{avg-daily-open-to-close}}} \quad (4)$$

The annualized daily volatility of open to close returns over the sample period is .0585 and the annualized daily volatility of close to close returns is .0765, resulting in a scaling factor of 1.31. This scaling factor is fairly close to the 1.2 scaling factor calculated by Martens (2002) for the S&P 500 futures contract.

A later section of this paper examines trades that are triggered by divergences between the implied volatility of TLT options and out of sample time series forecasts of actual volatility. This paper constructs an index that is referred to as the TLT Volatility Index to capture the implied volatility of near-term, at the money TLT options. The methodology for calculating the TLT Volatility Index is similar to that of the S&P Volatility Index or VIX prior to its revision in 2004. The TLT Volatility Index is constructed from the implied volatilities of the two closest to the money calls and the two closest to the money puts of the two front month contracts. These eight implied volatilities are interpolated so that the TLT Volatility Index reflects the average implied volatility on a business day basis of at the money options that are 22 business days from expiration.

Figure 1 shows the history of TLT prices over the sample period from July 2003 through May 2007. The figure shows that TLT prices fell a few percent on balance over the sample period from a starting share price of around $90 and traded as high as $96 and as low as $81 over the sample period. These TLT price changes correspond to a 120 basis point trading range of 30-year Treasury bond rates over the sample period.

Table 1 shows the implied volatilities, the TLT Volatility Index and the annualized realized volatility of TLT returns over the sample period. The implied volatilities are calculated for TLT options that are between 2 and 9 weeks to expiration, are not more than 3 strikes (or about 3 to 4 percent) in or out of the money and pass the previously mentioned screens for possible data errors. The table also shows the implied volatilities separately for calls and puts by year and by moneyness. The moneyness categories are the two closest strikes to the money (ATM), more than one strike in the money (ITM) and more than one strike out of the money (OTM). To make realized and implied volatilities comparable, all implied volatilities included in the averages shown in the table have corresponding realized volatilities for the same day that are also reflected in the average of realized volatilities.

Consistent with other studies, such as Bollen and Whaley (2004), the implied volatility of TLT options tends to be higher than realized volatility and exceeds realized volatility by an average of about 2-1/2 to 3 percentage points over the sample period. Implied volatility is at its highest in 2003 when it averages abound 14 percent and falls over the next few years to an average of about 8-1/2 percent in 2007. This aspect of the sample period favors option selling strategies. The table also shows that volatility skewness is present in TLT implied volatilities, as lower strike options--both out of the money puts and in the money calls--have substantially higher implied volatilities than at the money options. However, in contrast to the typical pattern in equity index options, where implied volatility declines at higher strikes across the entire strike spectrum, the implied volatility of TLT options shows a mixed pattern from at the money to higher strikes. As a result, the implied volatility curve is characterized by a crooked smile rather than by a smirk, with rising implied volatilities moving from at the money strikes to lower strikes.[5] Finally, the table also shows that the TLT Volatility Index closely mirrors the calculated at the money implied volatilities.

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[5] The tendency for TLT option implied volatility not to fall at higher strikes as in equity options may reflect the possibility that volatility also rises as bond prices rise owing to flights to the safety of US government bonds during

II. Daily Returns of Delta-hedged Short Option Positions

This section provides preliminary evidence on the daily profitability of delta-hedged short call and short put positions. Short call positions are delta-hedged by buying delta-equivalent amounts of TLT shares, while short put positions are delta-hedged by shorting delta-equivalent amounts of TLT shares. Short option positions benefit from a drop in implied volatility and from an absence of large TLT price changes in either direction, as such changes cause delta to move unfavorably for option sellers owing to gamma.[6] On the other hand, delta-hedged short option positions benefit when implied volatility falls and from time decay, which causes option prices to converge to their intrinsic value. Thus, traders with delta-hedged short option positions are short both actual volatility (gamma) and implied volatility (vega) and are long time decay (theta). To get a sense of how these tradeoffs affect the profitability of delta-hedged short option positions, the effects on profitability from gamma, theta and vega are reported as follows:

$$\text{Gamma Effect} = \tfrac{1}{2} * \text{Gamma} * \Delta(\text{TLT})^2 \qquad (5)$$

$$\text{Theta Effect} = \Delta\text{Business Day} * \text{Theta} \qquad (6)$$

$$\text{Vega Effect} = \Delta\text{IV} * \text{Vega} \qquad (7)$$

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tumultuous periods in world financial markets. Evidence presented later suggests that conditional volatility asymmetries are absent over the sample period.

[6] Gamma is the second derivative of the call or put option price with respect to changes in the underlying instrument or the first derivative of delta. Gamma reflects the tendency of call and put deltas to rise in absolute value as their moneyness increases and to fall in absolute value as their moneyness decreases. Gamma favors option buyers because directional exposure increases when the directional bet is right and decreases when the directional bet is wrong. Gamma is unfavorable to option sellers for the same reason.

For option sellers, the gamma effect is either neutral or unfavorable, whereas the theta effect is always favorable. The vega effect can be either favorable or unfavorable depending on whether the implied volatility change (ΔIV) is negative or positive, respectively.

Option positions are assumed to be held for one day with positions entered and exited at the mid-point of the closing bid-ask spread, while the delta-hedging long or short TLT equity positions are entered and exited at the closing quote. This preliminary analysis abstracts from transactions costs and is performed for TLT options that are 2 to 9 weeks until expiration, are not more than three strikes in or out of the money and pass the screens for bad quotes described in the previous section. To determine whether TLT options of different maturities and moneyness are more or less profitable to short, the analysis is performed across maturity and moneyness categories. The maturity categories are for options that are 2 to 5 weeks to expiration and 6 to 9 weeks until expiration. The moneyness categories are the two closest strikes to the money (ATM), more than one strike in the money (ITM) and more than one strike out of the money (OTM).

The daily profits of delta-hedged short call and short put positions are shown in tables 2 and 3, respectively. The tables show for each option category the number of observations, the average daily profit in cents, average profits scaled by option selling prices, the number of winners and losers, the average size of winning and losing trades, the cutoffs for the top and bottom deciles of returns and gamma, theta and vega profits.

The results indicate that unconditional option selling strategies typically are significantly profitable at better than the 1 percent level. Daily profits for call options for all moneyness categories together are a highly statistically significant 1 to 1-1/3 cent per option or roughly 1 percent of the value of the call options when they are sold. The results also indicate that the frequency of winning trades outpaces that of losing trades and that average profits of winning days exceed average losses of losing days. In addition, the cutoffs for the top and bottom decile returns are a gain of 8 to 9 cents and a loss of 6 to 7 cents, respectively. Thus, the distribution of returns is fairly symmetric, despite the unlimited potential losses and the limited potential returns of call option selling strategies The average profits can be explained largely by the average 2-1/2 cent gain from time decay more than countering the average 1-1/2 cent loss from gamma, as vega has a much smaller average impact on profits.[7] The table also shows that shorter-dated calls are more profitable to sell than longer-dated calls and selling in the money calls is substantially more profitable than selling out of the money calls. This finding is consistent with the higher implied volatilities of in the money calls relative to out of the money calls, which is reflected by higher profits from time decay relative to losses from gamma.

The results for put option trades in table 3 indicate that selling puts on a delta-hedged basis is generally highly statistically significantly profitable but less profitable than selling calls. Average daily profits across all maturities examined average 1/3 to 5/8 cent and again selling short-dated puts is more profitable than selling long-dated puts. The lower profitability stems from less favorable ratios of winning to losing trades and from less favorable ratios of profits on winning trades to losses on losing trades. Decomposing the sources of profits, daily theta gains about match daily gamma losses, whereas vega explains much of the profit, contributing about 3/8 cent per day. The results also show that despite the generally lower implied volatilities of in the money puts relative to out of the money puts, selling in the money puts is substantially more profitable than selling out of the money puts.

[7] This does not imply that vega has only a minor effect on the profitability of these trades as, unlike the effect of gamma and theta, vega can work in both directions and has a large effect on the swings in profitability not withstanding its small average impact.

Overall, the results suggest that in the absence of transactions costs, selling options and delta-hedging generally is profitable on a daily basis as the benefits of time decay outweigh the losses from being short both actual and implied volatility. The results also show that most of the P&L effect comes from the tradeoff between theta and gamma, whereas the impact of vega tends to be smaller on average in most cases. The findings also suggest that shorter-dated options are better instruments to sell than longer-dated options. However, these results have not considered transactions costs. The next section of the paper examines the profitability of selling straddles and strangles with transaction costs included.

III. Unconditional Strangle and Straddle Selling Strategies

This section examines the profitability of unconditionally selling strangles and straddles. Short strangle trades consist of delta-equivalent short positions in roughly equally out of the money calls and puts with the same expiration months. Short straddle trades consist of delta-equivalent short positions in the closest to the money calls and puts with the same strike price and expiration month. The bets behind these trades are that implied volatility falls and the benefit of time decay more than offsets the potential costs associated with implied volatility rising or the delta moving against these trades in the event of sizeable TLT price changes, owing to negative gamma.[8] The main difference between short strangle and short straddle trades is that the negative gammas of short strangles are greater than those of short straddles because out of

[8] For example, large TLT price increases cause deltas of short call positions to become larger negative numbers (which is unfavorable), while deltas of short put positions become larger positive numbers (which is favorable). However, because the moneyness of calls is increasing and the moneyness of puts is decreasing, deltas of calls change by more than the deltas of puts and the losses on short call positions tend to be greater than the gains on short put positions. The results are similar for large TLT price declines.

the money options have higher gammas than at the money options.[9] However, the benefits from the faster time decay of short straddles is countered by the potential costs stemming from greater negative gammas.

The simulations examine the profitability of selling straddles and strangles on a delta-neutral basis at the outset. The simulations are conducted separately for options that have roughly four weeks until expiration (the front contract) and roughly eight weeks until expiration (the second contract). Options both one and two strikes out of the money are chosen for strangles, whereas straddles are formed with options having the closest to the money strikes. Trades are entered each month on expiration day and are exited on the next expiration date. Thus, front contract straddles and strangles are held until expiration, whereas second contract strangles and straddles are held over the same period of time for the sake of comparison. The simulations assume that traders sell $10,000 of calls and a roughly similar value of puts that makes trades initially delta neutral.[10] The reported dollar gains and losses per trade can be translated loosely into returns on roughly $150,000 accounts, as shorting $20,000 of straddles and strangles is possible from the standpoint of margin requirements for $150,000 accounts.[11]

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[9] The simulations assume that the same dollar value of strangles and straddles are sold so that more options are sold with strangles than with straddles. While the options sold in strangles are further out of harm's way, the greater number of options sold increases the risk of strangles relative to straddles for very large moves in the price of the underlying instrument. For extreme TLT prices increases, the deltas of calls rise to 1 and the deltas of puts fall to zero leaving the strangle or straddle seller short deltas equal to the number of calls sold and likewise for extreme TLT price decreases, the deltas of puts go to -1 and the deltas of calls go to zero leaving the strangle or straddle seller long deltas equal to the number of puts sold.

[10] Because out of the money puts typically have higher implied volatilities than out of the money calls as shown in table 1, the absolute deltas of OTM puts tend to be greater than the deltas of OTM calls, which causes the number of calls sold to be greater than the number of puts sold. Also, overall deltas may be slightly different than zero at the outset because of the assumption that round numbers of options are sold.

[11] For short straddle positions, initial and maintenance margin requirements are equal to the greater of the short put or short call requirements, plus the proceeds received on the other side. Short uncovered index calls and puts have initial and maintenance requirements equal to the proceeds received plus the greater of 15% of the underlying index less the amount out of the money, or 10% of the underlying index. For example, if the TLTs are trading at $90 and traders sell 100 at the money calls and puts each for $1, the proceeds are $20,000 and the margin requirement is $155,000 (fifteen percent of $90,000 plus the $20,000 proceeds of selling the calls and the puts). At these assumed option prices, traders would sell 100 calls and 100 puts to short $20,000 of straddles and only somewhat more strangles. Thus, traders with equity of around $135,000 (before receiving the proceeds of their option sales) would

Each round of simulations is run both with delta-hedging using the underlying TLT shares and without delta-hedging. With short option positions, delta-hedging locks in losses from gamma because deltas become negative after TLT price increases which causes TLT shares to be bought at higher prices, and deltas become positive after TLT price decreases which causes TLT shares to be sold at lower prices. Thus, delta-hedging should reduce the profitability of short straddles and strangles if the underlying TLT share price is range bound because delta-hedging results in frequently buying TLT shares at the high end of the range and selling TLT shares at the low end of the range. On the other hand, delta-hedging should enhance profitability if TLT share prices move in a sustained manner in either direction and should reduce the volatility of returns by removing the directional bets on TLT prices that emerge from short option positions in the absence of adjusting deltas. Because traders typically do not adjust positions in response to minor delta changes, the simulations assume that deltas are rebalanced with TLT shares at the close of each trading day only when not doing so would cause the absolute values of deltas of options plus existing TLT share hedging positions to be greater 500. Thus, only transactions that involve buying or selling at least 500 TLT shares are executed. Finally, proceeds of option sales plus proceeds from shorting TLT shares or minus funds used to buy TLT shares are assumed to be invested at the 3-month Treasury bill rate.[12]

The trading simulations are performed with transactions costs included. Transaction costs from brokerage fees are assumed to be $1 per option contract and $5 per equity trade each way, consistent with commissions charged by discount brokers. The simulations assume that

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be able to sell only about $20,000 of options. However, this figure varies widely over the sample for different trades as traders selling 50 at the money calls and puts for $2 each with the TLTs trading at $90 would need only $70,000 of margin in their account before the trade. In an interview in Derivatives Strategy (2000), Max Ansbacher, who runs a highly successful CTA firm devotedly exclusively to selling S&P futures options states that his fund limits leverage to no more than $1 of options sold per $4 of account equity.

[12] These trades often generate cash outflows rather than inflows because the proceeds from shorting $20,000 of options are less than the funds needed to buy TLT shares when TLT share prices rise and deltas become negative. In this case, the assumption is that traders would liquidate Treasury bill holdings to fund the purchase of TLT shares.

TLT share trades occur at the closing price plus 1 cent (minus 1 cent) in the case of purchases (sales), as TLT bid-ask spreads typically are no more than 2 cents. The simulations also assume that option transactions occur at the mid-point of the bid-ask spread. This is because while quoted bid-ask spreads typically are 10 to 15 cents for TLT options trading for less than $3 and a bit wider for TLT options trading for greater than $3, trading frequently occurs well within the bid-ask spread.[13] In any event, implementing the strategies examined in this paper by buying at the offer and selling at the bid frequently leads to substantial losses.[14]

The first round of simulations examines short strangle and straddle trades in the front month contracts. These trades are entered on the day that the previous contract expires and are held until expiration. The results in table 4 show mean profits and corresponding p-values, Sharpe ratios, the number of winning and losing trades, the average profits and losses of winning and losing trades, the top and bottom 10% profit cutoffs, the profits and losses owing to the greeks and transactions costs.[15] The profits and losses attributed to the greeks are calculated each day with updated greeks and are accumulated for the duration of trades.

The results demonstrate that all of the strategies are highly significantly profitable. For strategies with delta-hedging, profits average between $2,300 and $4,600 per $20,000 of options sold with Sharpe ratios of around .7. Profits owe to a roughly 3:1 ratio of winning to losing

[13] Also, bid-ask spread costs for short straddles could be reduced substantially by synthetically creating short straddles. These positions would be executed by placing limit orders to sell $20,000 of both calls and puts at prices between the bid and the ask. When one of the trades is executed, the other is cancelled. If calls have been sold, $10,000 of TLT shares are bought, which turns $10,000 of the calls sold or half of the calls sold into covered calls or synthetic short puts. If puts are sold, $10,000 of TLT shares are shorted, which turns $10,000 of the puts or half of the puts sold into covered puts or synthetic short calls.

[14] Other studies deal with transactions costs in a variety of ways. Bakshi and Kapadia (2003) do not consider transactions costs in their study of S&P 500 options. Coval and Shumway (2001) assume that S&P 500 options are sold at the bid side of the market but are held until expiration and thus the cost associated with the bid-ask spread is incurred only upon entry. By contrast, when Bollen and Whaley (2004) consider bid-ask spreads, they assume that options are sold at the ask because they are examining the trades of market makers. None of these papers incorporates commissions.

[15] The Sharpe ratios are included in the tables, but should be interpreted with care and in light of the other information provided because some of the trading strategies result in non-normal return distributions.

trades and to profits on winning trades exceeding losses on losing trades by roughly a 2:1 margin. Despite the limited return and unlimited risk profile of short strangle and straddle trades, the top and bottom 10 percent profit cutoffs reflect two to four times larger extreme profits than extreme losses with the bottom decile hovering around a loss of around $3,000. A decomposition of profits show that they owe primarily to theta profits outpacing gamma losses, whereas vega has a much smaller effect and delta has a negligible impact as expected, as it is hedged.[16]

The table also shows that refraining from delta-hedging about doubles average profits. The increased profitability stems largely from profits on unhedged delta exposures and to a lesser extent from foregoing the transactions costs incurred in delta-hedging. The profits from delta exposure owe to the choppiness of TLT prices, as higher (lower) TLT prices cause deltas to become negative (positive), which tends to be followed by subsequent TLT price decreases (increases). However, the greater average profits without delta-hedging come at the cost of much greater profit variability. This is evidenced by lower Sharpe ratios and by the fact that the average sizes of losing trades balloon from about $2,000 to $3,000 with delta-hedging to $8,000 to $21,000 without delta-hedging. Likewise, the cutoff for the lowest decile of profits increases from $1,500 to $3,500 with delta-hedging to $13,000 to $15,000 without delta-hedging. Thus, the reward to risk ratios for delta-hedged trading strategies are far superior to non delta-hedged strategies over the sample period. Comparing the various strategies with delta hedging, the

[16] Vega has little impact relative to gamma because the vega of options near to expiration is small and because implied volatility does not change in a sustained way often enough for vega to have a large impact on profits. Thus, one could look at the implied volatility of TLT options as providing information about how expensive options are priced in terms of how much TLT prices have to change for the non-linearity of option prices to offset time decay. In addition, the table shows that the greeks explain most of returns, which suggests that the effects of cross-derivatives and second derivatives other than gamma are fairly small.

results suggest that selling strangles with strikes further away from the money is preferable to selling closer strangles or selling straddles.

Table 5 provides the results from selling strangles and straddles in the second contract to expiration. For the sake of comparability with the results from selling the front contract, these trades are entered and exited on the same days as the front contract--trades are entered on the day that the contract that expires two months earlier expires and are exited when the contract that expires one month earlier expires. The results demonstrate a substantial drop in profitability as none of the strategies with delta-hedging is significantly profitable. The sharp drop off in profitability stems not so much from a reduction in the percentage of winning trades, which is about 2:1, but more from increases in average losses on losing trades relative to average profits on winning trades. From the standpoint of the greeks, theta profits are greater than gamma losses only by an amount equal to transactions costs, and vega has little overall effect on profits.

By contrast, the results also show that selling strangles and straddles in the second contract to expiration generally remains significantly profitable in the absence of delta-hedging. For these strategies, profitability owes to a more favorable ratio of winning to losing trades because the average profit on winning trades is about equal to only slightly higher than the average loss on losing trades. The enhanced results in the absence of delta-hedging owe primarily to the profits from unhedged deltas and to a lesser extent from economizing on transactions costs, as the absence of delta-hedging does not alter profits from the other greeks. Again, owing to the choppy nature of swings in TLT prices over the sample period, not adjusting delta adds to profits. It is also interesting to note that even with the larger vegas for second contracts to expiration owing to their longer times to expiration, vega continues to play a minor role in the average profitability of short option strategies. Finally, the magnitude of large losses as reflected by the bottom decile cutoff for profits does not increase much in the absence of delta-hedging and is around $3,500. Nevertheless, the average magnitude of losses is a fairly substantial $5,000 to $7,000 and by not delta-hedging, option sellers are exposed to a higher risk of large losses from originally non-directional bets becoming directional bets, even if such large losses do not occur within the sample period.

Overall, the results indicate that selling front contract straddles and strangles on an unconditional basis and delta-hedging and holding to expiration offered attractive opportunities over the sample period. The next section examines shorter term conditional strangle and straddle selling strategies in the front contract.

IV. Conditional Strangle and Straddle Selling Strategies

This section examines the effect of entry and exit rules on the profitability of short term strangle and straddle selling strategies. These trades are more realistic than those in the previous section because they are entered only when options appear to be overpriced. Entry rules are based on the difference between a general measure of TLT option implied volatility--the TLT Volatility Index--and out of sample forecasts of realized volatility over the next 5 days. The reason for using the TLT Volatility Index rather than the implied volatilities of the specific options that are sold as a trigger for entering trades is that the former is more robust.[17] Out of sample volatility forecasts are constructed from models of the realized volatility of TLT log returns. Models are estimated first from the pre-sample period from July 2002 through May 2003. Parameter estimates from these models are used to construct out of sample volatility

[17] More specifically, using a broader index of implied volatility reduces the possibility that options are sold when their implied volatility is high because option prices are misquoted at prices that are too high. As was the case in the previous section, options not passing screens for bad quotes are not used in the simulations that follow.

forecasts for the period from June 2003 through June 2004. Models are re-estimated with an additional year of data and the parameter estimates are used to form out of sample volatility forecasts for each subsequent year.

A variety of parsimonious specifications were estimated for the volatility process and the chosen specification incorporates mean reversion in volatility and allows for asymmetric responses of subsequent volatility to positive and negative TLT returns. The forecasting equations are specified as

$$\sigma_{t+1} = \alpha_1 + \alpha_2 T + \alpha_3\sigma_t + \alpha_3\sigma_{t-1} + \alpha_4\sigma_{t-2} + \alpha_5 \log(TLT_t/TLT_{t-1})^{POS} + \alpha_6(\log(TLT_t/TLT_{t-1})^{NEG} + \varepsilon_{t+1}, \quad (8)$$

where realized volatility for day t+1 is regressed on a constant, up to three own lags depending on the significance of the extra lags and whether they are required to flatten the autocorrelations in each sub-period, and separate variables for positive and negative lagged TLT log returns. The specification allows realized volatility to revert toward its mean, consistent with preliminary analyses (not shown) that strongly indicate that the realized volatility of TLT returns is stationary in levels. The specification does not constrain the reaction of actual volatility to be the same following negative and positive returns of equal magnitude. If larger positive and negative TLT returns give rise to higher subsequent volatility, the coefficients on these terms should be significantly positive and negative, respectively.

The models shown in Table 6 are estimated for the pre-sample period and then are re-estimated with another year of data through the end of the sample period. The table shows heteroscedasticity-consistent standard errors in parentheses, and statistical significance at the 1 and 5 percent levels is denoted by one and two asterisks, respectively. The results show that actual volatility is strongly mean reverting and that volatility shocks dissipate very quickly. This suggests that both out of sample time series forecasts of volatility for the subsequent five days does not stray far from their unconditional means and that much of the divergence between implied volatility and time series forecasts of volatility owes to variation in implied volatility.[18] The estimates also indicate that both large positive and negative TLT returns generally give rise to higher volatility with the exception of the pre-sample period where large negative TLT returns do not give rise to greater subsequent volatility. The results also indicate that large positive and negative TLT returns of equal magnitude give rise to similar volatility increases as one percent positive and negative returns are both associated with roughly one percent subsequent volatility increases.[19] An examination of the estimates across subperiods indicate that the models are stable across subperiods. Each set of parameter estimates are used to form recursive, out of sample average volatility forecasts for the next five business days for each year from June 2003 through May 2007.

As mentioned earlier, this section assesses the profitability of short term trades involving selling straddles and strangles when the TLT Volatility Index is high relative to average volatility forecasts. The strangles and straddles that are sold are the contracts closest to expiration that have at least 4 weeks until expiration. The first set of simulations examines the profitability of shorting $20,000 of strangles and straddles at the close of trading when the TLT Volatility Index exceeds out of sample forecasts of average volatility over the next 5 business days by at least 2 percentage points. In order to focus on the impact of entry rules, the first round of simulations

[18] Little persistence in volatility was also found for TLT returns when GARCH models were estimated on daily returns.
[19] The absence of conditional volatility asymmetries is consistent with Hunter and Simon (2005) and Capiello, Engle and Shephard (2006), who find little evidence of conditional volatility asymmetries in US and other major world bond markets. This statement is supported by Wald tests and also by casual inspection of the estimates and standard errors of the coefficient on lagged returns in table 6.

assume that positions are exited at the close 5 business days later.[20] The simulations are performed again with 3 strategies--strangles using both the closest and second closest out of the money calls and puts and then straddles constructed from the closest to the money calls and puts. The trades are examined both with and without delta-hedging with the same rules for delta-hedging and the same assumptions concerning transaction costs as in the previous section.

Table 7 shows that shorting strangles and straddles when implied volatility is high relative to volatility forecasts offers attractive risk reward tradeoffs. With delta-hedging, one week profits per $20,000 of options sold range from a statistically significant $500 to $1,200. Profitability can be attributed mostly to a roughly 2:1 ratio of winning to losing trades, as only a modest tendency exists for profits on winning trades to be greater than losses on losing trades. The results also indicate that large losses are manageable and do not exceed large gains, as the cutoff for the lowest decile of profits ranges across strategies at losses from $1,400 to $4,500, compared to the highest decile of profits, which ranges from $2,300 to $6,000. In terms of the greeks, time decay benefits offset gamma losses by $2,000 to $3,000, and vega now contributes importantly to profits. These results suggest that entering short option trades when implied volatility is elevated relative to volatility forecasts allows market participants to profit from enhanced time decay benefits that owe to higher implied volatility and from implied volatility falling toward the lower volatility forecasts. It is important to note that unreported results indicate that the same strategies with random entries are not significantly profitable.

The table also shows that the absence of delta-hedging enhances the average profitability of short term option selling strategies with average profits almost doubled and with somewhat higher Sharpe ratios. The enhanced profitability owes largely to profits on unhedged deltas,

[20] The results of the simulations can also be viewed as providing information about whether trades would be showing gains or losses after 5 days regardless of whether positions are exited.

reflecting a tendency for TLT prices to revert toward previous levels and to the short horizon of the trades, which reduces the likelihood of sustained large TLT price changes.[21] Consistent with this observation, the table also shows that the absence of delta-hedging does not lead to greater extreme losses as the cutoffs for the bottom decile of profits for delta-hedged and non-delta-hedged strategies are similar.

Overall, the results show that the case for delta-hedging for 5 business day horizons is far less compelling than for the one month horizons examined in the previous section where Sharpe ratios were substantially enhanced by delta-hedging. Nevertheless, during periods where TLT prices trend strongly, delta-hedging would play an important risk management role in limiting the frequency and severity of large losses. Another risk management strategy that could serve a similar purpose involves stop loss orders. Stop loss orders cause trades to be exited when losses exceed predetermined levels. Stop loss orders are triggered if the underlying instrument trades at the level of the stop loss price, at which point the stop loss order becomes a market order. The motivation for using stop loss orders is two-fold. The first is to impose discipline on traders and to prevent manageable losses from becoming catastrophic losses. Another underpinning for stop loss orders may be the conviction that a market that hits specific key levels is likely to continue in the same direction. In this case, stop loss orders can be viewed as momentum strategies.[22]

The next round of simulations examine the same entry rules as in table 7--the TLT volatility index exceeds out of sample time series forecasts of average volatility over the next 5 days by at least 2 percent--augmented by stop loss orders set at $2,000. A variety of stop loss

[21]Again, unhedged deltas generate profits if for example TLT prices increases lead to subsequent TLT price decreases because price increases cause deltas to go negative, which lead to delta profits if such increases are subsequently reversed. Note that the assumed original increase in TLT prices in this example gives rise to gamma losses as negative deltas are generated as losses on short call positions that are moving toward the money exceed gains on short put positions that are moving more out of the money.

[22] Traders also use stop orders to enter positions. For example, traders place orders to buy on stops above current market levels in order to be long when an instrument rises above key technical levels.

levels were examined and this level was chosen to be not so low that trades are frequently stopped out by ordinary volatility, but not so high that they are irrelevant. The stop loss orders cause trades to be exited at the close when losses exceed $2,000. If stop loss orders are not triggered, trades are exited when 5 business days have elapsed as in the previous simulations. After trades are exited, new trades are entered as soon as entry conditions are triggered.

The results in table 8 indicate that stop loss orders greatly reduce the profitability of short strangle and straddle trades over the sample period. For delta-hedged trades, average profits fall as do Sharpe ratios and none of the strategies is significantly profitable. While stop loss orders generally would be expected to increase the frequency but reduce the severity of losses, the results show the opposite--the frequency of losses is little changed, the average size of losing trades is generally higher and the bottom decile cutoff for profits shows substantially higher losses. The finding that the ratio of winning to losing trades is unchanged by stop loss orders suggests that stopped out trades generally would not have turned into winning trades, but would have resulted in smaller losses. A decomposition of profits from the greeks indicates that gamma losses are about the same as without stop loss orders, but theta profits are generally lower as trades as earlier exits from trades reduce time decay profits.

Without delta-hedging, the effects of stop loss orders are a bit less negative as two of the three strategies remain significantly profitable at conventional significance levels, although stop loss orders decrease average profits. Again, stop loss orders do not increase the frequency of losses but increase the magnitude of extreme losses, as reflected by the cutoff for the bottom decile of profits.

Because stop loss orders and delta-hedging attempt to limit risk, they could be substitutes for the short term trades examined here. However, delta-hedging focuses solely on eliminating the risk associated with deltas moving against option sellers, whereas stop loss orders limit exposure to all of the potential risks associated with selling strangles and straddles. The relative efficacies of these two risk management strategies can be examined by comparing the results of selling strangles and straddles with delta-hedging and exiting in 5 days (top panel of table 7) and the results of employing stop loss orders but not delta-hedging (bottom panel of table 8). A comparison indicates that over the sample period stop loss orders without delta hedging provided similar results to just delta hedging.

While the overall findings indicate that stop loss orders diminished trading results, it is possible that take profit orders might enhance the results of shorting strangles and straddles. The argument for take profit orders stems from the limited potential gains and unlimited potential losses in short strangle and straddle trades, as it would make little sense to maintain exposure to potentially unlimited losses after a meaningful portion of possible gains have been earned. The simulations examine take profit strategies that cause trades to be exited when profits are greater than $2,000 or 5 business days have elapsed. This level represents roughly half of the theta profits that are earned over 5 day periods, as shown in table 7 for 5 day holding periods, and is also symmetric with the level of stop loss orders.

The results shown in table 9 indicate that average profits and Sharpe ratios are generally about the same as with 5 day exits. However, with take profit orders the ratio of winning to losing trades rises to 3:1 from 2:1. More importantly, the number of trades increases by roughly 20 percent because profits are taken quickly, which boosts overall returns for some but not all of the strategies. It is also important to note that take profit orders generally do not lower the average profit on winning trades by much, although the cutoff for the top decile of profits falls.

The table also shows that these strategies with take profit rules modestly improve the results of non-delta hedged strategies. Average profits with take profit orders are about the same as those without take profit orders and again highly statistically significant and the ratio of winning to losing trades rises to 4:1. The number of trades also increases substantially, which results in greater returns over the sample period. The results also indicate that these strategies with take profit orders are more compelling without delta hedging than with delta hedging. This likely stems from the short term horizon of the strategies and from the tendency of TLT price movements to reverse over the sample period.

IV. Conclusions

This paper examines the profitability of TLT option selling strategies from July 2003 through May 2007. The results demonstrate that unconditionally selling strangles and straddles in the front contract about one month before expiration and holding through expiration results in attractive risk-adjusted returns, particularly when these positions are delta-hedged, as average profits after transactions costs are a highly statistically significant $2,000 to $4,500 per $20,000 of options sold and winning trades outpace losing trades by a 3:1 ratio. The paper then examines short term strangle and straddle selling strategies. The profitability of 5 day short strangle and straddle trades are enhanced by entering trades when the TLT Volatility Index is 2 percent greater than out of sample volatility forecasts. In this case, weekly profits average a highly statistically significant $500 to $1,200 per $20,000 of options sold after transactions costs, with winning trades outpacing losing trades by a 2:1 margin. The profitability of these trades is worsened by stop loss orders, and take profit orders have only modest favorable effects on the trading results. Overall, the results indicate that rebalancing the deltas of these trades enhances the performance of longer term trades, but hurts the performance of short term trades. The latter may be sample-specific as sustained TLT price changes were fairly short-lived over the sample period, and as a result, rebalancing deltas by buying TLT shares at higher levels and selling TLT shares at lower levels led to meaningful losses.

The findings of this paper should be tempered by the fairly short sample period and the exposure of the strategies to potentially large losses. However, traders pursuing the short TLT strangle and straddle trades examined in this paper could have bought extremely cheap, well out of the money calls and puts to protect against potential huge losses. It is also important in evaluating these strategies not to consider returns to be dollar gains divided by the dollar value of options sold as margin requirements generally require roughly $150,000 of account value to sell $20,000 of options. Thus, weekly returns of $1,000 on $20,000 of options sold more realistically represent returns of 2/3 percent rather than 5 percent. Nonetheless, the results indicate that the returns on short strangle and short strangle TLT option trades were attractive and the losses were manageable over the sample period.

Figure 1. TLT Prices (July 2003 - May 2007)

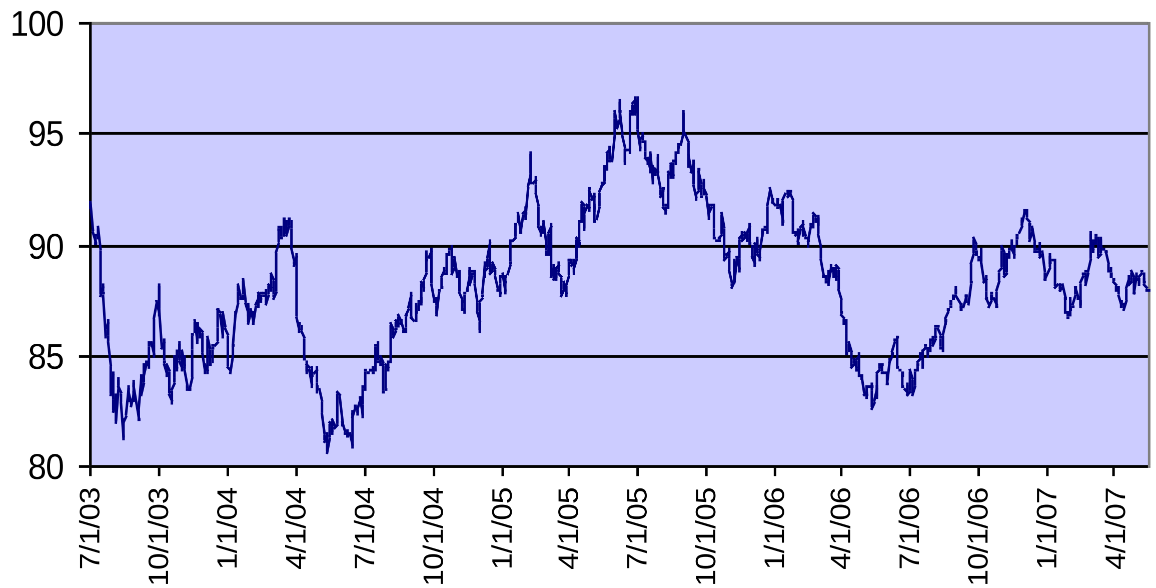

Table 1. TLT option implied volatilities for options with 2 to 9 weeks until expiration that are no more than 3 strikes (about 4 percent) in or out of the money, the TLT Volatility Index and Realized Volatility over the sample period from July 2003 through May 2007. ITM options are 2 and 3 strikes in the money, ATM options are no more than 1 strike in or out of the money and OTM options are 2 to 3 strikes out of the money. Implied volatilities are calculated using a binomial model and the TLT Volatility Index represents at the money implied volatility for at the money options with 22 business days to expiration and is interpolated from the two closest to the money calls and puts from the two contracts closest to expiry.

	2003 -2007	2003	2004	2005	2006	2007
Call Options						
Implied Volatilities						
All	10.53	14.09	10.82	10.61	9.11	8.85
ITM	11.36	15.07	12.00	11.36	9.87	9.28
ATM	9.96	13.71	10.11	10.21	8.61	7.93
OTM	9.96	13.40	9.89	10.07	8.53	8.21
Put Options						
Implied Volatilities						
All	10.69	14.03	11.29	10.91	9.11	8.48
ITM	10.61	13.73	11.29	10.77	9.14	8.87
ATM	10.28	13.78	10.85	10.65	8.79	7.96
OTM	11.13	14.55	11.59	11.24	9.39	8.41
TLT Volatility Index	10.16	13.65	10.50	10.42	8.70	8.00
Realized Volatility	7.76	11.02	7.80	7.95	6.71	5.86

Table 2. The daily profitability in cents of delta-hedged short TLT call option trades in the two front contracts without transactions costs. Call options are shorted and then purchased at the mid-point of the bid-ask spread at the close and are delta-hedged with long TLT shares using closing quotes. The sample includes options that are 2 to 9 weeks from expiration and are no more than 3 strikes in or out of the money. ATM options are not more than one strike in or out of the money, ITM options are two and three strikes in the money and OTM options are two and three strikes out of the money. Because of convergence issues, options are also excluded if their deltas are greater than .95 or if the mid-point of the bid and ask is less than 15 cents. The sample runs from July 2003 – May 2007.

Maturity/ Moneyness	NOBS	¢ Profit (p-value)	Profit/Starting Option Value (p-value)	#Winners /#Losers	Average ¢ Winner/Loser	Top 10% Profit Cutoff	Bottom 10% Profit Cutoff	Gamma Profit	Theta Profit	Vega Profit
2-9 weeks	9491	1.15 (<.01)	.0095 (<.01)	5552 / 3939	5.27 / -4.66	8.73	-6.50	-1.46	2.40	.10
2-5 weeks	2941	1.33 (<.01)	.0115 (<.01)	2313 / 1628	5.71 / -4.89	9.34	-6.99	-1.64	2.73	.17
6-9 weeks	5550	1.02 (<.01)	.0080 (<.01)	3239 / 2311	4.96 / -4.50	8.28	-5.98	-1.35	2.17	.13
OTM										
2-9 weeks	2666	.56 (<.01)	.0173 (<.01)	1543 / 112	3.77 / -3.85	6.26	-5.12	-1.41	1.84	-.03
2-5 weeks	823	.54 (<.01)	.0246 (<.01)	470 / 353	3.93 / -3.97	6.36	-5.82	-1.64	2.18	-.30
6-9 weeks	1943	.57 (<.01)	.0140 (<.01)	1073 / 770	3.70 / -3.79	6.13	-4.91	-1.31	1.69	.08
ITM										
2-9 weeks	4045	1.44 (<.01)	.0037 (<.01)	2318 / 1727	6.44 / -5.27	10.83	-7.44	-1.25	2.60	.11
2-5 weeks	1857	1.61 (<.01)	.0041 (<.01)	1055 / 802	6.97 / -5.43	11.73	-7.99	-1.33	2.79	.22
6-9 weeks	218	1.30 (<.01)	.0034 (<.01)	1263 / 925	6.00 / -5.15	10.33	-7.10	-1.18	2.43	.01
ATM										
2-9 weeks	2754	1.25 (<.01)	.0099 (<.01)	1674 / 1080	4.99 / -4.53	8.34	-5.91	-1.86	2.65	.37
2-5 weeks	1249	1.41 (<.01)	.0133 (<.01)	780 / 469	5.05 / -4.65	8.51	-6.03	-2.12	2.98	.41
6-9 weeks	1505	1.14 (<.01)	.0070 (<.01)	894 / 611	4.94 / -4.43	8.21	-5.79	-1.64	2.38	.33

Table 3. The daily profitability in cents of delta-hedged short TLT put option trades in the two front contracts without transactions costs. Put options are shorted and then purchased at the mid-point of the bid-ask spread at the close and are delta-hedged with short TLT shares using closing quotes. The sample includes options that are 2 to 9 weeks from expiration and are no more than 3 strikes in or out of the money. ATM options are not more than one strike in or out of the money, ITM options are two and three strikes in the money and OTM options are two and three strikes out of the money. Because of convergence issues, options are also excluded if their deltas are greater than .95 or if the mid-point of the bid and ask is less than 15 cents. The sample runs from July 2003 – May 2007.

Maturity/ Moneyness	NOBS	¢ Profit (p-value)	Profit/Starting Option Value (p-value)	#Winners /#Losers	Average Winner/Loser	Top 10% Profit Cutoff	Bottom 10% Profit Cutoff	Gamma Profit	Theta Profit	Vega Profit
2-9 weeks	8649	.45 (<.01)	.0040 (<.01)	4811 / 3838	4.48 / -4.60	7.27	-6.64	-1.62	1.61	.34
2-5 weeks	3646	.63 (<.01)	.0056 (<.01)	2070 / 1576	4.48 / -4.42	7.34	-6.53	-1.79	1.90	.47
6-9 weeks	5003	.32 (<.01)	.0028 (<.01)	2741 / 2262	4.49 / -4.72	7.16	-6.73	-1.49	1.40	.25
OTM										
2-9 weeks	5937	.32 (<.01)	.0049 (<.01)	3260 / 2677	4.16 / -4.34	6.63	-6.41	-1.62	1.73	.13
2-5 weeks	2403	.42 (<.01)	.0071 (<.01)	1344 / 1059	4.16 / -4.32	6.86	-6.45	-1.87	2.10	.07
6-9 weeks	3534	.26 (<.01)	.0033 (.02)	1916 / 1618	4.15 / -4.35	6.50	-6.36	-1.45	1.48	.17
ITM										
2-9 weeks	2699	.71 (<.01)	.0018 (<.01)	1543 / 1156	5.13 / -5.18	8.34	-7.08	-1.61	1.35	.80
2-5 weeks	1237	1.01 (<.01)	.0025 (<.01)	722 / 515	5.04 / -4.62	8.20	-6.66	-1.64	1.52	1.24
6-9 weeks	1462	.46 (.02)	.0012 (.10)	821 / 641	5.22 / -5.63	8.58	-7.40	-1.58	1.21	.42
ATM										
2-9 weeks	2771	.23 (.06)	.0011 (.37)	1488 / 1283	4.68 / -4.92	7.34	-7.44	-1.91	1.81	.25
2-5 weeks	1260	.35 (.04)	.0023 (.29)	692 / 568	4.58 / -4.81	7.45	-7.35	-2.16	2.22	.21
6-9 weeks	1511	.13 (.44)	.0008 (.94)	796 / 715	4.76 / -5.01	7.30	-7.58	-1.70	1.51	.28

Table 4. The profitability after transactions costs of shorting on expiration date and holding until the next expiration date roughly $20,000 of front contract strangles and straddles. Strangles are formed with the first out of the money calls and puts (1st Strangle) and the second out of the money calls and puts (2nd Strangle). Straddles are formed with options that are the closest to the money strikes. The trades are set up to be delta-neutral. Trades with delta-hedging assume that deltas are rebalanced daily with TLT shares when deltas exceed plus or minus 500 shares. Transactions costs are assumed to be $1 per option contract, while option trades are assumed to be executed at the mid-point of the bid-ask spread. Transactions costs associated with buying and selling TLT shares are assumed to be $5 per trade for brokerage fees and 1 cent for bid-ask spreads. Proceeds from shorting options plus proceeds from shorting TLT shares or minus funds used to purchase TLT shares earn the 3-month Treasury bill rate. The sample period is from July 2003 through May 2007.

Type	$ Profit (p-value)	Sharpe Ratio	Winners / Losers	Average Winner /Average Loser	Top and Bottom 10% P&L Cutoff	Gamma Profits	Theta Profits	Vega Profits	Delta Profits	Trans. Costs
With Delta-hedging										
1st Strangle	$2,697 (<.01)	.73	33/12	$4,387 / -$1,953	$7,661 / -$3,449	-$11,543	$14,063	$485	-$25	$949
2nd Strangle	$4,569 (<.01)	.71	33/12	$7,266 / -$2,847	$13,169 / -$3,056	-$18,106	$21,714	-$1,077	-$32	$1,532
Straddle	$2,254 (<.01)	.70	36/9	$3,311 / -$1,978	$6,509 / -$1,598	-$9,113	$15,890	$1,051	- $12	$761
Without Delta-hedging										
1st Strangle	$5,733 (<.01)	.41	31/14	$12,876/ -10,084	$21,227 / -$14,651	-$11,543	$14,063	$485	$3,290	$528
2nd Strangle	$9,697 (<.01)	.52	36/9	$17,381/ -21,038	$21,977 / -$14,937	-$18,106	$21,714	-$1,077	$5,665	$991
Straddle	$3,786 (.03)	.34	30/15	$9,858 / -8,356	$16,614 / -$12,775	-$9,113	$15,890	$1,051	$1,713	$395

Table 5. The profitability after transactions costs of shorting on expiration date and holding until the next expiration date roughly $20,000 of next to front contract strangles and straddles. Strangles are formed with the first out of the money calls and puts (1st Strangle) and the second out of the money calls and puts (2nd Strangle). Straddles are formed with options that are the closest to the money strikes. The trades are set up to be delta-neutral. Trades with delta-hedging assume that deltas are rebalanced daily with TLT shares when deltas exceed plus or minus 500 shares. Transactions costs are assumed to be $1 per option contract, while option trades are assumed to be executed at the mid-point of the bid-ask spread. Transactions costs associated with buying and selling TLT shares are assumed to be $5 per trade for brokerage fees and 1 cent for bid-ask spreads. Proceeds from shorting options plus proceeds from shorting TLT shares or minus funds used to purchase TLT shares earn the 3-month Treasury bill rate. The sample period is from July 2003 through May 2007.

Type	$ Profit (p-value)	Sharpe Ratio	Winners /Losers	Average Winner/ Average Loser	Top and Bottom 10% P&L Cutoff	Gamma Profits	Theta Profits	Vega Profits	Delta Profits	Trans. Costs
				With Delta-hedging						
1st Strangle	$740 (.18)	.20	30/15	$2,631 / -$3,042	$4,094 / -$3,418	-$5,432	$6,224	$74	$22	$612
2nd Strangle	$1,105 (.17)	.21	31/14	$3,792 / -$4,845	$6,702 / -$5,921	-$7,594	$8,632	$49	$29	$884
Straddle	$423 (.28)	.17	31/14	$1,830 / -$2,693	$3,150 / -$3,809	-$4,768	$7,922	$55	-$46	$527
				Without Delta-hedging						
1st Strangle	$2,497 (<.01)	.42	33/12	$5,315 / -$5,250	$8,169 / -$3,844	-$5,432	$6,225	$74	$1,575	$377
2nd Strangle	$3,736 (<.01)	.45	33/12	$7,591 / -$6,865	$10,457/ -$3,780	-$7,593	$8,632	$49	$2,532	$596
Straddle	$1,723 (.07)	.28	31/14	$4,750 / -$4,981	$6,931 / -$3,525	-$4,768	$7,921	$55	$1,572	$307

Table 6. Forecasting models used to construct out of sample volatility forecasts where realized volatility is regressed on a constant, a deterministic time trend, up to three own lags and separate variables for positive and negative lagged TLT log returns. The number of own lags is determined by specification tests.

$$\sigma_{t+1} = \alpha_0 + \alpha_1 T + \alpha_2\sigma_t + \alpha_3\sigma_{t-1} + \alpha_4\sigma_{t-2} + \alpha_5 \log(TLT_t/TLT_{t-1})^{pos} + \alpha_6 (\log(TLT_t/TLT_{t-1})^{neg} + \varepsilon_{t+1}, \quad (8)$$

	7/31/02- 5/15/03	7/31/02-5/17/04	7/31/02-5/13/05	7/31/02-5/13/06
α_0	.0745**	.0570 **	.0619**	.0629**
	(.0117)	(.0078)	(.0065)	(.0055)
α_1	-.0000	-.00000	-.000031**	-.00002**
	(.0000)	(.0001)	(.000001)	(.0000004)
α_2	.1357	.1327**	.1363**	.1199**
	(.0689)	(.0436)	(.0345)	(.0310)
α_3	.0834	.0859	.0888*	.0987**
	(.0640)	(.0467)	(.0379)	(.0344)
α_4	--	.1683**	.1610**	.1401**
		(.0514)	(.0436)	(.0379)
α_5	1.801*	1.367*	1.135**	1.110**
	(.816)	(.546)	(.4241)	(.3757)
α_6	-.8895	-1.129**	-.9458**	-.8889**
	(.6121)	(.427)	(.3568)	(.3157)
$RBAR^2$	.061	.091	.159	.166
Q(6)	6.31	2.32	5.42	6.71
(Sign.)	(.389)	(.887)	(.492)	(.348)

Table 7. The profitability of short term strategies involving selling strangles and straddles when the TLT Option Volatility Index is two percentage points higher than out of sample time series volatility forecasts for the next five days and exiting after five days. Roughly $20,000 of the closest to expiration options with at least 20 days until expiry are sold. Profitability is examined both with and without delta-hedging. In the former case, positions are delta-hedged with the underlying TLT shares when deltas exceed plus or minus 500 shares. Strangles are formed with the first out of the money calls and puts (1st Strangle) and the second out of the money calls and puts (2nd Strangle). Straddles are formed with options that are the closest to the money strikes. Transactions costs are assumed to be $1 per option contract, while option trades are assumed to be executed at the mid-point of the bid-ask spread. Transactions costs associated with buying and selling TLT shares are assumed to be $5 per trade for brokerage fees and 1 cent for bid-ask spreads. Proceeds from shorting options plus proceeds from shorting TLT shares or minus funds used to purchase TLT shares earn or pay the 3-month Treasury bill rate. The sample period is from July 2003 through May 2007.

Type	$ Profit (p-value)	Sharpe Ratio	Winners /Losers	Average Winner/ Average Loser	Top and Bottom 10% P&L Cutoff	Gamma Profits	Theta Profits	Vega Profits	Delta Profits	Trans. Costs
				With Delta-hedging						
1st Strangle	$871 (.01)	.33	40/22	$2,296 / -$1,718	$3,963/ -$1,795	-$2,277	$4,132	$773	$19	$498
2nd Strangle	$1,245 (.04)	.31	39/24	$3,637 / -$2,643	$6,005/ -$4,552	-$3,365	$6,138	$874	-$17	$838
Straddle	$481 (.04)	.26	43/22	$1,436 / -$1,385	$2,237/ -$1,428	-$1,979	$3,367	$564	$21	$413
				Without Delta-hedging						
1st Strangle	$1,480 (<.01)	.55	43/19	$2,865 / -$1,653	$4,693/ -$1,918	-$2,277	$4,132	$773	$393	$427
2nd Strangle	$1,811 (<.01)	.47	39/24	$4,290 / -$2,216	$6,966/ -$2,676	-$3,365	$6,138	$873	$265	$754
Straddle	$871 (<.01)	.36	47/18	$1,941 / -$1,921	$3,322/ -$1,978	-$1,978	$3,367	$563	$261	$352

Table 8. The effect of stop loss rules on the profitability of short term strategies involving selling strangles and straddles when the TLT Option Volatility Index is two percentage points higher than out of sample time series volatility forecasts for the next five days. Trades are exited when losses are greater than $2,000 or in five days. Roughly $20,000 of the closest to expiration options with at least 20 days until expiry are sold. Profitability is examined both with and without delta-hedging. In the former case, positions are delta-hedged with the underlying TLT shares when deltas exceed plus or minus 500 shares. Strangles are formed with the first out of the money calls and puts (1st Strangle) and the second out of the money calls and puts (2nd Strangle). Straddles are formed with options that are the closest to the money strikes. Roundtrip option transactions costs are assumed to be $2 per contract, while option trades are assumed to be executed at the mid-point of the bid-ask spread. Roundtrip transactions costs associated Transactions costs are assumed to be $1 per option contract, while option trades are assumed to be executed at the mid-point of the bid-ask spread. Transactions costs associated with buying and selling TLT shares are assumed to be $5 per trade for brokerage fees and 1 cent for bid-ask spreads. Proceeds from shorting options plus proceeds from shorting TLT shares or minus funds used to purchase TLT shares earn or pay the 3-month Treasury bill rate. The sample period is from July 2003 through May 2007.

Type	$ Profit (p-value)	Sharpe Ratio	Winners /Losers	Average Winner/ Average Loser	Top and Bottom 10% P&L Cutoff	Gamma Profits	Theta Profits	Vega Profits	Delta Profits	Trans. Costs
				With Delta-hedging						
1st Strangle	$608 (.11)	.20	43/22	$2,205 / -$2,513	$3,963/ -$2,831	-$2,309	$3,929	$706	$0	$495
2nd Strangle	$724 (.18)	.16	42/27	$3,422 / -$3,475	$6,005/ -$5,944	-$3,005	$5,360	$605	-$25	$820
Straddle	$304 (.23)	.15	42/26	$1,552 / -$1,711	$2,601/ -$2,425	-$1,931	$3,239	$472	$6	$413
				Without Delta-hedging						
1st Strangle	$1,046 (.02)	.30	48/19	$2,811 / -$3,409	$4,693/ -$3,218	-$2,272	$3,873	$716	$138	$431
2nd Strangle	$918 (.10)	.19	43/29	$4,146 / -$3,869	$6,756/ -$5,083	-$3,139	$5,302	$559	$79	$752
Straddle	$688 (.03)	.27	50/19	$1928 / -$2,575	$3,171/ -$3,028	-$1,873	$3,208	$491	$195	$351

Table 9. The effect of take profit rules on the profitability of short term strategies involving selling strangles and straddles when the TLT Option Volatility Index is two percentage points higher than out of sample time series volatility forecasts for the next five days. Trades are exited when gains are greater than $2,000 or in five days. Roughly $20,000 of the closest to expiration options with at least 20 days until expiry are sold. Profitability is examined both with and without delta-hedging. In the former case, positions are delta-hedged with the underlying TLT shares when deltas exceed plus or minus 500 shares. Strangles are formed with the first out of the money calls and puts (1st Strangle) and the second out of the money calls and puts (2nd Strangle). Straddles are formed with options that are the closest to the money strikes. Transactions costs are assumed to be $1 per option contract, while option trades are assumed to be executed at the mid-point of the bid-ask spread. Transactions costs associated with buying and selling TLT shares are assumed to be $5 per trade for brokerage fees and 1 cent for bid-ask spreads. Proceeds from shorting options plus proceeds from shorting TLT shares or minus funds used to purchase TLT shares earn or pay the 3-month Treasury bill rate. The sample period is from July 2003 through May 2007.

Type	$ Profit (p-value)	Sharpe Ratio	Winners /Losers	Average Winner/ Average Loser	Top and Bottom 10% P&L Cutoff	Gamma Profits	Theta Profits	Vega Profits	Delta Profits	Trans. Costs
				With Delta-hedging						
1st Strangle	$1,291 (<.01)	.69	57/16	$2,023 / -$1,315	$3,152 /-$868	-$1,666	$3159	$882	$24	$479
2nd Strangle	$923 (<.01)	.34	61/23	$2,216 / -$2,507	$3,478/ -$2,323	-$2,434	$4,331	$804	$13	$839
Straddle	$503 (.02)	.30	45/24	$1,462 / -$1,298	$2,427/ -$1,428	-$1,761	$2,948	$555	$7	$410
				Without Delta-hedging						
1st Strangle	$1,440 (<.01)	.54	60/16	$2,455 / -$2,364	$3,627/ -$1,092	-$1,618	$3,092	$800	$250	$430
2nd Strangle	$1,369 (<.01)	.41	73/16	$2,589 / -$4,197	$3,785/ -$2,321	-$2,175	$3,999	$723	$323	$767
Straddle	$741 (.02)	.28	55/18	$1,860 / -$2,679	$2,702/ -$1,978	-$1,729	$2,850	$365	$313	$366

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