Equity Volatility Term Structures and the Cross-Section of Option Returns

Aurelio Vasquez
ITAM School of Business*

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Abstract

The slope of the implied volatility term structure is positively related to future option returns. We rank firms based on the slope of the volatility term structure and analyze the returns for straddle portfolios. Straddle portfolios with high slopes of the volatility term structure outperform straddle portfolios with low slopes by an economically and statistically significant amount. The results are robust to different empirical setups and are not explained by traditional factors, higher-order option factors, or jump risk. The most plausible explanation of our results is that the slope of the volatility term structure is measuring volatility underreaction and overreaction.

JEL Classification: C21, G12, G13, G14.

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1 Introduction

We investigate if the shape of the term structure of implied volatility is related to the cross-section of future one-month option returns. Every month, we sort stocks by the slope of the volatility term structure, group them in deciles, and examine the average future straddle returns.

We find a strong positive relation between the slope of the volatility term structure and future straddle returns. The straddle, a trading strategy that bets on the direction of volatility, has an average monthly return of -9.2% for the decile with the lowest slope of the volatility term structure and a return of 7.3% for the decile with the highest slope. The long-short strategy generates a monthly return of 16.5% with a t-statistic of 10.02.

These findings hold across different time periods, alternative horizons, moneyness levels, weighting schemes, and alternative definitions of the slope of the volatility term structure. Fama-MacBeth (1973) regressions of the type proposed by Brennan, Chordia, and Subrahmanyam (1998), and double sorts on firm characteristics further confirm our findings. The coefficients of the slope of the volatility term structure and the long-short straddle returns are positive and significant when we control for firm size, book-to-market, realized higher moments, jump risk and option greeks.

We compute the alphas of the long-short straddle strategy using the Carhart model as well as the coskewness and cokurtosis factor models proposed by Vanden (2006) that include higher order moments of the market return and the market option return. The alphas from the Carhart, coskewness and cokurtosis models are large and significant, and are very close to the raw returns.

We perform an extensive analysis on the relation between the slope of the volatility term structure and several measures of volatility minus current implied volatility, IV_{1M}. These measures can be divided into three groups: measures of the volatility risk premium, measures of volatility underreaction and overreaction, and option anomaly measures. Following Bollerslev, Tauchen, and Zhou (2009), we compute the volatility risk premium as the difference between realized volatility computed from five-minute returns and IV_{1M}. Stein (1989) and Poteshman (2001) report that investors overreact (underreact) to current volatility changes. The measures of volatility underreaction and overreaction are lagged one month, three months, six months and average implied volatility minus IV_{1M}. Finally, we include two measures of volatility related to an existing option anomaly. Goyal and Saretto (2009) find that straddle returns are positively related to the difference between historical and implied volatility, $HV - IV_{1M}$. Cao and Han (2013) find that delta-hedged call returns are negatively related to idiosyncratic volatility.

We study the behavior of these volatility measures across decile portfolios ranked by the slope of the volatility term structure. All measures of volatility misreaction (minus IV_{1M}), the volatility risk premium, and the option anomaly measure monotonically increase from portfolio 1 to portfolio 10. Moreover, all volatility measures report a negative value for portfolio 1 (lowest slope of term structure) and a positive value for portfolio 10 (highest slope of the volatility term structure). An examination of the correlation among these variables shows that the slope of the volatility term structure is highly correlated with measures of volatility overreaction ranging from 51% to 65%. The correlation with the volatility risk premium is much lower, at only 15%. The slope of the volatility term structure reports a correlation of 46% with $HV - IV_{1M}$, an option anomaly documented by Goyal and Saretto (2009).

Next, we explore the relation between these volatility measures and future straddle returns. The univariate Fama-MacBeth regressions reveal that each one of these measures can individually predict straddle returns. There is a positive and significant relation between each volatility measure and future straddle returns. The volatility risk premium predicts future straddle returns. Also, the average one month implied volatility over the last six months (minus IV_{1M}), and the lagged implied volatility for one, three and six month (minus IV_{1M}) predict future straddle returns. We perform a horserace among all these volatility measures and the slope of the volatility term structure to see how they jointly predict straddle returns.

We find that only three variables report positive and significant coefficients: the slope of the volatility term structure, lagged three month volatility minus current implied volatility, and idiosyncratic volatility minus current implied volatility. The slope of the volatility term structure reports the highest coefficient of 0.201 with a Newey-West t-statistic of 2.80.

The large straddle returns potentially represent a compensation for jump risk. Several measures of jump risk are proposed in the literature. Bakshi and Kapadia (2003) show that risk-neutral skewness and risk-neutral kurtosis proxy for jump risk. Xing, Zhang and Zhao (2010) proxy risk neutral skewness with the slope of the volatility smile. Yan (2011) demonstrates that the spread between at-the-money put and call volatilities is a proxy of jump risk. Bollerslev and Todorov (2011) propose two measures of risk-neutral jump, one for the right tail and one for the left tail of the distribution. After controlling for jump risk, the Fama-MacBeth coefficients of the slope of the volatility term structure, and the long-short straddle returns in the double sorts remain positive and significant.

This paper contributes to the finance literature in two ways. Our paper is one of the first to document that the slope of the term structure of implied volatilities has a positive relation with subsequent option returns in the cross-section.[1] The shape of the volatility term structure has previously been used to test the expectations hypothesis, and the overreaction of long-term volatilities. Notable research in this area includes papers by Stein (1989), Diz and Finucane (1993), Heynen, Kemna, and Vorst (1994), Campa and Chang (1995), Poteshman (2001), Mixon (2007), and Bakshi, Panayotov, and Skoulakis (2011). However, our paper is among the first to use the shape of the term structure to identify mispriced options.

A second contribution relates to the forecasting of future realized volatility minus current implied volatility. Since the slope of the volatility term structure is positively related with option returns, we test if it forecasts future realized volatility minus current implied volatility. Recent studies by Cao, Yu, and Zhong (2010) and Busch, Christensen, and Nielsen (2011)

[1] In contemporaneous work, Jones and Wang (2012) document a similar finding.

show that short-term implied volatility, historical volatility and realized volatility are all good predictors of future volatility.[2] We document that the slope of the volatility term structure also contributes to the prediction of future realized volatility minus current volatility.

Empirical option research has focused primarily on index options.[3] This paper explores the cross-section of equity options. In the literature on the cross-section of equity options, Cao and Han (2013) find that delta-hedged option returns are negatively related to total and idiosyncratic volatility. Jones and Shemesh (2010) document the options weekend effect, option returns are lower on weekends than on weekdays, and Choy (2011) reports a negative relation between option returns and retail trading proportions. Bali and Murray (2012) create skewness-assets using options and the underlying stock and find a negative relation between the skewness-asset returns and their risk-neutral skewness. The most closely related paper is Goyal and Saretto (2009), who show that option returns are positively related to the difference between individual historical realized volatility and at-the-money (ATM) implied volatility.

The implied volatility term structure is used in the option pricing literature. Christoffersen, Jacobs, Ornthanalai, and Wang (2008) and Christoffersen, Heston, and Jacobs (2009) show that an option pricing model that properly fits the volatility term structure has a superior out-of-sample performance compared to classical option pricing models such as the Heston model. This result suggests that the volatility term structure contains crucial information on future option prices. Our paper documents a positive relation between the slope of the volatility term structure and future option returns.

The remainder of this paper is organized as follows. Section two describes the option data. Section three describes the option trading strategies and the portfolio characteristics. The straddle returns using different setups are presented in section four, and section five

[2]See Granger and Poon (2003) for a review on volatility forecasting.

[3]Coval and Shumway (2001) study index option returns and find that zero cost at-the-money straddle positions on the S&P 500 produce average losses of approximately 3% per week. Other studies of index option returns are Bakshi and Kapadia (2003), Jones (2006), Bondarenko (2003), Saretto and Santa-Clara (2009), Bollen and Whaley (2004), Shleifer and Vishny (1997), Jackwerth (2000), Buraschi and Jackwerth (2001), and Liu and Longstaff (2004).

contains a series of robustness checks. In Section six we discuss possible explanations for the results. Section seven concludes the paper.

2 Data

In this section, we describe the data and explain the filters that are applied.

We use the cross-section of options from the OptionMetrics Ivy database. The OptionMetrics Ivy database is a comprehensive source of high quality historical price and volatility data for the US equity and index options markets. We use data for all US equity options and their underlying prices for the period starting on January 4, 1996 through January 30, 2012. Each observation contains information on the closing bid and ask quotes for American options, open interest, daily trading volume, implied volatilities, and Greeks. Implied volatilities and Greeks are computed using the Cox, Ross, and Rubinstein (1979) binomial model.

OptionMetrics also provides stock prices, dividends, and risk-free rates. A complete history of splits is also available for each security. The risk-free rates are linearly interpolated to match the maturity of the option. If the first risk-free rate maturity is greater than the option maturity, no extrapolation is performed and the first available risk-free rate is used.

Next, we apply standard filters for individual options as in Goyal and Saretto (2009). We eliminate the prices that violate arbitrage bounds.[4] That is, we eliminate call option prices that fall outside of the interval $(S - Ke^{-\tau r} - De^{-\tau r}, S)$, and put option prices that fall outside of the interval $(-S + Ke^{-\tau r} + De^{-\tau r}, S)$, where S is the price of the underlying stock, K is the strike of the option, r is the risk-free rate, D is the dollar dividend, and τ is the time to expiration. An observation is eliminated if the ask is lower than the bid, the bid (ask) is equal to zero, or the spread is lower than the minimum tick size. The minimum tick size is \$0.05 for options trading below \$3 and \$0.10 for other options. Whenever the bid and ask prices

[4] Duarte and Jones (2007) point out that options that violate arbitrage bounds might still be valid options. The inclusion of options that violate arbitrage bounds does not change the conclusions.

are both equal to the previous day's quotes, the observation is also eliminated. We filter one-month options with zero volume or zero open-interest to ensure that the one-month option prices are valid. Options with underlying stock prices lower than $5 are removed from the sample. Finally, the moneyness of the options must be between 0.95 and 1.05, and volatilities should lie between 3% and 200%.[5]

Each month, we compute the slope of the volatility term structure for each stock. The slope of the volatility term structure is defined as the difference between the long-term and the short-term volatility. The short-term volatility, IV_{1M}, is defined as the average of the one-month ATM put and call implied volatilities. The long-term volatility, IV_{LT}, is the average volatility of the ATM put and call options that have the longest time-to-maturity available and the same strike as that of the short-term options. The longest time to expiration is between 50 and 360 days. Hence, the maturity of the long-term options is different across stocks and, for any given stock, can change across months.[6]

3 Portfolio Formation and Trading Strategies

In this section, we explain how portfolios are constructed and provide a summary of different characteristics across portfolios. Then, we describe the return computation for straddles.

3.1 Portfolio Formation

Each month, we form ten portfolios based on the slope of the volatility term structure, $IV_{LT} - IV_{1M}$.[7] Decile portfolios contain the one-month ATM options that are available on the second trading day (usually a Tuesday) after the expiration of the previous one-month options, which occurs on the third Saturday of the month. We extract the ATM put and

[5] The conclusions hold when the volatility range is 3% to 100%.

[6] Note that option returns are computed only for short-term options. Long-term options are only used to extract long-term volatility to compute the slope of the volatility term structure.

[7] Alternative definitions of the slope of the volatility term structure using variance, the square root of volatility, volatility cubed, the cubed root of volatility, or the logarithm of volatility do not change the results.

call options that are one-month away from maturity. The one-month option maturity ranges from 26 to 33 days. The strike price is as close as possible to the closing price. For example, if the stock price is 17, and the two closest strikes are 15 and 20, we select the options with strike price 15. If the selected put or call options do not pass the filtering process, we choose the two options with a strike price of 20. If either of those two options is filtered out, that particular stock is excluded for that month because it has no valid options.

On the option expiry date, we compute the straddle returns. Then, we form decile portfolios based on the slope of the volatility term structure. Since decile portfolios are formed based on the options availability, stocks drop in and out of the sample from month to month. On average, there are 515 stocks per month.

3.2 Characteristics of Portfolios Sorted by the Slope of the Volatility Term Structure

Panel A of Table 1 reports the time-series averages for different firm characteristics for the ten portfolios ranked by the slope of the volatility term structure. The characteristics included are divided into three groups: variables related to the slope of the volatility term structure, firm and option characteristics, and higher moment measures.

[Insert Table 1 here]

The variables related to the slope of the volatility term structure are IV_{1M}, IV_{LT} and the slope of the term structure $IV_{LT} - IV_{1M}$. The firm and option characteristics are the options size (in $ thousands), defined as the open interest for calls and puts multiplied by their price, the average maturity of IV_{LT}, the average put-call spread of at-the-money implied volatility, the bid-to-mid spread of at-the-money implied volatility, option Greeks, firm size, and book-to-market. Finally, the higher moment measures are the risk-neutral volatility, skewness and kurtosis extracted from one-month options using the methodology proposed by Bakshi, Kapadia, and Madan (2003), the risk-neutral jump as proposed by Yan (2011), idiosyncratic volatility computed from the one month daily returns using the Fama-French factors, and future volatility, FV, defined as the standard deviation of the underlying stock return over the life of the option.

As reported in Panel A of Table 1, the slope of the volatility term structure increases from -14.7% to 7.6% for portfolios 1 to 10. Portfolio 1 has the highest IV_{1M} and the highest IV_{LT}. The average maturity of long-term options is approximately 221 days (7 months) for all decile portfolios. Thus, the slope of the volatility term structure is computed using volatilities that are on average six months apart. Extreme portfolios have the lowest vegas of 7.1 and 7.3 compared with the vegas for portfolios 4 to 9 that are all over 9.1. According to vega, extreme portfolios are the least sensitive to volatility movements. Additionally, portfolios 1 and 10 (with portfolio 2) hold the firms with the lowest value of \$4.8 billion and \$9.7 billion, respectively. Firms in portfolios 5 and 6 have an average size of \$16.6 and \$18.4 billion, respectively. Companies in extreme portfolios have a high risk-neutral jump. No pattern is observed between the slope of the volatility term structure and risk-neutral volatility, skewness and kurtosis, book to market, option size, and option delta.

Panel B of Table 1 reports the time series average of a battery of volatility measures minus IV_{1M}. These volatility measures are related to the volatility risk premium, investor misreaction to volatility changes, and option anomalies. The volatility risk premium (VRP) is defined as the $RV_{1M} - IV_{1M}$ as proposed by Bollerslev, Tauchen, and Zhou (2009). Realized volatility is computed with 5-minute returns over month (RV_{1M}). We also include the 1-day (RV_{1d}), and 1-week (RV_{1w}) realized volatility measures. We include a set of variables that control for investor misreaction to volatility changes. Poteshman (2001) and Stein (1989) document that investors can underreact or overreact to changes in volatility. Hence, investors might be buying (selling) options that are overpriced (underpriced) and that will generate negative (positive) future returns. To account for high volatility periods and investor misreactions, we include measures of previous volatilities minus current implied volatility, IV_{1M}. The volatility measures are the one-month (IV_{1M}^{t-1}), 3-month (IV_{1M}^{t-3}), and 6-month

(IV_{1M}^{t-6}) lagged implied volatility as well as the maximum ($IV_{1M}^{\max}$) and the average implied volatility (IV_{1M}^{avg}) over the previous 6-months. Finally two variables account for option anomalies: $HV - IV_{1M}$, and $IdioVol - IV_{1M}$. Goyal and Saretto (2009) find that straddle and delta-hedged call returns have a positive relation with the difference between historical and implied volatility, $HV - IV_{1M}$. Cao and Han (2013) report that delta-hedged call returns decrease with the level of idiosyncratic volatility.

According to Panel B of Table 1, all volatility measures minus IV_{1M} increase from portfolio 1 to portfolio 10. For example, $FV - IV_{1M}$ increases from -6.8% to 1.3%, VRP increases from -7.1% to 5.7%, $IV_{1M}^{t-6} - IV_{1M}$ increases from -14.6% to 8.7%, and $idioVol - IV_{1M}$ increases from -70.3% to -45.7%. Panel C reports the correlations of the volatility variables minus IV_{1M}. The correlation structure confirms the results from Panel B: most of the correlations are positive. In particular, the slope of the volatility term structure reports a positive correlation with all the volatility measures (minus IV_{1M}). There is a low correlation between the slope of the volatility term structure and realized volatility measures minus IV_{1M}. The correlation between the slope of the volatility term structure and the volatility risk premium (VRP) is 15.0%. There is a high correlation between the slope of the volatility term structure and measures of volatility overreaction ranging from 51.3% to 65.1%. For example there is a positive correlation of 65.1% between the slope of the volatility term structure and $IV_{1M}^{t-6} - IV_{1M}$. Finally, the slope of the volatility term structure has a positive correlation of 46.3% and 29.2% with $HV - IV_{1M}$ and $idioVol - IV_{1M}$, respectively.

In summary, Table 1 shows that the slope of the volatility term structure appears to be related to past and future volatility (minus IV_{1M}). We now attempt to establish a cross-sectional relation between the slope of the volatility term structure and future option returns.

3.3 Trading Strategy and Option Returns

The analysis of option returns is not as straightforward as that of stock returns. Option investors have several degrees of freedom when buying an option. Calls and puts with different maturities and strike prices are available. Hence, many different trading strategies can be implemented. Saretto and Santa-Clara (2009) analyze 23 different option trading strategies for the S&P 500 index. Since liquidity is a major constraint when studying individual stock options, we work with the most liquid options: at-the-money options that are close to expiration. Given the positive relation between the slope of the volatility term structure and several volatility measures, we study the returns of the option strategy that bets on the future direction of volatility: straddle.

A straddle is an investment strategy that involves the simultaneous purchase (or sale) of one call option and one put option. A long straddle return is defined as

$$r_{t,T}^{straddle} = \frac{|S_T - K|}{p_t + c_t} - r_{t,T}^{f} \tag{1}$$

where c_t and p_t are the average of the bid and ask prices of a call and a put option, on trading day t, $r_{t,T}^{f}$ is the future value of one dollar from time t to T, K is the strike price, and S_T is the stock price at maturity T.

Given that the average bid to mid option spread for portfolios 1 and 10 is 6.2% and 8.1%, and to avoid paying high transaction costs more than once, options are held until maturity. By holding the options until maturity, the large transaction costs for the option are only paid when opening the position and are avoided at expiration.

4 Slope of the Volatility Term Structure and the Cross-Section of Option Returns

In this section, we first analyze the relation between the slope of the volatility term structure and the one-month straddle returns. We report the raw straddle returns as well as the Carhart, coskewness and cokurtosis risk adjusted alphas for the long-short straddle portfolio. Second, we use the modified two-stage Fama and MacBeth (1973) cross-sectional regressions proposed by Brennan, Chordia, and Subrahmanyam (1998) to determine the significance of the slope of the volatility term structure and that of the other measures of volatility minus IV_{1M}. Third, we use double sorts to further understand the relation between the slope of the volatility term structure, other volatility measures minus IV_{1M}, and future straddle returns. Then, we control for higher moments and jump risk. Finally, we assess the impact of transaction costs on straddle returns.

4.1 Sorting Straddle Returns by the Slope of the Volatility Term Structure

[Insert Table 2 here]

Each month, we rank stocks by the slope of their volatility term structure and form ten option portfolios. Panel A on Table 2 reports equally weighted portfolio returns for straddles. Straddle returns increase from portfolio 1 to portfolio 10. In particular, the straddle returns are negative for portfolios 1 to 8 and are positive for portfolios 9 and 10. The long-short straddle strategy (portfolio 10 minus portfolio 1) yields a 16.5% monthly average return with a t-statistic of 10.02. Both portfolios contribute to the long-short portfolio return since the straddle returns are -9.2% and 7.3% for portfolios 1 and 10, respectively.

[Insert Figure 1 here]

Figure 1 displays the time series of the long-short straddle returns. About 85% of the monthly straddle returns are positive. The maximum long-short straddle return is 139% and the minimum is -48%. Over the sample period, most of the positive returns are below 50%.

[Insert Figure 2 here]

Figure 2 displays the qq-plot of the long-short straddle returns. The distribution of straddle returns has fatter tails than the normal distribution. Fat tails in the straddle return distribution are confirmed by the excess kurtosis of 5.4 reported in Panel A of Table 2. Finally, the long-short straddle returns report a positive skewness of 1.2.

The long-short straddle returns are highly non-normal, confirming the findings of Broadie, Chernov, and Johannes (2009). Hence, the conventional t-statistic of 10.02 should be interpreted with care. We include in Panel B of Table 2 the bootstrapped critical values for the t-statistic of the long-short straddle returns. We compute the critical values for the t-statistic by bootstrapping the long-short returns 50,000 times. The critical value at the 1% level in a two-sided test is 2.165 which confirms that the long-short straddle return of 16.5% is significant at the 1% level.

In conclusion, we find a clear positive and highly significant relation between the slope of the volatility term structure and the cross section of straddle returns. Bootstrapped critical values confirm this relation.

4.2 Alphas of Portfolios from Coskewness and Cokurtosis Pricing Models

We now regress the long-short straddle returns, portfolio 10 minus portfolio 1, on various linear pricing models. The linear pricing models are the Fama and French (1993) model, the Carhart (1997) model, and the coskewness and cokurtosis models developed by Vanden (2006). The coskewness model incorporates not only the market return and the square of the market return but also the option return, the square of the option return, and the product of the market and the option returns. Similarly, the cokurtosis model includes the cubes of the market return and the option return, as well as the product between the market return and the option return squared, and the product between the market return squared and the option return.

The general version of the model is defined as

$$
\begin{aligned}
r_P &= \alpha_P + \beta_1(R_m - R_f) + \beta_2 SMB + \beta_3 HML + \beta_4 UMD + && (2)\\
&\quad \beta_5(R_o - R_f) + \beta_6(R_m^2 - R_f) + \beta_7(R_o^2 - R_f) + \beta_8(R_o R_m - R_f) && (3)\\
&\quad \beta_9(R_o^3 - R_f) + \beta_{10}(R_m^3 - R_f) + \beta_{11}(R_o^2 R_m - R_f) + \beta_{12}(R_o R_m^2 - R_f) + \varepsilon, && (4)
\end{aligned}
$$

where R_m is the market return, R_o is the market option return, R_f is the risk-free rate, and SMB, HML and UMD are the Fama-French and momentum factors. This equation embeds three factor models: the Fama-French-Carhart model (the first line of the equation), the coskewness model (the market return on part of the first line, and the second line), and the cokurtosis model (the market return on part of the first line, and the second and third lines). For the market option return, we use the straddle return of the S&P 500.[8]

Panel C of Table 2 contains the results of the model regressions for the long-short straddle returns. The first column presents the results of the Carhart model. The alpha is 17.4% with a t-statistic of 10.18. The coefficient of the market factor R_m is negative and significant. Hence, when the market goes down the long-short straddle return goes up.

The second and third columns present the results for the coskewness and cokurtosis factors. The alpha for the long-short straddle return is positive and significant for both models. The alpha is 14.7% with a t-statistic of 7.8 for the coskewness model, and 13.0% with a t-statistic of 3.75 for the cokurtosis model. The coefficients of the S&P 500 straddle return, $R_o - R_f$, and its square, $R_o^2 - R_f$, are positive and significant at the 10% level for both models. The coefficient of the $R_o R_m - R_f$ factor is negative and significant at the 10% level for coskewness model.

The market factor has a negative and significant coefficient while the market straddle factor has a positive and significant coefficient.

Given the strong factor structure in firm volatility documented by Herskovic, Kelly,

[8] Using other option strategies for the S&P 500 option return such as naked call, naked put, delta-hedged call or delta-hedged put, does not change the results.

Lustig and Van Nieuwerburgh (2014), and that the returns of a straddle mainly depend on volatility changes, the long-short straddle portfolio. This result confirms the leverage effect documented in the option literature. When the stock market decreases, volatility increases. , when the market goes down the long-short straddle portfolio reports positive returns.

In the fourth column we regress the long-short straddle returns against all factors. The alpha is 13.5% with a significant t-statistic of 3.85. The market factor is negative but not significant anymore. The factor with the highest t-statistic is the straddle return of the S&P 500 with a coefficient of 0.08 and a t-statistic of 1.83.

We conclude that the Carhart, coskewness and cokurtosis factor models that include the market return and the market option return do not explain the long-short straddle returns. The alphas for all models are of the same magnitude as the raw returns of the long-short straddle portfolio reported in Panel A of Table 2. The most important factors are the S&P 500 straddle return and its square that report a positive and significant coefficient in all regressions.

4.3 Alternative Volatility Measures and the Slope of the Volatility Term Structure

The results presented in Table 2 show that there is a strong positive relation between individual straddle returns and the slope of the volatility term structure. In Table 1, Panels B and C, we report that the slope of the volatility term structure is positively related with other measures of volatility minus IV_{1M}. In this section we explore the predictability power of each alternative measure of volatility (minus IV_{1M}) and test how they jointly predict future straddle returns.

To confirm that the slope of the volatility term structure is positively related with option returns in the cross section, we run the modified two-stage Fama and MacBeth (1973) regressions proposed by Brennan, Chordia, and Subrahmanyam (1998). An advantage of the standard Fama and MacBeth (1973) regression is that it does not impose breakpoints for portfolio formation but allows for an evaluation of the interaction among variables and the slope of the volatility term structure. The modified regression proposed by Brennan, Chordia, and Subrahmanyam (1998) corrects for the error in variables problem and is defined as

$$r_{i,t} - \widehat{\beta}_i F_t = \gamma_{0,t} + \gamma'_{0,t} Z_{i,t-1} + \varepsilon_{i,t}$$

where $r_{i,t}$ is the straddle return in excess of the risk free rate for each security i at time t, F_t are the Fama-French-Carhart, coskewness and cokurtosis factors, and $Z_{i,t-1}$ are the characteristics for each stock i at time $t-1$. The $\widehat{\beta}_i$ are estimated in the first stage for each stock i using the entire sample. In the second stage, for each month t, a regression is run with the option return on the left hand side and the slope of the volatility term structure along with other variables on the right hand side. From stage two, we obtain a time series of t coefficients that are averaged in the third stage to obtain an estimator for each coefficient. We evaluate the coefficient's significance using the Newey-West t-statistic with 3 lags.[9]

[Insert Table 3 here]

Table 3 reports the regression results of the risk adjusted straddle returns on all volatility measures minus the one-month implied volatility and t-statistics for the modified Fama-MacBeth. As previously explained, these volatility measures (minus current implied volatility) account for the volatility risk premium, investor misreaction to volatility changes, and option anomalies. The first eleven columns present the results of the univariate regressions, and the last column reports the results of the multivariate regression. The first regression confirms the positive relation between the slope of the volatility term structure and straddle returns. The coefficient of the slope of the volatility term structure is 0.257 with a significant Newey-West t-statistic of 4.73. All the other volatility measures but one report a positive

[9] Our results remain qualitatively the same when the number of lags in the Newey-West estimator takes alternative values from 0 to 15.

coefficient, and five out of ten have a significant t-statistic greater than 3.27. Confirming the results by Goyal and Saretto (2009), $HV - IV_{1M}$ reports a positive coefficient of 0.040 and a t-statistic of 1.77. All volatility measures related with volatility overreaction ($IV_{1M}^{t-1} - IV_{1M}$, $IV_{1M}^{t-3} - IV_{1M}$, $IV_{1M}^{t-6} - IV_{1M}$, and $IV_{1M}^{avg} - IV_{1M}$) report a positive and significant coefficient. For example, the coefficient of $IV_{1M}^{t-3} - IV_{1M}$ is 0.122 with a t-statistic of 4.74. The volatility risk premium has a positive relation with future straddle returns with a coefficient of 0.045 and a t-statistic of 1.86. Only one variable, $IV_{1M}^{\max} - IV_{1M}$, reports a negative but not significant coefficient.

The last column of Table 3 reports the multivariate regression with the eleven measures of volatility minus IV_{1M}. Only three variables report positive and significant coefficients: the slope of the volatility term structure, $IV_{1M}^{t-3} - IV_{1M}$, and $IdioVol - IV_{1M}$. The slope of the volatility term structure reports the highest coefficient (0.201) with a t-statistic of 2.80. The coefficients of $IV_{1M}^{t-3} - IV_{1M}$ and $IdioVol - IV_{1M}$ are 0.088 and 0.0730 with t-statistics of 3.02 and 2.63 respectively. As opposed to the results in the univariate regressions, five variables report negative coefficients in the multivariate regression: $HV - IV_{1M}$, $RV_{1w} - IV_{1M}$, $RV_{1M} - IV_{1M}$, $IV_{1M}^{t-1} - IV_{1M}$, and $IV_{1M}^{\max} - IV_{1M}$. The most important finding in the multivariate regression is that the slope of the volatility term structure predicts risk-adjusted straddle returns in the presence of ten volatility measures.

[Insert Table 4 here]

To ensure that the slope of the volatility term structure is related with straddle returns, we use the double sorting methodology. In the first stage, we rank the stocks by the firm characteristic and form five portfolios. Portfolio 1 (5) has stocks with low (high) values of the characteristic. In the second stage, we sort the stocks into five portfolios using the slope of the volatility term structure within each firm characteristic portfolio. Then, we compute the average option return for each level of the slope of the volatility term structure and also report the long-short option return. Table 4 reports quintile straddle returns, the long-short option returns and the t-statistics for each volatility measure minus IV_{1M}. All the long-short straddle returns are positive and significant. The long-short straddle returns are between 7.1% and 12.2%, while the t-statistics are between 6.43 and 9.70. The lowest long-short return of 7.1% occurs when double sorting by the difference between the lagged 3-month implied volatility and implied volatility, $IV_{1M}^{t-3} - IV_{1M}$.

Using the modified Fama-MacBeth regressions and double sorts, we conclude that the slope of the volatility term structure predicts straddle returns over and above all volatility measures. We now explore the source of this predictability.

4.4 Exploring the Source of Predictability

In the previous section we document that the slope of the volatility term structure is related with future straddle returns. In addition, we find that other volatility measures (minus IV_{1M}) are also related with straddle returns. In this section we explore the source of predictability of straddle returns.

The straddle is a trading strategy to buy or sell volatility. Positive (negative) straddle returns are generated when the volatility over the life of the option (FV), defined as the standard deviation of the underlying stock return, is greater (lower) than the implied volatility (IV_{1M}) of the straddle at the time of its purchase. We illustrate this point with an in-sample exercise. We form ten straddle portfolios based on the difference between future volatility (FV) and current volatility, $FV - IV_{1M}$, and examine contemporaneous straddle returns. In unreported results, sorting by $FV - IV_{1M}$ produces a long-short monthly straddle return of 90.0% with a t-statistic of 34.83. This result confirms that straddle returns are largely driven by the spread between future realized volatility and current implied volatility, $FV - IV_{1M}$.

We now explore whether the slope of the volatility term structure and other volatility measures can predict future realized volatility minus current implied volatility, $FV - IV_{1M}$. Following the analysis of Cao, Yu, and Zhong (2010), we perform time-series regressions of the difference between future realized volatility (FV) minus implied volatility (IV_{1M}) on several volatility measures minus IV_{1M}. Each month, we perform the following regression:

$$FV_{i,t} - IV_{1M_{i,t}} = B_{0,t} + B_{1,t}(IV_{LT_{i,t}} - IV_{1M_{i,t}}) + B_{k,t}(Volatility\ Measures_{k,t} - IV_{1M_{i,t}}) + \varepsilon_{i,t}.$$

We run the two stage Fama and MacBeth (1973) regression. In the first stage, we run the regression for every month. In the second stage, we obtain the average for each regressor. To account for autocorrelation and heteroscedasticity, we evaluate the significance of the regressor with the Newey-West t-statistic with 3 lags.

[Insert Table 5 here]

Table 5 summarizes the results for seven regressions. We report the average coefficients, their t-statistics, and the percentage of times that the coefficients are significant. In the first (univariate) regression the coefficient of the slope of the volatility term structure is 0.347 with a Newey-West t-statistic of 10.73. In addition, 65% of the time the coefficient is statistically significant. In the second univariate regression, the coefficient of $HV - IV_{1M}$ is 0.19 with a t-statistic of 10.13, and it is statistically significant 64% of the time. Next, we perform the regressions on the realized volatility measures minus IV_{1M}. Corsi (2009) and Busch, Christensen, and Nielsen (2011) document that the one-day, one-week and one-month realized volatility measures are good predictors of future volatility. We include the Heterogeneous Autoregressive model of realized volatility (HAR) proposed by Corsi (2009) to forecast future volatility. Consistent with his results, the coefficients of $RV_{1d} - IV_{1M}$ and $RV_{1M} - IV_{1M}$ are positive and significant, and are significant 18% and 45% of the time, respectively. Regressions 4 and 5 use lagged implied volatility measures (minus IV_{1M}) to account for volatility overreaction. The coefficients of $IV_{1M}^{t-1} - IV_{1M}$, $IV_{1M}^{t-3} - IV_{1M}$, $IV_{1M}^{t-6} - IV_{1M}$ and $IV_{1M}^{avg} - IV_{1M}$ are positive and significant. $IV_{1M}^{\max} - IV_{1M}$ reports a negative and significant coefficient of -0.189 with a t-statistic of -6.44. Regression 6 reports the regression on idiosyncratic volatility minus IV_{1M}. The coefficient is positive and significant.

Finally, we perform a multivariate regression with all volatility measures. Six volatility measures report a positive and significant coefficient: the slope of the volatility term structure ($IV_{LT_{i,t}} - IV_{1M_{i,t}}$), $HV - IV_{1M}$, $RV_{1d} - IV_{1M}$, $RV_{1w} - IV_{1M}$, the volatility risk premium ($RV_{1M} - IV_{1M}$), and $IV_{1M}^{avg} - IV_{1M}$. These results confirm that the HAR model is good at forecasting future volatility. The highest coefficients are those of the slope of the volatility term structure ($IV_{LT_{i,t}} - IV_{1M_{i,t}}$), $HV - IV_{1M}$, the volatility risk premium ($RV_{1M} - IV_{1M}$), and $IV_{1M}^{avg} - IV_{1M}$ that range between 0.100 and 0.183. Also, the percentage of times that these coefficients are positive is between 21% and 28%. On the other hand, the coefficients of $IV_{1M}^{t-1} - IV_{1M}$, $IV_{1M}^{t-6} - IV_{1M}$ and $IV_{1M}^{\max} - IV_{1M}$ are negative and significant.

We conclude that the slope of the volatility term structure is related with future straddle returns because of its ability to predict future volatility (minus IV_{1M}). However, the slope of the volatility term structure is not a perfect predictor of future volatility (minus IV_{1M}). Most of the other volatility measures, eight out of ten in the multivariate regression, are needed to explain future realized volatility.

4.5 Controlling for Higher Moments and Jump Risk

Using the modified Fama and MacBeth (1973) regressions proposed by Brennan, Chordia, and Subrahmanyam (1998), we examine whether risk-adjusted straddle returns are explained by the higher moments or jump risk. Higher risk-neutral moments, risk-neutral volatility ($RNVol$), skewness ($RNSkew$) and kurtosis ($RNKurt$), are computed with the model free methodology proposed by Bakshi, Kapadia, and Madan (2003). To account for jump risk, we include six proxy variables in the regressions. Bakshi and Kapadia (2003) show that risk-neutral skewness and risk-neutral kurtosis proxy for jump risk. Another proxy for jump risk is the slope of the volatility smile, $OptionSkew$, the difference between out-of-the-money and at-the-money volatilities proposed by Xing, Zhang and Zhao (2010). Yan (2011) proposes a risk neutral jump measure, $RNJump$, computed as the spread between short-term at-the-money put and call implied volatilities. Finally, we include the model-free measures of left tail ($RNJump\ Left$) and right tail ($RNJump\ Right$) risk-neutral jump derived by

Bollerslev and Todorov (2011).

[Insert Table 6 here]

Table 6 reports the regressions of risk-adjusted option returns on the slope of the volatility term structure, higher moments, and jump risk measures. The coefficient of the slope of the volatility term structure is positive and significant for the two regressions. Comparing the univariate and the multivariate regressions, we conclude that the strong positive relation between the slope of the volatility term structure and straddle returns is not explained by higher moments or by jump risk. The univariate regression shows that the coefficient for the slope of the volatility term structure is 0.298 with a t-statistic of 4.97. After including higher moments and jump risk proxies, the coefficient of the slope of the volatility term structure increases to 0.303 and the t-statistic is now 3.42. Therefore, including higher moments and jump risk exacerbates the effect of the slope of the term structure instead of reducing it.

[Insert Table 7 here]

To further test that the abnormal straddle returns are not driven by higher moments or jump risk, we perform the double sorting methodology between the slope of the volatility term structure and each measure. Table 7 reports quintile straddle returns, the long-short straddle returns and the t-statistics using two-way sorts for the higher moments and the jump risk measures. The long-short straddle returns are positive and significant across all measures. The long-short straddle returns are between 10.6% and 11.7%, while the t-statistics are between 8.11 and 10.10.

To summarize, we have shown that the positive relation between straddle returns and the slope of the volatility term structure is not explained by higher risk neutral moments or jump risk. The modified Fama-MacBeth regressions and two-way sorts confirm that there is a positive relation between the straddle returns and the slope of the volatility term structure. Moreover, controlling for jump risk and higher moments in the modified Fama-MacBeth regressions increases the effect of the slope of the volatility term structure.

4.6 Transaction Costs

The results presented so far do not include trading frictions. We investigate the impact on the long-short straddle returns of two types of trading frictions: bid-ask spreads and margin requirements. In Panel A of Table 1 we report an average bid-to-mid percent spread for option prices of 6.6% and 8.5% for portfolios 1 and 10. Hence, the bid-ask spreads will reduce the large profits of the straddle long-short strategy. To mitigate the effect of the bid-ask spreads, options are held until maturity. When expired, the payoff for the option is based only on the stock price and the strike price. If the option expires in-the-money, the stock incurs transaction costs.[10]

Financial research has reported that the effective option spread can be lower than 50% of the quoted spread (De Fontnouvelle, Fisher, and Harris (2003) and Mayhew (2002)), but in some cases it can be as large as 1.0 (Battalio, Hatch, and Jennings (2004)). Recent work by Muravyev and Pearson (2014) shows that average investors and algorithmic traders get an effective spread that is 50% and 12.5% lower than the bid-ask spread based on daily closing quotes. Panel A of Table 8 reports the long-short straddle returns for effective bid-ask spreads of 25%, 50%, 75% and 100% across quartiles portfolios formed on bid-ask spread. Quartile 1 (Q1) contains straddles with the smallest quoted bid-ask spread and quartile 4 (Q4) contains straddles with the highest quoted bid-ask spread. An effective bid-ask spread ratio of 50% (100%) is equivalent to paying half (full) the bid-ask quoted spread when executing the option trading strategy.

[Insert Table 8 here]

Table 8, Panel A reports the long-short straddle return of quartile portfolios ranked by their bid-ask spread across ratios of the effective bid-ask spread. The first three quartile portfolios (Q1, Q2 and Q3) report a positive and significant return for all effective spread ratios (Q2 is not significant when the ratio is 100%). For example, the portfolio with the

[10] For stocks, bid and ask quotes are obtained from the CRSP database.

lowest bid-ask spread (Q1) reports a long-short straddle return of 16.7% with a t-statistic of 4.88 when the effective spread ratio is 25%. The combined portfolio of Q1 and Q2, or Q1, Q2 and Q3 also reports positive and significant returns for all ratios. The long-short straddle return for Q1, Q2 and Q3 is 6.8% with a t-statistic of 3.72 when the effective option spread is 100% of the quoted spread. The results are similar for the portfolio that trades Q1 and Q2 simultaneously.

The portfolio with the highest bid-ask spreads, Q4, reports a significant return of 8.7% with a t-statistic of 2.98 when the transaction can be executed at an effective bid-ask ratio of 25%. However, for a ratio of 50% the long-short return is positive but not significant, and turns negative for ratios of 75% and 100%. Finally, the long-short straddle return for the entire sample is positive and significant when the effective option bid-ask spread ratio is lower or equal to 75%. When the ratio is 75%, the long-short straddle return is 6.5% with a t-statistic of 3.91, compared with a return of 16.5% when trading at mid prices.

We now turn to the second type of trading friction: margin requirements. Saretto and Santa-Clara (2009) document that margin requirements can be very high when shorting options. Given that the long-short trading strategy involves a short position on straddles for portfolio 1, an investor must open and maintain a margin account. The initial margin requirement is the amount needed to open a position. Afterwards and until the position is closed, a maintenance margin is computed on a daily basis to maintain the position open. When the maintenance margin is greater than the initial margin requirement, the exchange issues a margin call and the investor has to increase the margin or close out the position.

We compute the margin haircut ratio for Portfolio 1 as proposed by Saretto and Santa-Clara (2009). The margin haircut ratio is the amount of required margin that exceeds the price at which the straddle was written. The haircut ratio is equal to $(M_t - V_0)/V_0$, where M_t is the margin at the end of each day t, and V_0 is equal to the proceeds received at the beginning of the trade for the straddle. To compute the margin requirements, we follow the CBOE Margin Manual methodology. Specifically, for a straddle, the margin requirement at time t is equal to the maximum of the call or put margin plus the option proceeds of the other side. The call and put margins are defined as

$$\text{Call Margin:} \qquad M_t = \max(c_t + \alpha S_t - \max(K - S_t, 0), c_t + \beta S_t) \text{ and}$$

$$\text{Put Margin:} \qquad M_t = \max(p_t + \alpha S_t - \max(S_t - K, 0), p_t + \beta K)$$

where c_t and p_t are the call and put option prices at time t, S_t is the underlying stock price at time t, K is the strike price of the options, and $\alpha = 20\%$ and $\beta = 10\%$ as specified in the CBOE Margin Manual.

Panel B of Table 8 reports descriptive statistics for the haircut ratio and the percentage of wealth that must be used for margin requirements given the haircut ratio. On average, an investor must deposit \$1.54 in the margin account (in addition to the proceeds from the straddle sale) for every dollar received from writing straddles. The maximum historical haircut ratio for portfolio 1 is \$4.41 and the minimum is 23 cents. The inverse of the haircut ratio gives the percentage of wealth to be allocated to the margin account. An investor must allocate on average 35% of his wealth, and up to a maximum of 77%, when shorting portfolio 1. This analysis applies to individual investors since we used CBOE rules. Saretto and Santa-Clara (2009) show the margin cost to write straddles is about three times lower for institutional investors than for individual investor. Since large firms can dedicate enough cash for margin, the implementation of the long-short strategy should possible.

We conclude that in most cases the long-short straddle returns are positive and significant after transaction costs. To profit from the long-short straddle strategy, an investor should trade the options in the lowest 75 percentile bid-ask spreads paying special attention to execute the trades within the quoted bid-ask spread. Additionally, an individual investor must allocate on average 35% of his wealth to maintain the margin account of the short side of the portfolio.

5 Robustness Analysis

In this section, we check the robustness of the relation between the slope of the volatility term structure and straddle returns. First, we check that the results are robust to different firm characteristics such as option illiquidity, size, book-to-market, historical higher moments, and option greeks. Second, we investigate the robustness of the results for different subgroups of the data, and for different definitions of the filters and input variables. Third, we look at straddle returns for different horizons.

5.1 Controlling for Stock Characteristics

Table 9 reports the results of the modified Fama and MacBeth (1973) regressions proposed by Brennan, Chordia, and Subrahmanyam (1998) of straddle returns on firm characteristics to further control that the slope of the volatility term structure predicts option returns. In addition to the slope of the term structure, the regression includes the option volume (in dollars and in contracts), option open interest, option bid-to-mid spread, size of the firm, historical volatility, book-to-market, skewness and kurtosis, and the option Greeks: delta, gamma and vega.

[Insert Table 9 here]

Table 9 presents the results for three regressions. The coefficient of the slope of the volatility term structure is positive and significant for the three regressions. The first regression includes the slope of the volatility term structure, and the option Greeks. The coefficient of the slope of the volatility term structure is 0.266 with a Newey-West t-statistic of 5.69. The second regression includes the slope of the volatility term structure, option illiquidity measures and the option Greeks. The coefficient of the slope of the volatility term structure is 0.253 with a Newey-West t-statistic of 5.60. The coefficient of the bid-to-mid option spread is 0.014 with a Newey-West t-statistic of 2.14, implying that options with higher bid-ask spread report higher straddle returns. The dollar-volume coefficient is negative and slightly significant. The other two liquidity measures, option contract volume and option open interest, yield positive and not significant coefficients. As for the option greeks, the delta shows a positive and significant relation with the long-short straddle returns. The coefficient is 0.111 with a Newey-West t-statistic of 4.36. We conclude that the relation between the slope of the volatility term structure is not explained by option liquidity or option Greeks.

In the third regression, we regress risk-adjusted straddle returns on option greeks and five firm characteristics: size, book-to-market, historical volatility, skewness and kurtosis. The coefficient of the slope of the volatility term structure slightly increases to 0.303 with a Newey-West t-statistic of 6.30. The coefficients of size of the firm, and historical volatility are negative and significant. The higher volatility is, the lower the straddle return. The same negative relation applies for size: small firms report a higher straddle return than large firms. Finally, delta displays a positive and significant relation with straddle returns. The other variables (book-to-market, skewness, kurtosis, gamma and vega) show no strong relation with straddle returns.

[Insert Table 10 here]

Table 10 reports the long-short straddle returns and the t-statistics for each firm characteristic using the two-way sort methodology. As in the previous double sorting tables, all of the long-short straddle returns are positive and significant. In this case, the long-short straddle returns range between 10.3% and 12.4%, while the t-statistics are between 7.89 and 13.99.

In conclusion, the slope of the volatility term structure is positively related to straddle returns according to the modified Fama-MacBeth regressions and the two-way sorting methodology. We show that the slope of the volatility term structure is not a proxy for option illiquidity or firm characteristics such as size, book to market, historical moments or option greeks.

5.2 Moneyness

[Insert Table 11 here]

In our study, the moneyness level for call and put options is between 0.95 and 1.05. Table 11 shows that when the moneyness bounds are changed to 0.975 and 1.025, the long-short straddle return is 16.9% with a t-statistic of 9.94. In this case, the number of stocks per month decreases from 516 to 328. If the moneyness is not bounded, the long-short straddle return decreases to 15.4% with a t-statistic of 9.55, and the number of stocks per month increases from 516 to 652. The magnitude of the straddle returns and the t-statistics remains very similar to those reported in the primary analysis.

5.3 Sub-samples

We divide the sample into two sub-periods: 1996 to 2003 and 2004 to 2012. The long-short straddle returns decrease from the first period to the second. For the 1996-2003 period, the long-short straddle portfolio has an average monthly return of 19.0% with a t-statistic of 6.93, and the 2004-2012 period has a return of 14.0% with a t-statistic of 7.78. The decrease in option returns from the first to the second sub-period is compensated by a decrease in trading costs as reported by De Fontnouvelle, Fisher, and Harris (2003), Battalio, Hatch, and Jennings (2004), and Hansch and Hatheway (2001).

Next, we ensure that the triple witching Friday is not driving the results. The triple witching Friday refers to the third Friday of every March, June, September, and December when three different types of securities expire on the same day: stock index futures, stock index options and stock options. Since the market is particularly active in these months, we divide the sample into two groups: options that expire on the triple witching-Friday and options that expire in any other month. The two groups obtain similar straddle returns. Table 11 shows that the triple-witching Friday group has a long-short straddle return of 16.6% with a t-statistic of 5.54 and the other group has a return of 16.5% with a t-statistic of 8.34.

We also control for the January effect that causes stock prices to increase during that month. Option returns in the month of January are compared to those for the rest of the year. As Table 11 reports, the January group has an average long-short straddle return of 20.4% with a t-statistic of 3.48 while the non-January group has a return of 16.2% with a t-statistic of 9.42.

In conclusion, the relation between the slope of the volatility term structure and the long-short straddle return holds for different sub-samples.

5.4 Filters, Implied Volatility, and Arbitrage Bounds

Options that violate arbitrage bounds are excluded from the analysis. Duarte and Jones (2007) note that options that violate arbitrage bounds might be valid options that, at some point in time, have their prices below intrinsic value making it impossible to solve for an implied volatility. To account for this bias and to include as many options as possible, we relax the filters. First, all options with a positive volume are included even if they do not have an implied volatility. Since some options do not have volatility, we now extract all of the implied volatilities from the standardized OptionMetrics Volatility Surface database. IV_{1M} and IV_{LT} are defined as the average implied volatility of the call and put options with 30 and 365 days to expiration, and an absolute delta of 0.5. When no volatility is available, we look for a valid volatility on the 10 days before the transaction date and select the volatility from the closest date to the transaction date. Third, all options have exactly 30 days to expiration. When options with 30 days to maturity are not available, we extract all of the at-the-money options with expirations between 20 and 40 days, and choose the pair with the closest maturity to 30 days. When two pairs are available, say 28 and 32 days to expiration, we select the one with the highest total volume. All the other filters are applied: positive bid-ask spread, volatility between 3% and 200%, moneyness between 0.95 and 1.05, and underlying price above $5.

The results are robust to the inclusion of options that violate arbitrage bounds. As reported in Table 11, the long-short straddle return is 15.9% with a t-statistic of 10.18. The average number of stocks per month increases from 516 to 892. Options that violate arbitrage bounds only account for 0.4% of the sample data. The increase in the number of stocks comes from the usage of the OptionMetrics Volatility Surface to extract implied volatilities.

In summary, straddle returns are robust to the inclusion of options that violate arbitrage bounds.

5.5 Earnings Announcements

Dubinsky and Johannes (2005) report that earnings announcements enhance the uncertainty of a company, defined as the implied volatility. Volatility increases before earnings are announced and decreases after the announcement. To confirm that the returns occur in periods other than the earnings announcement periods, we exclude all firms that have an earnings announcement date that falls between the transaction day and the expiration day.

When firms with earnings announcements are excluded, the magnitude of the long-short straddle return increases to 19.0% with a significant t-statistic of 9.61 as reported in Table 11. When firms with earnings announcements are included, the long-short straddle return is 15.1% with a t-statistic of 3.85. Therefore, the long-short straddle returns are robust to earnings announcements.

5.6 Controlling for Weighting Schemes

In the primary analysis, the portfolios are equally weighted. We now explore the robustness of the results for two different weighting schemes. First, we study value-weighted portfolios which are based on the option dollar volume for each stock. Second, straddles portfolios are weighted by the minimum dollar value of the volume or the open interest between the put and the call. With the new weighting schemes, the long-short straddle returns are significant and of the same magnitude as the original returns. As shown in Table 11, the long-short straddle returns for the value-weighted and the open-interest weighted portfolios are 12.2% and 15.3%, respectively, and the t-statistics are above 3.11. Hence, the results are robust to the weighting methodology.

5.7 Alternative Definitions for the Slope of the Volatility Term Structure

In the main analysis, the slope of the volatility term structure is defined as the difference between the long-term implied volatility minus the one-month implied volatility. The maturity of the long-term implied volatility can arbitrarily range from 2 to 12 months depending on the availability of long-term options. We now study the robustness of the results to different definitions of the slope of the volatility term structure where the long-term maturity is fixed at 3-months, 6-months and 9-months. With the new definitions of the slope of the volatility term structure, the long-short straddle returns are positive and significant. As shown in Table 11, the long-short straddle returns for the 3-month, 6-month and 9-month definitions of the slope of the volatility term structure are 12.7%, 15.8% and 16.9% respectively, and the t-statistics are above 7.65. The greater the maturity of the long-term implied volatility, the higher the long-short straddle return. We conclude that the definition of the slope of the volatility term structure does not change the results.

5.8 Alternative Forecast Horizons

Thus far the empirical analysis has been based on one-month straddle returns. In this section we study two-week and three-week holding periods. The two-week returns are constructed with options that are 2 weeks and 4 weeks away from maturity. We form straddle portfolios based on the slope of the volatility term structure four weeks before options expiration and hold these portfolios for two weeks. Then, we construct new straddle portfolios based on the slope of the volatility term structure and hold the new portfolios until maturity. The three-week straddle returns are constructed three weeks before the option's maturity.

[Insert Table 12 here]

Table 12 contains the results for the two-week and three-week straddle returns. We report the average straddle returns of decile portfolios, their t-statistic, standard deviation, skewness and kurtosis. The two-week returns are 12.8% with a t-statistic of 7.68, and the three week returns are 13.6% with a t-statistic of 6.16. The standard deviation is similar for the 2-week and 3-week returns at 32.8% and 31.0%. The two-week straddle returns are highly non-normal with a skewness of 3.3 and a kurtosis of 29.0. The three-week return is closer to the normal distribution with a skewness of 0.2 and a kurtosis of 4.9.

The strong positive relation between the slope of the volatility term structure and straddle returns in Table 2 is confirmed for the two-week and three-week horizons.

6 Discussion

In this section we explore the possibility of a risk-based explanation for the documented pattern in straddle returns. First, we study the risk of the portfolios with two measures of portfolio risk, value-at-risk and expected shortfall. Second, we examine possible explanations of our results.

6.1 Risk Based Explanations

In Panel C of Table 2, we conclude that factor models such as Carhart, coskewness, and cokurtosis cannot explain the difference in returns between portfolio 10 and portfolio 1. To further explore the pattern of straddle returns across decile portfolios, we compute standard risk measures for each portfolio. If straddle returns are explained by risk, higher levels of risk should translate into higher returns.

[Insert Table 13 here]

Table 13 reports two risk measures: value-at-risk and expected shortfall at the 5 percent level. Given that straddle returns are not normally distributed, we compute both measures using historical monthly returns. An advantage of the historical method is that it does not impose a particular distribution on returns. We find that portfolio 1, the one with the lowest return, is riskier than portfolio 10, the one with the highest returns. The 5% value-at-risk is 39.3% for portfolio 1 and 24.5% for portfolio 10. Similarly, the 5% expected shortfall is 46.0% and 34.7% for portfolios 1 and 10.

We conclude that standard risk measures such as value-at-risk and expected short fall do not explain our results.

6.2 Discussion

We now explore other possible explanations of our empirical results such as volatility overreaction, volatility risk premium, idiosyncratic risk, and demand pressures.

Poteshman (2001) and Stein (1989) document that investors can underreact or overreact to changes in short-term volatility. In Table 1 and Table 3 we include several measures of volatility misreaction: $IV_{1M}^{t-1} - IV_{1M}$, $IV_{1M}^{t-3} - IV_{1M}$, $IV_{1M}^{t-6} - IV_{1M}$, and $IV_{1M}^{avg} - IV_{1M}$. Given that volatility is mean reverting, a measure such as $IV_{1M}^{avg} - IV_{1M}$ captures deviations of current implied volatility from its historical average. A positive (negative) value of $IV_{1M}^{avg} - IV_{1M}$ means that current volatility has underreacted (overreacted) compared to its historical average and such options are potentially underpriced (overpriced). According to Panel B of Table 1, the magnitude of the slope of the volatility term structure and the measures of volatility overreaction is very similar. For example, the slope of the volatility term structure is -14.7%, -1.5%, and 7.6% for portfolios 1, 5 and 10, while $IV_{1M}^{t-6} - IV_{1M}$ is -14.6%, -0.2%, and 8.7% for the same portfolios. The correlation matrix on Panel C of Table 1 indicates a high correlation (ranging from 51.3% to 65.1%) between the slope of the volatility term structure and the measures of volatility misreaction. The correlation among the four measures of volatility overreaction is between 36.1% and 82.0%. In addition, the univariate modified Fama-MacBeth regressions in Table 3 report a positive and significant relation between the four measures of volatility overreaction and straddle returns. In the multivariate regression, only the slope of the volatility term structure and $IV_{1M}^{t-3} - IV_{1M}$ remain positive and significant. Given the large correlations and the results of the modified Fama-MacBeth regressions, it is possible that the slope of the volatility term structure is measuring volatility underreaction and overreaction.

Investor underreaction and overreaction to current events is supported by models of investor sentiment such as the ones proposed by Barberis, Shleifer, and Vishny (1998) and Daniel, Hirshleifer, and Subrahmanyam (1998). The logic from these models can be applied to straddle returns and volatility misreaction as follows. In calm periods, when volatility is low for a given firm, investors underreact and underestimate volatility. This mistake is corrected the following period (month) when straddles report positive returns. On the contrary, in turbulent periods, investors overreact and overestimate volatility. This is corrected in the following period when straddles report negative returns. These models support that the slope of the volatility term structure could potentially capture underreaction and overreaction in volatility.

Another possible explanation is that the slope of the volatility term structure is measuring the volatility risk premium. We define the volatility risk premium as $FV - IV_{1M}$ following Carr and Wu (2008). On Table 5, we show that the slope of the volatility term structure predicts $FV - IV_{1M}$, a measure of the ex-post volatility risk premium. However, there are five more measures of volatility that also predict $FV - IV_{1M}$. Panel C of Table 1 shows that the correlation between the slope of the volatility term structure and the (ex-post) volatility risk premium is very low. The correlation between slope of the volatility term structure and $FV - IV_{1M}$ is only 3.6%, and that with the volatility risk premium, $RV_{1M} - IV_{1M}$, is 15.0%. In unreported results, we document that sorting by the ex-post volatility risk premium,

$FV - IV_{1M}$, produces a long-short monthly straddle return of 90.0% with a t-statistic of 34.83. When we include $FV - IV_{1M}$ in Fama-MacBeth regressions similar to those on Table 3, the coefficient is 1.72 with a t-statistic of 19.68 in the univariate regression. In the multivariate regressions the coefficient remains virtually unchanged, and the coefficient of the slope of the volatility term structure remains positive and significant. If the slope of the volatility term structure were capturing cross-sectional volatility-risk premium its coefficient in the multivariate regression should not be significant. Its explanatory power would be subsumed by that of the ex-post volatility risk premium. Overall, we do not find strong support that the slope of the volatility term structure is a proxy of the volatility risk premium.

An alternative explanation of the large long-short straddle returns is idiosyncratic risk. Pontiff (2006) defines idiosyncratic risk as an arbitrage cost faced by arbitrageurs when trying to profit from mispricing. The fact that the arbitrageur cannot hedge away idiosyncratic risk might prevent the arbitrageur from entering the transaction. Even if the arbitrageur holds a diversified portfolio, the idiosyncratic risk of each individual straddle in the portfolio prevents the arbitrageur from the transaction altogether. To profit from the long-short straddle portfolio, the arbitrageur must sell portfolio1. According to Table 1, Panel A, options in portfolio 1 have the largest average IV_{1M} of 73.6%. When selling this portfolio, the arbitrageur increases his vega (volatility) exposure considerably. The arbitrageur could hedge the systematic volatility exposure of portfolio 1. However, the exposure of each individual straddle might be impossible to hedge away given the large implied volatility and the large number of stocks (52 on average). This idiosyncratic risk might move the arbitrageur away from this profitable strategy.

A final alternative explanation for the positive relation between the slope of the volatility term structure and future straddle returns are demand pressures of the type studied by Garleanu, Pedersen, and Poteshman (2009). On the one hand, when IV_{1M} is too high compared to IV_{LT}, option investors demand more short-term options to hedge away further volatility increments. This positive demand pressure makes these options more expensive. On the other hand, when IV_{1M} is too low compared to IV_{LT}, there is no demand pressure and options become cheap. Carr and Wu (2008) provide evidence of a similar phenomenon for variance swaps, where variance swap buyers are willing to suffer negative returns to hedge away upward movements in the variance. Similar results are reported in Black and Scholes (1972), who find that options of high variance stocks are overpriced and options of low variance stocks are underpriced. Therefore, demand-pressure effects might be causing the mispricing in current option prices that leads to large future returns.

7 Conclusions

This paper documents a positive relation between the slope of the implied volatility term structure and straddle returns in the cross section. The slope of the volatility term structure is defined as the difference between implied volatilities of long- and short-dated at-the-money options. Every month, we rank stocks according to the slope of the volatility term structure and study subsequent one month straddle returns. We find that as the slope of the volatility term structure increases, so does the one-month future straddle return. The straddle portfolio with the highest slope of the volatility term structure outperforms the portfolio with the lowest slope by a significant 16.5% per month.

The large abnormal returns hold for different time periods, alternative horizons, weighting schemes, and for options that violate arbitrage bounds. Fama-MacBeth regressions of the type proposed by Brennan, Chordia, and Subrahmanyam (1998) and double sorts confirm the predictive power of the slope of the volatility term structure. The abnormal straddle returns are not explained by the Fama-French-Carhart factors, option factors, jump risk or firm characteristics. Transaction costs, namely bid-ask spreads, reduce the straddle monthly profits. However, positive and significant returns can be generated when trading within the bid-ask spread options in the lowest 75 percentile of the quoted bid-ask spread.

The most likely explanation underlying the large and significant individual option returns is underreaction and overreaction to volatility. Options are cheap (expensive) when investors underreact (overreact) in their estimates of volatility. Once the misreaction is corrected, straddle portfolios with cheap option generate positive returns and the ones with expensive options generate negative returns. The evidence does not support a volatility risk premium explanation for the slope of the volatility term structure effect.

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Figure 1: Time Series of Straddle Returns

Straddle returns are generated as in Table 2. The figures below display the option returns of the long-short portfolios defined as the difference between decile 10 (highest slope of volatility term structure) and decile 1 (lowest slope of volatility term structure) straddle portfolios. The sample period is January 1996 to January 2012.

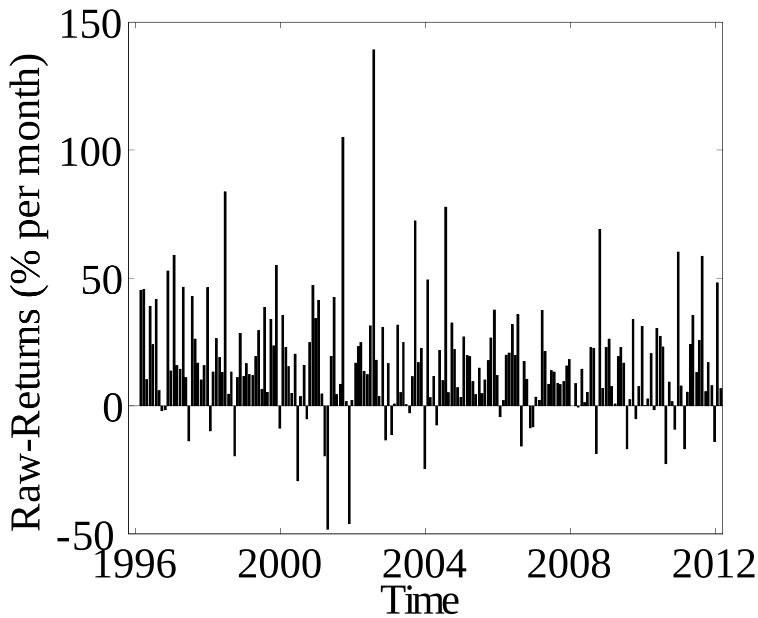

Figure 2: QQ-plot of Straddle Returns

Straddle returns are generated as in Table 2. The figures below display the qq-plots of the straddle returns of the long-short portfolios defined as the difference between decile 10 (highest slope of volatility term structure) and decile 1 (lowest slope of volatility term structure) portfolios. The sample period is January 1996 to January 2012.

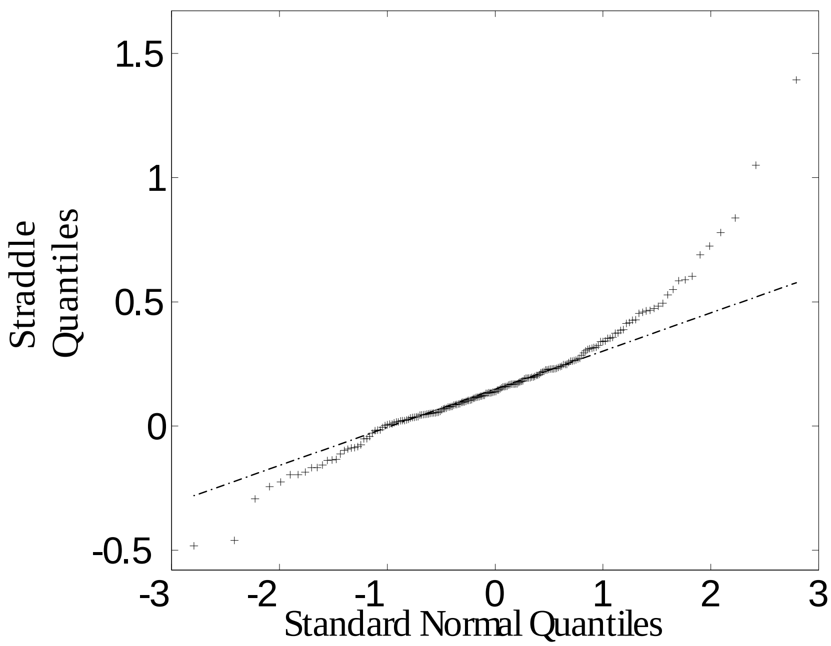

Table 1
Characteristics of Portfolios Sorted by the Slope of the Volatility Term Structure

Panel A reports the characteristics of ten portfolios sorted by the slope of the volatility term structure, ($Slope\ VTS$ defined as $IV_{LT} - IV_{1M}$) for the period January 1996 to January 2012. Average characteristics of the portfolios are reported for IV_{1M} (the one-month implied volatility defined as the average of the ATM call and ATM put implied volatilities), IV_{LT} (the long-term implied volatility defined as the average of the ATM call and ATM put implied volatilities of the options with the more distant time-to-maturity), $ Size Options (Open interest of the ATM call and put multiplied by their respective mid price, in $ thousands), DTM of IV_{LT} (average days to maturity of the long-term implied volatility), the put-call spread of IV_{1M}, the bid to mid spread of IV_{1M} , Delta Call, Delta Put, Gamma, Vega, Size (market capitalization in $ billions), BE/ME (book-to-market ratio), risk-neutral volatility ($RNvol$), skewness ($RNskew$) and kurtosis ($RNkurt$) as defined in Bakshi, Kapadia, and Madan (2003), risk-neutral jump ($RNjump$) is the spread between short-term at-the-money put and call implied volatilities defined as in Yan (2011), idiosyncratic volatility ($idioVol$), future volatility (FV) computed as the standard deviation of the underlying stock return over the life of the option. Panel B reports on volatility measures minus IV_{1M}. Volatility measures are the long-term implied volatility (IV_{LT}), future volatility (FV), the one-year historical volatility of daily returns (HV), realized volatility computed with 5-minute returns over 1 day (RV_{1d}), 1 week (RV_{1w}) and 1 month (RV_{1M}), implied volatility lagged by one month (IV_{1M}^{t-1}), 3 months (IV_{1M}^{t-3}), and 6 months (IV_{1M}^{t-6}), the maximum ($IV_{1M}^{\max}$) and average (IV_{1M}^{avg}) implied volatilities over the previous 6-months, and idiosyncratic volatility ($idioVol$). Panel C reports the correlations of the volatility variables minus IV_{1M}.

Panel A: Portfolio Characteristics

Deciles	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10
Slope of the Volatility Term Structure										
Slope VTS	-0.147	-0.068	-0.043	-0.027	-0.015	-0.005	0.005	0.015	0.030	0.076
IV_{1M}	0.736	0.584	0.517	0.473	0.435	0.408	0.392	0.391	0.403	0.482
IV_{LT}	0.590	0.515	0.474	0.445	0.420	0.403	0.397	0.406	0.432	0.558
Option and Firm Characteristics										
$ Size Options	822	661	681	643	665	638	685	712	750	618
DTM of IV_{LT}	222	220	221	221	221	222	221	223	222	220
Put-Call Spread IV_{1M}	0.017	0.009	0.008	0.008	0.008	0.007	0.009	0.009	0.009	0.017
Bid to Mid Spread IV_{1M}	0.066	0.066	0.067	0.067	0.068	0.067	0.069	0.069	0.071	0.085
Delta call	0.551	0.547	0.544	0.541	0.540	0.530	0.526	0.521	0.520	0.523
Delta put	-0.449	-0.455	-0.459	-0.462	-0.465	-0.475	-0.479	-0.485	-0.486	-0.481
Gamma	0.199	0.210	0.213	0.219	0.226	0.228	0.241	0.246	0.257	0.312
Vega	7.15	8.21	8.68	9.12	9.34	9.89	9.63	9.69	9.36	7.34
Size	4.80	7.74	10.39	13.31	16.62	18.36	20.87	21.00	19.41	9.71
BE/ME	0.43	0.45	0.45	0.50	0.58	0.44	0.44	0.42	0.45	0.42
Higher Moments										
RNVol	0.679	0.586	0.537	0.499	0.464	0.441	0.425	0.422	0.436	0.510
RNSkew	-0.402	-0.440	-0.493	-0.520	-0.551	-0.571	-0.616	-0.624	-0.641	-0.597
RNKurt	3.739	3.915	4.109	4.232	4.360	4.413	4.617	4.641	4.702	4.676
RNJump	0.018	0.010	0.008	0.009	0.008	0.007	0.009	0.009	0.010	0.018
IdioVol	0.033	0.027	0.024	0.022	0.021	0.019	0.019	0.019	0.020	0.026
FV	0.668	0.561	0.497	0.459	0.425	0.403	0.389	0.388	0.407	0.494

Table 1 (Continued)

Panel B: Volatility Measures (minus IV_{1M})

Volatility Measures minus IV_{1M}										
Deciles	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10
Slope VTS	-0.147	-0.068	-0.043	-0.027	-0.015	-0.005	0.005	0.015	0.030	0.076
FV-IV_{1M}	-0.068	-0.023	-0.020	-0.014	-0.010	-0.006	-0.003	-0.003	0.004	0.013
HV-IV_{1M}	-0.096	-0.018	-0.001	0.013	0.019	0.028	0.037	0.051	0.072	0.125
RV_{1d}-IV_{1M}	-0.064	-0.030	-0.031	-0.024	-0.025	-0.022	-0.015	-0.012	-0.003	0.021
RV_{1w}-IV_{1M}	-0.062	-0.030	-0.027	-0.021	-0.022	-0.019	-0.013	-0.010	-0.002	0.027
VRP (=RV_{1M}-IV_{1M})	-0.071	-0.021	-0.018	-0.009	-0.010	-0.007	0.000	0.004	0.017	0.057
IV_{1M}^{t-1}-IV_{1M}	-0.118	-0.042	-0.021	-0.008	0.003	0.011	0.021	0.032	0.048	0.091
IV_{1M}^{t-3}-IV_{1M}	-0.134	-0.050	-0.026	-0.012	-0.001	0.010	0.018	0.028	0.044	0.087
IV_{1M}^{t-6}-IV_{1M}	-0.146	-0.057	-0.033	-0.016	-0.002	0.009	0.017	0.031	0.046	0.087
IV_{1M}^{avg}-IV_{1M}	-0.077	-0.025	-0.012	-0.003	0.004	0.010	0.016	0.023	0.035	0.068
$\text{IV}_{1M}^{\max}$-IV_{1M}	0.064	0.065	0.063	0.064	0.066	0.067	0.073	0.082	0.099	0.159
IdioVol-IV_{1M}	-0.703	-0.556	-0.493	-0.451	-0.415	-0.390	-0.374	-0.372	-0.383	-0.457

Panel C: Correlation Matrix

	Slope VTS											
FV-IV_{1M}	3.6	FV-IV_{1M}										
HV-$\text{IV}_{1\text{M}}$	46.3	2.1	HV−$\text{IV}_{1\text{M}}$									
RV_{1d}-IV_{1M}	3.3	10.0	5.0	RV_{1d}-IV_{1M}								
RV_{1w}-IV_{1M}	4.2	13.2	3.6	79.1	RV_{1w}-IV_{1M}							
VRP (=RV_{1M}-IV_{1M})	15.0	11.5	13.8	55.3	71.5	VRP (=RV_{1M}-IV_{1M})						
IV_{1M}^{t-1}-IV_{1M}	57.9	-0.4	43.9	4.3	3.6	18.5	IV_{1M}^{t-1}-IV_{1M}					
IV_{1M}^{t-3}-IV_{1M}	54.3	-2.8	60.2	1.1	-2.7	3.9	47.4	IV_{1M}^{t-3}-IV_{1M}				
IV_{1M}^{t-6}-IV_{1M}	51.3	-1.9	68.8	0.6	-1.7	4.0	36.1	62.4	IV_{1M}^{t-6}-IV_{1M}			
IV_{1M}^{avg}-IV_{1M}	65.1	0.9	45.3	2.4	3.4	28.2	82.0	48.0	39.9	IV_{1M}^{avg}-IV_{1M}		
$\text{IV}_{1M}^{\max}$-IV_{1M}	17.9	1.9	17.6	4.0	9.5	29.2	49.2	7.1	1.2	61.1	$\text{IV}_{1M}^{\max}$-IV_{1M}	
IdioVol-IV_{1M}	29.2	2.5	24.5	18.2	23.1	36.2	28.1	17.4	18.3	33.2	22.5	IdioVol-IV_{1M}

Table 2
The Slope of the Volatility Term Structure and the Cross-Section of Straddle Returns

Portfolios are constructed as in Table 1. Panel A reports the monthly equal-weighted straddle returns of decile portfolios along with the t-statistics (t-stat), standard deviation (StDev), skewness and kurtosis values. The last column displays the difference between decile portfolio 10 (highest slope of volatility term structure) and decile 1 (lowest slope of volatility term structure). In Panel B, we sample the long-short ($P10 - P1$) straddle returns 50,000 times to generate the reported finite sample critical value for the t-statistic. Panel C presents coefficients and t-statistics from the following regression:

$$\begin{aligned} r_{straddle} = {} & \alpha_P + \beta_1(R_m - R_f) + \beta_2 SMB + \beta_3 HML + \beta_4 UMD + \\ & \beta_5(R_o - R_f) + \beta_6(R_m^2 - R_f) + \beta_7(R_o^2 - R_f) + \beta_8(R_o R_m - R_f) \\ & \beta_9(R_o^3 - R_f) + \beta_{10}(R_m^3 - R_f) + \beta_{11}(R_o^2 R_m - R_f) + \beta_{12}(R_o R_m^2 - R_f) + \varepsilon \end{aligned}$$

where R_m is the return of the market, R_o is the straddle return of the S&P 500, R_f is the risk-free rate, and SMB, HML and UMD are the Fama-French and momentum factors, $r_{straddle}$ is the straddle return of the long-short portfolio. The first row gives the coefficients of the regression and the second row gives the t-statistics (in parentheses). Adjusted R^2 is reported at the bottom of the table. The sample period is January 1996 to January 2012.

Panel A: Straddle Returns

Deciles	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P10-P1
Mean	-0.092	-0.036	-0.044	-0.035	-0.028	-0.025	-0.033	-0.006	0.016	0.073	0.165
t-stat	(-5.96)	(-2.02)	(-2.58)	(-1.85)	(-1.44)	(-1.31)	(-1.64)	(-0.30)	(0.73)	(3.50)	(10.02)
StDev	0.213	0.249	0.237	0.260	0.267	0.264	0.276	0.288	0.302	0.291	0.228
Skewness	1.1	1.7	2.0	2.4	2.2	2.4	1.9	2.6	2.1	1.9	1.2
Kurtosis	3.3	6.1	8.9	10.7	9.3	10.0	6.5	11.8	8.1	6.9	5.4

Panel B: Bootstrapped Critical Values for the t-statistic

Percentile (%)	Bootstrapped t-statistic
1	-2.531
2.5	-2.115
5	-1.754
10	-1.357
90	1.234
95	1.562
97.5	1.842
99	2.165

Table 2 (Continued)

Panel C: Risk-Adjusted Returns

	(1)	(2)	(3)	(4)
Alpha	0.174	0.147	0.130	0.135
	(10.18)	(7.38)	(3.75)	(3.85)
R_m - R_f	-0.801	-0.399	-0.197	-0.240
	(-2.05)	(-1.16)	(-0.45)	(-0.50)
SMB	-0.769			-0.493
	(-1.56)			(-1.04)
HML	-0.723			-0.361
	(-1.39)			(-0.72)
UMD	0.110			-0.087
	(0.35)			(-0.28)
$R_o - R_f$		0.057	0.079	0.080
		(2.12)	(1.81)	(1.83)
$R_m^2 - R_f$		-6.39	-7.18	-7.65
		(-1.46)	(-1.32)	(-1.39)
$R_o^2 - R_f$		0.043	0.080	0.081
		(1.80)	(1.80)	(1.80)
$R_m R_o - R_f$		-0.946	-0.823	-0.847
		(-1.92)	(-1.36)	(-1.39)
$R_o^3 - R_f$			-0.026	-0.027
			(-1.01)	(-1.03)
$R_m^3 - R_f$			-1.64	-0.88
			(-0.14)	(-0.08)
$R_m R_o^2 - R_f$			-0.346	-0.295
			(-0.49)	(-0.41)
$R_m^2 R_o - R_f$			-0.335	-0.094
			(-0.05)	(-0.01)
Adj. R^2	0.029	0.150	0.139	0.131

Table 3
Volatility Measures and Straddle Returns

This table reports the results from the modified Fama-MacBeth monthly cross-sectional regressions proposed by Brennan, Chordia, and Subrahmanyam (1998) as in

$$r_{i,t} - \widehat{\beta}_i F_t = \gamma_{0,t} + \gamma'_{0,t} Z_{i,t-1} + \varepsilon_{i,t}$$

where $r_{i,t}$ is the straddle return in excess of the risk free rate for each security i at time t, F_t are the Fama-French-Carhart, coskewness and cokurtosis factors, and $Z_{i,t-1}$ are the characteristics for each stock i at time $t-1$. The $\widehat{\beta}_i$ are estimated in the first stage for each stock i using the entire sample. The characteristics are volatility measures minus IV_{1M}. Volatility measures are the long-term implied volatility (IV_{LT}), the one-year historical volatility of daily returns (HV), realized volatility computed with 5-minute returns over 1 day (RV_{1d}), 1 week (RV_{1w}) and 1 month (RV_{1M}), implied volatility lagged by one month (IV_{1M}^{t-1}), 3 months (IV_{1M}^{t-3}), and 6 months (IV_{1M}^{t-6}), the maximum ($IV_{1M}^{\max}$) and average (IV_{1M}^{avg}) implied volatilities over the previous 6-months, and idiosyncratic volatility ($idioVol$). The first row gives the coefficients of the regression and the second row gives the Newey-West t-statistics (in parentheses). Adjusted R^2 is reported at the bottom of the table. The sample period is January 1996 to January 2012.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Intercept	0.001	-0.001	0.000	0.000	0.001	0.001	-0.001	-0.002	0.001	0.000	0.035	0.027
	(0.14)	(-0.11)	(0.02)	(-0.03)	(0.22)	(0.16)	(-0.09)	(-0.27)	(0.08)	(-0.02)	(2.90)	(2.25)
Slope VTS	0.257											0.201
	(4.73)											(2.80)
HV-IV$_{1M}$		0.040										-0.082
		(1.77)										(-2.54)
RV$_{1d}$-IV$_{1M}$			0.011									0.008
			(0.83)									(0.39)
RV$_{1w}$-IV$_{1M}$				0.005								-0.021
				(0.35)								(-0.73)
VRP (=RV$_{1M}$-IV$_{1M}$)					0.045							-0.035
					(1.86)							(-0.98)
IV$_{1M}^{t-1}$-IV$_{1M}$						0.096						-0.017
						(3.58)						(-0.32)
IV$_{1M}^{t-3}$-IV$_{1M}$							0.122					0.088
							(4.74)					(3.02)
IV$_{1M}^{t-6}$-IV$_{1M}$								0.076				0.030
								(3.91)				(1.04)
IV$_{1M}^{avg}$-IV$_{1M}$									0.156			0.090
									(3.27)			(0.83)
IV$_{1M}^{\max}$-IV$_{1M}$										-0.009		-0.065
										(-0.26)		(-1.54)
IdioVol-IV$_{1M}$											0.094	0.073
											(4.72)	(2.63)
Adj. R^2	0.0026	0.002	0.0001	-0.0002	0.0005	0.0017	0.0023	0.0023	0.0018	0.0011	0.0046	0.0089

Table 4
The Slope of the Volatility Term Structure,
Volatility Measures and Straddle Returns

Each month, firms are first sorted into quintiles based on volatility measures (minus IV_{1M}), and then, within each quintile, firms are sorted by the slope of the volatility term structure, defined as $IV_{LT} - IV_{1M}$. The slope-of-the volatility term structure portfolios are averaged over each of the five characteristic portfolios. Volatility measures are the long-term implied volatility (IV_{LT}), the one-year historical volatility of daily returns (HV), realized volatility computed with 5-minute returns over 1 day (RV_{1d}), 1 week (RV_{1w}) and 1 month (RV_{1M}), implied volatility lagged by one month (IV_{1M}^{t-1}), 3 months (IV_{1M}^{t-3}), and 6 months (IV_{1M}^{t-6}), the maximum ($IV_{1M}^{\max}$) and average (IV_{1M}^{avg}) implied volatilities over the previous 6-months, and idiosyncratic volatility ($idioVol$). This table reports the average straddle return for quintiles 1 to 5, the difference between quintile 5 and quintile 1, and the t-statistics (in parentheses). The sample period is January 1996 to January 2012.

Control	P1	P2	P3	P4	P5	P5-P1
HV-IV$_{1M}$	-0.064	-0.039	-0.028	-0.022	0.047	0.110
	(-4.15)	(-2.32)	(-1.52)	(-1.14)	(2.29)	(8.07)
RV$_{1d}$-IV$_{1M}$	-0.067	-0.036	-0.035	-0.018	0.049	0.115
	(-4.31)	(-2.11)	(-1.92)	(-0.92)	(2.41)	(8.81)
RV$_{1w}$-IV$_{1M}$	-0.072	-0.027	-0.037	-0.021	0.051	0.122
	(-4.68)	(-1.56)	(-2.09)	(-1.09)	(2.56)	(9.65)
VRP (=RV$_{1M}$-IV$_{1M}$)	-0.064	-0.041	-0.030	-0.017	0.046	0.109
	(-4.01)	(-2.50)	(-1.65)	(-0.88)	(2.35)	(9.22)
IV$_{1M}^{t-1}$-IV$_{1M}$	-0.058	-0.038	-0.022	-0.018	0.030	0.088
	(-3.77)	(-2.17)	(-1.18)	(-0.96)	(1.56)	(7.41)
IV$_{1M}^{t-3}$-IV$_{1M}$	-0.045	-0.040	-0.033	-0.014	0.026	0.071
	(-2.82)	(-2.25)	(-1.89)	(-0.74)	(1.32)	(6.43)
IV$_{1M}^{t-6}$-IV$_{1M}$	-0.054	-0.044	-0.027	-0.016	0.035	0.089
	(-3.40)	(-2.61)	(-1.53)	(-0.85)	(1.77)	(7.38)
IV$_{1M}^{avg}$-IV$_{1M}$	-0.053	-0.034	-0.024	-0.017	0.022	0.076
	(-3.39)	(-1.94)	(-1.32)	(-0.89)	(1.19)	(6.83)
IV$_{1M}^{\max}$-IV$_{1M}$	-0.067	-0.037	-0.029	-0.003	0.030	0.097
	(-4.39)	(-2.17)	(-1.58)	(-0.16)	(1.53)	(7.67)
IdioVol-IV$_{1M}$	-0.070	-0.044	-0.028	-0.008	0.043	0.113
	(-4.59)	(-2.59)	(-1.56)	(-0.39)	(2.25)	(9.70)

Table 5
Forecasting Realized Volatility

This tables reports the average coefficients and Newey-West t-statistics from the two pass Fama-MacBeth (1973) regressions. Each month, future realized volatility minus IV_{1M} is regressed on various volatility measures minus IV_{1M} as in $FV_{i,t} - IV_{1M_{i,t}} = B_{0,t} + B_{1,t}(IV_{LT_{i,t}} - IV_{1M_{i,t}}) + B_{k,t}(Volatility\ Measures - IV_{1M_{i,t}}) + \varepsilon_{i,t}$. In the second step, the estimator for each coefficient is the average of the time series coefficients. Future realized volatility ($FV_{i,t}$) is the standard deviation of the underlying daily stock return over the life of the option. Volatility measures are the long-term implied volatility (IV_{LT}), the one-year historical volatility of daily returns (HV), realized volatility computed with 5-minute returns over 1 day (RV_{1d}), 1 week (RV_{1w}) and 1 month (RV_{1M}), implied volatility lagged by one month (IV_{1M}^{t-1}), 3 months (IV_{1M}^{t-3}), and 6 months (IV_{1M}^{t-6}), the maximum ($IV_{1M}^{\max}$) and average (IV_{1M}^{avg}) implied volatilities over the previous 6-months, and idiosyncratic volatility ($idioVol$). We report adjusted R^2 and Newey-West t-statistics with 3 lags in parentheses. Additionally, this table reports the percentage of regressors with t-statistics over 1.96 for each estimator. The sample period is January 1996 to January 2012.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Intercept	-0.009	-0.014	-0.007	-0.016	-0.006	-0.006	-0.007
	(-1.16)	(-1.82)	(-1.14)	(-2.28)	(-0.93)	(-0.77)	(-1.24)
IV_{LT}-IV_{1M}	0.347						0.173
	(10.73)						(5.33)
HV-IV_{1M}		0.190					0.148
		(10.13)					(6.27)
RV_{1d}-IV_{1M}			0.031				0.024
			(3.59)				(2.98)
RV_{1w}-IV_{1M}			0.013				0.024
			(0.97)				(2.05)
VRP (=RV_{1M}-IV_{1M})			0.166				0.100
			(8.34)				(4.86)
IV_{1M}^{t-1}-IV_{1M}				0.076			-0.035
				(5.67)			(-1.92)
IV_{1M}^{t-3}-IV_{1M}				0.078			0.002
				(5.13)			(0.14)
IV_{1M}^{t-6}-IV_{1M}				0.057			-0.035
				(3.50)			(-2.74)
IV_{1M}^{avg}-IV_{1M}					0.475		0.183
					(12.34)		(3.94)
$\mathrm{IV}_{1M}^{\max}$-IV_{1M}					-0.189		-0.141
					(-6.44)		(-6.23)
IdioVol-IV_{1M}						0.056	-0.011
						(5.78)	(-1.22)
Adj. R^2	4%	3%	4%	4%	4%	1%	10%
Percentage of t⩾1.96 (IV_{LT}-IV_{1M})	65%						26%
Percentage of t⩾1.96 (HV-IV_{1M})		64%					28%
Percentage of t⩾1.96 (RV_{1d}-IV_{1M})			18%				15%
Percentage of t⩾1.96 (RV_{1w}-IV_{1M})			13%				11%
Percentage of t⩾1.96 (RV_{1M}-IV_{1M})			45%				28%
Percentage of t⩾1.96 (IV_{1M}^{t-1}-IV_{1M})				26%			9%
Percentage of t⩾1.96 (IV_{1M}^{t-3}-IV_{1M})				30%			13%
Percentage of t⩾1.96 (IV_{1M}^{t-6}-IV_{1M})				28%			6%
Percentage of t⩾1.96 (IV_{1M}^{avg}-IV_{1M})					65%		21%
Percentage of t⩾1.96 ($\mathrm{IV}_{1M}^{\max}$-IV_{1M})					8%		7%
Percentage of t⩾1.96 (IdioVol-IV_{1M})						35%	7%

Table 6
Controlling for Higher Moments and Jump Risk

This table reports the results from the modified Fama-MacBeth monthly cross-sectional regressions proposed by Brennan, Chordia, and Subrahmanyam (1998) as in

$$r_{i,t} - \widehat{\beta}_i F_t = \gamma_{0,t} + \gamma'_{0,t} Z_{i,t-1} + \varepsilon_{i,t}$$

where $r_{i,t}$ is the straddle return in excess of the risk free rate for each security i at time t, F_t are the Fama-French-Carhart, coskewness and cokurtosis factors, and $Z_{i,t-1}$ are the characteristics for each stock i at time $t-1$. The $\widehat{\beta}_i$ are estimated in the first stage for each stock i using the entire sample. The characteristics are higher moments and jump risk variables. The variables included are the slope of the volatility term structure, risk-neutral volatility, skewness and kurtosis (Bakshi, Kapadia, and Madan (2003)), option skew (Xing, Zhang and Zhao (2010)), risk-neutral jump (Yan (2011)), and the right-tail and left-tail risk neutral jumps (Bollerslev and Todorov (2011)). The first row gives the coefficients of the regression and the second row gives the Newey-West t-statistics (in parentheses). Adjusted R^2 is reported at the bottom of the table. The sample period is January 1996 to January 2012.

	(1)	(2)
Intercept	-0.001	0.038
	(-0.20)	(1.08)
Slope of VTS	0.298	0.303
	(4.97)	(3.42)
RNVol		-0.058
		(-1.06)
RNSkew		-0.004
		(-0.32)
RNKurt		-0.008
		(-0.81)
OptionSkew		0.172
		(2.54)
RNJump		-0.245
		(-2.88)
RNJump Right		-0.002
		(-0.03)
RNJump Left		0.004
		(0.04)
Adj. R^2	0.003	0.009

Table 7
The Slope of the Volatility Term Structure, Higher Moments and Jump Risk, and Straddle Returns

Each month, firms are first sorted into quintiles based on higher moments or jump risk, and then, within each quintile, firms are sorted by the slope of the volatility term structure, defined as $IV_{LT} - IV_{1M}$. The slope-of-the volatility term structure portfolios are averaged over each of the five characteristic portfolios. The characteristics included are risk-neutral volatility, skewness and kurtosis (Bakshi, Kapadia, and Madan (2003)), option skew (Xing, Zhang and Zhao (2010)) risk-neutral jump (Yan (2011)), and the right-tail and left-tail risk neutral jumps (Bollerslev and Todorov (2011)). This table reports the average straddle return for quintiles 1 to 5, the difference between quintile 5 and quintile 1, and the t-statistics (in parentheses). The sample period is January 1996 to January 2012.

Control	P1	P2	P3	P4	P5	P5-P1
RNVol	-0.074	-0.036	-0.029	-0.009	0.042	0.116
	(-4.99)	(-2.11)	(-1.57)	(-0.48)	(2.11)	(9.50)
RNSkew	-0.065	-0.037	-0.038	-0.013	0.047	0.112
	(-4.29)	(-2.16)	(-2.10)	(-0.64)	(2.32)	(8.59)
RNKurt	-0.066	-0.040	-0.030	-0.019	0.050	0.115
	(-4.35)	(-2.35)	(-1.62)	(-1.04)	(2.43)	(8.78)
OptionSkew	-0.066	-0.037	-0.030	-0.012	0.039	0.106
	(-4.31)	(-2.17)	(-1.66)	(-0.65)	(1.91)	(8.11)
RNJump	-0.065	-0.035	-0.031	-0.018	0.043	0.108
	(-4.19)	(-2.05)	(-1.75)	(-0.91)	(2.12)	(8.23)
RNJump Right	-0.074	-0.039	-0.030	-0.007	0.044	0.117
	(-4.88)	(-2.35)	(-1.63)	(-0.37)	(2.27)	(10.10)
RNJump Left	-0.070	-0.042	-0.026	-0.010	0.042	0.112
	(-4.74)	(-2.44)	(-1.43)	(-0.52)	(2.16)	(9.57)

Table 8
Straddle Returns with Transactions Costs

Each month, firms are first sorted into quartiles based on their bid-ask spread, and then, within each quartile, firms are sorted into deciles based on the slope of the volatility term structure, defined as $IV_{LT} - IV_{1M}$. Panel A reports the long-short straddle return and t-statistic for each quartile or group of quartiles computed with bid and ask quotes executed at bid-ask spread ratios of 0.25, 0.50, 0.75, and 1.00. Once a month, options are bought and held until maturity. The long position buys at the ask price and the short position sells at the bid price. At maturity, the terminal payoff depends on the strike price. Panel B reports the margin haircut of shorting portfolio 1, and the percentage of wealth used for margin requirements. The margin haircut is defined as the ratio $(M_t - V_0)/V_0$, where M_t is the straddle margin at the end of each day t, and V_0 is equal to the sum of the price of the call and the put when the position is opened. The percentage of wealth used for margin requirements is the inverse of the margin haircut. The sample period is January 1996 to January 2012.

Panel A: Long-Short Straddle Returns and Bid-Ask Spreads

	Ratio of Bid/Ask Spread			
Bid/Ask Spread Quartiles	0.25	0.50	0.75	1.00
Q1	0.167	0.154	0.141	0.128
	(4.88)	(4.51)	(4.14)	(3.76)
Q2	0.108	0.086	0.064	0.043
	(4.09)	(3.29)	(2.47)	(1.65)
Q3	0.140	0.109	0.078	0.046
	(5.99)	(4.69)	(3.37)	(2.00)
Q4	0.087	0.026	-0.036	-0.102
	(2.98)	(0.89)	(-1.25)	(-3.48)
Q1 and Q2	0.136	0.118	0.101	0.084
	(5.97)	(5.23)	(4.48)	(3.72)
Q1, Q2 and Q3	0.135	0.113	0.091	0.068
	(7.24)	(6.08)	(4.92)	(3.72)
All Sample	0.132	0.098	0.065	0.031
	(7.77)	(5.87)	(3.91)	(1.88)

Panel B: Margin Haircut

	P1 Haircut	% of Wealth used for Margin Requirement
Mean	1.54	35%
Median	1.47	32%
StDev	0.61	
Minimum	0.23	
Maximum	4.41	77%

Table 9
Controlling for Stock Characteristics

This table reports the results from the modified Fama-MacBeth monthly cross-sectional regressions proposed by Brennan, Chordia, and Subrahmanyam (1998) as in

$$r_{i,t} - \sum_{k=1}^{12} \widehat{\beta}_{i,k} F_{k,t} = \gamma_{0,t} + \gamma'_{0,t} Z_{i,t-1} + \varepsilon_{i,t}$$

where $r_{i,t}$ is the straddle return in excess of the risk free rate for each security i at time t, F_t are the Fama-French-Carhart, coskewness and cokurtosis factors, and $Z_{i,t-1}$ are the characteristics for each stock i at time $t-1$. The $\widehat{\beta}_i$ are estimated in the first stage for each stock i using the entire sample. Characteristics included in the regressions are the slope of the volatility term structure, option dollar volume ($\$Vol$), option volume contracts (Vol), option open interest (OI), bid-to-mid option spread (BM), size (market capitalization in \$ billions), BE/ME (book-to-market ratio), historical volatility (HV), skewness ($HSkew$) and kurtosis ($HKurt$), delta, gamma, and vega. The first row gives the coefficients of the regression and the second row gives the t-statistics (in parentheses). Adjusted R^2 is reported at the bottom of the table. The sample period is January 1996 to January 2012.

	(1)	(2)	(3)
Intercept	-0.016	0.028	0.112
	(-1.09)	(1.20)	(2.67)
Slope VTS	0.266	0.253	0.303
	(5.69)	(5.60)	(6.30)
Ln($Vol)		-0.004	
		(-1.88)	
Ln(Vol)		0.001	
		(0.34)	
Ln(OI)		0.002	
		(0.79)	
Ln(BM)		0.014	
		(2.18)	
Ln(size)			-0.005
			(-2.07)
BE/ME			-0.008
			(-1.18)
HV			-0.080
			(-3.49)
HSkew			0.002
			(0.70)
HKurt			-0.0001
			(-1.24)
Delta	0.115	0.111	0.113
	(4.49)	(4.36)	(4.40)
Gamma	0.019	-0.026	0.002
	(0.62)	(-0.83)	(0.08)
Vega	0.000	0.001	-0.001
	(0.42)	(1.02)	(-0.68)
Adj. R^2	0.020	0.025	0.028

Table 10
The Slope of the Volatility Term Structure,
Stock Characteristics and Straddle Returns

Each month, firms are first sorted into quintiles based on firm characteristics, and then, within each quintile, firms are sorted by the slope of the volatility term structure, defined as $IV_{LT} - IV_{1M}$. The slope-of-the volatility term structure portfolios are averaged over each of the five characteristic portfolios. Characteristics include option dollar volume ($\$Vol$), option volume contracts (Vol), option open interest (OI), bid-to-mid option spread (*Bid-to-Mid*), size (market capitalization in \$ billions), BE/ME (book-to-market ratio), historical volatility (HV), skewness ($HSkew$) and kurtosis ($HKurt$), realized volatility (RV) from intraday five-minute returns, delta, gamma, and vega. This table reports the average straddle return for quintiles 1 to 5, the difference between quintile 5 and quintile 1, and the t-statistics (in parentheses). The sample period is January 1996 to January 2012.

	Straddle					
Control	P1	P2	P3	P4	P5	P5-P1
$Vol	-0.067	-0.037	-0.027	-0.022	0.047	0.114
	(-4.50)	(-2.20)	(-1.42)	(-1.18)	(2.29)	(8.45)
Vol	-0.064	-0.040	-0.028	-0.016	0.043	0.107
	(-4.20)	(-2.35)	(-1.54)	(-0.83)	(2.12)	(7.89)
OI	-0.066	-0.037	-0.026	-0.022	0.045	0.111
	(-4.27)	(-2.20)	(-1.44)	(-1.14)	(2.25)	(8.35)
Bid-To-Mid	-0.063	-0.038	-0.032	-0.014	0.040	0.103
	(-4.18)	(-2.27)	(-1.78)	(-0.68)	(1.99)	(8.02)
Size	-0.077	-0.032	-0.031	-0.008	0.042	0.119
	(-4.91)	(-1.91)	(-1.73)	(-0.43)	(2.05)	(9.17)
BE/ME	-0.070	-0.035	-0.030	-0.026	0.055	0.124
	(-4.62)	(-2.14)	(-1.62)	(-1.35)	(2.63)	(9.28)
HV	-0.064	-0.039	-0.028	-0.022	0.047	0.110
	(-4.15)	(-2.32)	(-1.52)	(-1.14)	(2.29)	(8.07)
HSkew	-0.064	-0.039	-0.028	-0.022	0.047	0.110
	(-4.15)	(-2.32)	(-1.52)	(-1.14)	(2.29)	(11.42)
HKurt	-0.064	-0.039	-0.028	-0.022	0.047	0.110
	(-4.15)	(-2.32)	(-1.52)	(-1.14)	(2.29)	(13.99)
RV	-0.072	-0.040	-0.020	-0.019	0.045	0.117
	(-4.83)	(-2.36)	(-1.11)	(-0.99)	(2.26)	(10.68)
Delta	-0.072	-0.043	-0.025	-0.011	0.046	0.119
	(-4.96)	(-2.54)	(-1.37)	(-0.57)	(2.32)	(9.59)
Gamma	-0.066	-0.036	-0.037	-0.009	0.041	0.106
	(-4.32)	(-2.15)	(-2.06)	(-0.44)	(2.03)	(8.20)
Vega	-0.072	-0.037	-0.022	-0.020	0.043	0.115
	(-4.73)	(-2.15)	(-1.15)	(-1.04)	(2.15)	(8.84)

Table 11
Long-Short Straddle Returns for Different Sub-Samples

This table reports monthly equal-weighted straddle returns along with the t-statistics (t-stat) of decile portfolios for different sub-samples. The last column displays the difference between decile portfolio 10 (highest slope of volatility term structure) and decile 1 (lowest slope of volatility term structure). Moneyness is defined as the option strike over the stock price. The triple witching Friday (TWF) refers to the third Friday of every March, June, September and December when three different kinds of securities expire on the same day: stock index futures, stock index options and stock options. The January group includes only straddle returns for that month. The earnings announcement (EA) group includes stocks that made the announcement during the life of the options. The arbitrage-bounds group includes stocks that violate arbitrage bounds as suggested by Duarte and Jones (2007). Two weighting schemes are reported: option dollar volume and option dollar open interest. Finally, we form decile portfolio based on three definitions for the slope of the volatility term structure with a standardized maturity for the long-term volatility: $IV_{3M} - IV_{1M}, IV_{6M} - IV_{1M}$, and $IV_{9M} - IV_{1M}$. The data sample is from January 1996 to January 2012.

	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P10-P1
Baseline Portfolio	-0.092	-0.036	-0.044	-0.035	-0.028	-0.025	-0.033	-0.006	0.016	0.073	0.165
	(-5.96)	(-2.02)	(-2.58)	(-1.85)	(-1.44)	(-1.31)	(-1.64)	(-0.30)	(0.73)	(3.50)	(10.02)
Moneyness: 0.975 - 1.025	-0.090	-0.039	-0.036	-0.039	-0.029	-0.014	-0.037	0.005	0.010	0.080	0.169
	(-5.27)	(-2.07)	(-2.01)	(-1.83)	(-1.44)	(-0.62)	(-1.76)	(0.21)	(0.43)	(3.50)	(9.94)
Unbounded Moneyness	-0.096	-0.038	-0.047	-0.033	-0.025	-0.025	-0.033	-0.012	0.012	0.058	0.154
	(-7.00)	(-2.46)	(-2.95)	(-1.93)	(-1.45)	(-1.36)	(-1.74)	(-0.64)	(0.57)	(2.88)	(9.55)
Period 1996-2003	-0.084	-0.018	-0.037	-0.018	-0.020	-0.005	-0.007	0.022	0.055	0.106	0.190
	(-3.85)	(-0.75)	(-1.70)	(-0.74)	(-0.81)	(-0.21)	(-0.26)	(0.77)	(1.78)	(3.49)	(6.93)
Period 2004-2012	-0.100	-0.054	-0.052	-0.052	-0.036	-0.045	-0.058	-0.034	-0.023	0.040	0.140
	(-4.56)	(-2.06)	(-1.94)	(-1.80)	(-1.20)	(-1.57)	(-2.02)	(-1.14)	(-0.75)	(1.41)	(7.78)
TWF Months	-0.097	-0.065	-0.040	-0.040	-0.022	-0.026	-0.018	-0.008	0.017	0.069	0.166
	(-4.16)	(-2.39)	(-1.58)	(-1.47)	(-0.72)	(-0.88)	(-0.59)	(-0.24)	(0.52)	(2.00)	(5.54)
Non TWF Months	-0.089	-0.022	-0.046	-0.032	-0.030	-0.024	-0.040	-0.006	0.015	0.076	0.165
	(-4.46)	(-0.94)	(-2.07)	(-1.30)	(-1.25)	(-1.00)	(-1.55)	(-0.21)	(0.54)	(2.86)	(8.34)
January	-0.198	-0.104	-0.102	-0.111	-0.130	-0.105	-0.159	-0.065	-0.052	0.006	0.204
	(-4.26)	(-1.62)	(-2.25)	(-2.21)	(-2.47)	(-2.14)	(-2.97)	(-1.06)	(-0.84)	(0.09)	(3.48)
Non-January	-0.083	-0.031	-0.039	-0.028	-0.019	-0.018	-0.022	-0.001	0.022	0.079	0.162
	(-5.15)	(-1.63)	(-2.16)	(-1.42)	(-0.94)	(-0.90)	(-1.05)	(-0.06)	(0.94)	(3.58)	(9.42)
Arbitrage Bounds	-0.114	-0.077	-0.065	-0.059	-0.046	-0.049	-0.031	-0.022	-0.005	0.045	0.159
	(-8.19)	(-4.77)	(-3.92)	(-3.21)	(-2.52)	(-2.69)	(-1.57)	(-1.08)	(-0.20)	(2.00)	(10.18)
EA Months	-0.066	-0.057	-0.003	-0.013	0.064	0.037	0.030	0.008	-0.004	0.085	0.151
	(-2.56)	(-2.45)	(-0.12)	(-0.47)	(2.04)	(1.21)	(1.03)	(0.28)	(-0.16)	(2.50)	(3.85)
Non EA Months	-0.109	-0.057	-0.062	-0.035	-0.051	-0.054	-0.031	-0.007	0.021	0.081	0.190
	(-6.60)	(-2.63)	(-3.35)	(-1.64)	(-2.43)	(-2.41)	(-1.32)	(-0.31)	(0.86)	(3.55)	(9.61)
$ Volume Weighted	-0.070	-0.034	-0.033	-0.061	-0.048	-0.011	-0.033	-0.033	0.003	0.051	0.122
	(-2.69)	(-1.23)	(-1.05)	(-2.38)	(-1.62)	(-0.37)	(-1.06)	(-1.12)	(0.10)	(1.47)	(3.11)
$ Open Interest Weighted	-0.070	-0.035	-0.035	-0.045	-0.041	-0.005	-0.023	-0.014	0.009	0.084	0.153
	(-3.16)	(-1.31)	(-1.35)	(-1.92)	(-1.59)	(-0.19)	(-0.83)	(-0.53)	(0.34)	(2.81)	(4.94)
Slope VTS = IV_{3M}-IV_{1M}	-0.076	-0.046	-0.033	-0.027	-0.038	-0.021	-0.026	-0.020	0.028	0.051	0.127
	(-4.73)	(-2.70)	(-1.87)	(-1.39)	(-1.99)	(-1.04)	(-1.29)	(-0.99)	(1.41)	(2.45)	(7.65)
Slope VTS = IV_{6M}-IV_{1M}	-0.081	-0.060	-0.036	-0.027	-0.022	-0.034	-0.037	-0.010	0.012	0.076	0.158
	(-5.30)	(-3.62)	(-2.00)	(-1.50)	(-1.17)	(-1.75)	(-1.87)	(-0.49)	(0.56)	(3.58)	(10.03)
Slope VTS = IV_{9M}-IV_{1M}	-0.099	-0.044	-0.036	-0.033	-0.024	-0.027	-0.032	-0.005	0.011	0.070	0.169
	(-6.04)	(-2.38)	(-1.98)	(-1.68)	(-1.22)	(-1.29)	(-1.50)	(-0.24)	(0.50)	(3.21)	(9.28)

Table 12
Straddle Returns for Different Horizons

Portfolios are constructed as in Table 1. This table reports equal-weighted straddle returns for different horizons. We study 2-week and 3-week holding periods. We report t-statistics (t-stat), standard deviation (StDev), skewness and kurtosis values of the decile portfolio returns. Long-short returns are computed as the difference between decile portfolio 10 (highest slope of volatility term structure) and decile 1 (lowest slope of volatility term structure). The sample period is January 1996 to January 2012.

Panel A: Two-Week Horizon

Deciles	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P10-P1
Mean	-0.035	-0.004	0.019	0.011	0.015	0.011	0.041	0.046	0.052	0.093	0.128
t-stat	(-3.18)	(-0.32)	(1.22)	(0.76)	(1.13)	(0.86)	(2.45)	(2.75)	(3.48)	(5.53)	(7.68)
StDev	0.218	0.258	0.303	0.273	0.264	0.261	0.325	0.330	0.295	0.330	0.328
Skewness	0.9	1.3	3.3	1.5	1.5	1.8	3.7	3.9	2.0	4.3	3.3
Kurtosis	5.9	5.5	26.3	6.3	6.6	10.6	27.8	31.5	9.1	36.5	29.0

Panel B: Three-Week Horizon

Deciles	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P10-P1
Mean	-0.046	-0.013	-0.024	-0.013	-0.033	-0.014	-0.007	0.009	0.048	0.090	0.136
t-stat	(-2.76)	(-0.62)	(-1.30)	(-0.67)	(-1.80)	(-0.74)	(-0.33)	(0.42)	(2.09)	(3.66)	(6.16)
StDev	0.234	0.286	0.259	0.268	0.257	0.274	0.288	0.294	0.320	0.344	0.310
Skewness	2.5	2.1	1.9	1.6	1.8	2.2	2.4	2.0	2.0	1.7	0.2
Kurtosis	13.1	7.6	6.1	3.9	5.8	9.0	9.5	5.7	6.0	4.5	4.9

Table 13
Portfolio Risk Measures

This table reports two risk measures, the 5% value-at-risk and the 5% expected shortfall for each decile portfolio. The sample period is January 1996 to January 2012.

	Portfolio									
Risk Measures	1	2	3	4	5	6	7	8	9	10
Value at Risk - 5%	0.393	0.349	0.338	0.350	0.361	0.328	0.399	0.345	0.344	0.245
Expected Shortfall - 5%	0.460	0.412	0.405	0.385	0.419	0.398	0.456	0.383	0.406	0.347