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

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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.

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-week option returns. Every week, 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 weekly return of -2.9% for the decile with the lowest slope of the volatility term structure and a return of 2.2% for the decile with the highest slope. The long-short strategy generates a weekly return of 5.1% with a t-statistic of 19.9.

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 by firm characteristics such as firm size, book-to-market, risk neutral moments, and jump risk.

We compute the alphas of the long-short straddle strategy using the Carhart (1997) 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 (1997), 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 under- and over-reaction, and option anomaly measures. The volatility risk premium is computed as the difference between realized volatility computed from five-minute returns and IV_{1M} following Bollerslev, Tauchen, and Zhou (2009). We include realized volatility since Corsi (2009) and Busch, Christensen, and Nielsen (2011) show that it is a good predictor of future volatility. Volatility under- and over-reaction is measured with implied volatility lagged by one month, three months, and six months, and the average implied volatility (minus IV_{1M}). We include these measures since Stein (1989) and Poteshman (2001) report that investors over-react (under-react) to current volatility changes. The option anomaly measures are historical volatility and idiosyncratic volatility. Goyal and Saretto (2009) find that straddle returns are positively related to the difference between historical and implied volatility, and 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 measures monotonically increase from portfolio 1 to portfolio 10. Moreover, most of the 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 over-reaction ranging from 51% to 58%. The correlation with the volatility risk premium is much lower, at only 18%. The slope of the volatility term structure reports a correlation of 42% with $HV - IV_{1M}$, the option anomaly documented by Goyal and Saretto (2009).

Next, we explore the relation between these volatility measures and future straddle returns. Bivariate Fama and MacBeth (1973) regressions between the slope of the volatility term structure and each one of these volatility measures confirms the positive and significant relation between the slope of the term structure and future straddle returns. The slope of the volatility term structure is measuring something that is not captured by these other volatility variables.

The large straddle returns potentially represent a compensation for jump risk given that the straddle position is not gamma-neutral (Cremers, Halling, and Weinbaum (2015)). 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) measures jump risk with the spread between at-the-money put and call volatilities which may be caused by market imperfections, short sale constraints, or the trading activity of informed traders as documented by Cremers and Weinbaum (2010). 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 sortings 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. Contemporaneous work by Jones and Wang (2012) reports similar findings. However, there are three main differences between our paper and Jones and Wang (2012). First, in our paper we explore the sources of predictability. We perform an extensive analysis on the relation among the slope of the volatility term structure, the volatility risk premium, measures of volatility over-reaction, and measures of option anomalies. Second, in our paper we study the impact of transaction costs on straddle returns. Third, we analyze straddle returns for different horizons: one week, two weeks, three weeks and one month.

Previously, the shape of the volatility term structure has 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 short-term implied volatility. Cao, Yu, and Zhong (2010) and Busch, Christensen, and Nielsen (2011) show that short-term implied volatility, historical volatility and realized volatility are all good predictors of future volatility.[1] We document that the slope of the volatility term structure also contributes to the prediction of future realized volatility minus short-term volatility.

Empirical option research has focused primarily on index options.[2] 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 (2015) reports a negative relation between option returns and retail trading proportions. Bali and Murray (2013) 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, in addition to Jones and Wang (2012), 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 might contain crucial

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

[2] 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 (2014), Saretto and Santa-Clara (2009), Bollen and Whaley (2004), Shleifer and Vishny (1997), Jackwerth (2000), Buraschi and Jackwerth (2001), and Liu and Longstaff (2004).

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 portfolio formation and its characteristics. The straddle returns using different setups are presented in section four, and section five contains a series of robustness checks. Section six 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. Given that individual equity option are American-style, implied volatilities and Greeks are computed using a modified Cox, Ross, and Rubinstein (1979) binomial model.[3]

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

[3]OptionMetrics uses a proprietary option pricing algorithm based on the Cox, Ross, and Rubinstein (1979) model to extract implied volatilities and Greeks. This model can accommodate underlying securities with either discrete dividend payments or a continuous dividend yield. Regardless of the methodology to handle dividends, the impact on calculated option implied volatilities is small.

[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. These results are

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 are both equal to the previous day's quotes, the observation is also eliminated. We filter options with zero volume or zero open-interest to ensure that the 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 week, 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 short–term 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 time.[6,7]

discussed in the Robustness Section and reported in Table IA.5 in the Internet Appendix.

[5] The conclusions hold when the volatility range is 3% to 100%, and when the moneyness level is unbounded or between 0.975 and 1.025. These results are discussed in the Robustness Section and reported in Table IA.5 in the Internet Appendix.

[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] The results hold when we fix the long-term maturity to 3-months, 6-months, and 9-months. These results are discussed in the Robustness Section and reported in Table IA.5 in the Internet Appendix.

3 Portfolio Formation and Trading Strategy

In this section, we explain how portfolios are constructed and provide a summary of different characteristics across portfolios.

3.1 Portfolio Formation

Each week, we form ten portfolios based on the slope of the volatility term structure, $IV_{LT} - IV_{1M}$.[8] We extract the ATM put and call options that are on average 5 weeks away from maturity. We form straddle portfolios based on the slope of the volatility term structure and hold these portfolios for one week. One week later, we get the market price of the option to compute the straddle return. If no price is available, we interpolate the missing implied volatility from the OptionMetrics Volatility Surface and compute the theoretical option price with the Cox, Ross, and Rubinstein (1979) model. If the implied volatility is not available, the option price is set to the intrinsic value of the option. The options maturity ranges from 25 to 46 days. The strike price is as close as possible to the closing price.

We compute the straddle returns over one week.[9] 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 week to week. On average, there are 486 stocks per week and our sample contains more than 400 thousand firm-week observations.

[8] 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. Table IA.1 in the Internet Appendix reports the results for each definition.

[9] A long straddle return is defined as $r_{t,T}^{straddle} = \frac{p_T + c_T}{p_t + c_t} - r_{t,T}^{f}$, 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, and $r_{t,T}^{f}$ is the future value of one dollar from time t to T, which is one week.

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: measures of volatility, firm and option characteristics, and risk neutral measures.

[Insert Table 1 here]

The variables related to the slope of the volatility term structure are IV_{1M}, IV_{LT}, and $IV_{LT} - IV_{1M}$. We report volatility measures related to future volatility, the volatility risk premium, investor misreaction to volatility changes, and option anomalies. Future volatility, FV, defined as the standard deviation of the daily stock return over one week. 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 one month (RV_{1M}).[10] 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 volatility minus short-term implied volatility, IV_{1M}. The measures of previous volatility 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

[10] Note that FV is measured with daily returns over the next 5 trading days, while RV_{1M} is measured with five minute intraday returns over the previous 22 trading days.

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. These volatility measures are discussed in more detail in Appendix A.

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 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 risk neutral measures are the risk-neutral volatility, skewness and kurtosis extracted from one-month options using the methodology proposed by Bakshi, Kapadia, and Madan (2003), and the risk-neutral jump proposed by Yan (2011).

Panel A of Table 1 reports the results for decile portfolios sorted by the slope of the volatility term structure. All volatility measures minus IV_{1M} increase from portfolio 1 to portfolio 10. The average maturity of long-term options is 7 months. From portfolio 1 to portfolio 10, the bid-to-mid-spread of IV_{1M} increases, the gamma increases, and the delta and the book-to-market remain at the same level. Similar to portfolio 10, portfolio 1 contains stocks with higher put-call spread of IV_{1M}, lower vega, lower size, and higher risk neutral jump.

Panel B of Table 1 reports the correlations of the volatility variables minus IV_{1M}. The correlation structure confirms the results from Panel A for the volatility measures: 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}) but future volatility. There is a low correlation between the slope of the volatility term structure and the volatility risk premium (VRP) of 17.6%. There is a high correlation between the slope of the volatility term structure and measures of option anomalies and volatility overreaction.

In summary, Table 1 shows that the slope of the volatility term structure appears to be related to several measures of 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.

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-week straddle returns. We report the raw straddle returns as well as the Carhart (1997), coskewness and cokurtosis risk adjusted alphas for the long-short straddle portfolio. Second, we use double sorts and the modified two-stage Fama and MacBeth (1973) cross-sectional regressions proposed by Brennan, Chordia, and Subrahmanyam (1998) to understand the relation between the slope of the volatility term structure, other volatility measures minus IV_{1M}, higher moments, and jump risk. Third, we explore the source of predictability of the slope of the volatility term structure. Then, we assess the impact of return holding horizon and transaction costs on straddle returns. Finally, we discuss possible explanations of our empirical finding.

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

[Insert Table 2 here]

Each week, 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 5.1% weekly average return with a t-statistic of 19.9. Both portfolios contribute to the long-short portfolio return since the straddle returns are -2.9% and 2.2% for portfolios 1 and 10, respectively.

[Insert Figure 1 here]

Figure 1 displays the time series of the long-short straddle returns. About 78% of the weekly straddle returns are positive. The maximum long-short straddle return is 49% and the minimum is −29%. Over the sample period, most of the positive returns are below 20%.

[Insert Figure 2 here]

Figure 2 displays the qq-plot of the long-short straddle returns. The distribution of straddle returns is positively skewed and fat-tailed. Skewness of the distribution is 0.6 and kurtosis is 3.8 as reported in Panel A of Table 2.

The long-short straddle returns are non-normal, confirming the findings of Broadie, Chernov, and Johannes (2009). Hence, the conventional t-statistic of 19.9 should be interpreted with care. We report the 95% bootstrap confidence intervals for the mean of the long-short straddle returns. To construct the bootstrapped confidence interval, we draw with replacement from the original 837 weekly long-short straddle returns. For each of the $50,000$ bootstrap samples that contains 837 sampled values, we calculate the bootstrap sample mean. From the $50,000$ bootstrapped sample means, we extract the 2.5% and 97.5% percentiles to form the 95% bootstrap confidence interval. The 95% bootstrap confidence interval is [0.046, 0.055] which confirms that the long-short straddle return is positive and significantly different from zero.

We also include in Panel B of Table 2 the bootstrapped critical values for the t-statistic of the long-short straddle returns. First, we subtract the average long-short return of 5.1% to the time-series of long-short straddle returns. From the total sample of 837 demeaned returns, we draw with replacement $50,000$ samples. For each of the $50,000$ bootstrap samples that contains 837 demeaned returns, we calculate the bootstrap t-statistic. From the $50,000$ bootstrapped t-statistics, we compute the critical values for the t-statistic. The critical value at the 1% level in a two-sided test is 2.300 which confirms that the long-short straddle return of 5.1% 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 confidence interval and 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

$$\begin{aligned} r_{P,t} &= \alpha_P + \beta_1(R_{m,t} - R_{f,t}) + \beta_2 SMB_t + \beta_3 HML_t + \beta_4 UMD_t + & (1) \\ &\quad \beta_5(R_{o,t} - R_{f,t}) + \beta_6(R^2_{m,t} - R_{f,t}) + \beta_7(R^2_{o,t} - R_{f,t}) + \beta_8(R_{o,t}R_{m,t} - R_{f,t}) & (2) \\ &\quad \beta_9(R^3_{o,t} - R_{f,t}) + \beta_{10}(R^3_{m,t} - R_{f,t}) + \beta_{11}(R^2_{o,t}R_{m,t} - R_{f,t}) + \beta_{12}(R_{o,t}R^2_{m,t} - R_{f,t}), & (3) \end{aligned}$$

where $R_{m,t}$ is the market return, $R_{o,t}$ is the market option return, $R_{f,t}$ is the risk-free rate, and SMB_t, HML_t, and UMD_t are the Fama-French and momentum factors at time t. 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.[11]

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 (1997) model. The alpha is 5.6% with a t-statistic of 21.53. The coefficient of the market factor R_m is negative and significant. Hence, the long-short straddle portfolio provides a hedge against the market.

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 coefficient of the S&P 500 straddle return, $R_o - R_f$, is positive and significant for both models. The market factor reports a negative and significant coefficient.

In the fourth column, we regress the long-short straddle returns against all factors. The alpha is 5.4% with a significant t-statistic of 15.71. The market factor is negative and has the highest absolute t-statistic of 4.86.

Given that the distribution of the long-short straddle portfolio is non-normal and that the standard errors inherit this non-normality, we compute the 95% confidence interval for the alpha using bootstrap. The bootstrap procedure implemented for the raw returns is extended to the regression model. Our original sample contains 837 weekly observations for the long-short straddle return, the market return, the market option return, the risk-free rate, and the Fama-French and momentum factors, where each observation is denoted by $z_t = [r_{P,t}, R_{m,t}, R_{o,t}, R_{f,t}, SMB_t, HML_t, UMD_t]$. The observations $z_1, z_2, .., z_{837}$ are resampled with replacement b times, where $b = 50,000$. Each bootstrap sample, $z^*_{1b}, z^*_{2b}, .., z^*_{837b}$, produces a set of bootstrap regression coefficients $b^*_b = [\alpha^*_{pb}, \beta^*_{ib}]$. From the 50,000 bootstrapped alphas, α^*_{pb}, we extract the 2.5% and 97.5% percentiles to form the 95% bootstrap confidence interval.[12] The 95% bootstrap confidence interval in all regressions confirms that

[11] 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.

[12] Bootstrapping the residuals does not change the conclusion. In this case, we estimate the regression with the original sample, $r_{P,1}, r_{P,2}, .., r_{P,837}$, to obtain 837 residuals $\varepsilon_1, \varepsilon_2, .., \varepsilon_{837}$ and 837 observations $\widehat{r}_{P,1}, \widehat{r}_{P,2}, .., \widehat{r}_{P,837}$, where $\varepsilon_t = r_{P,t} - \widehat{r}_{P,t}$. The residuals are bootstrapped $b = 50,000$ times to obtain $\varepsilon^*_b = [\varepsilon^*_{1b}, \varepsilon^*_{2b}, .., \varepsilon^*_{837b}]$. Then, we compute the bootstrapped straddle returns $r^*_{P,b} = [r^*_{P,1b}, r^*_{P,2b}, .., r^*_{P,837b}]$, where $r^*_{P,tb} = \widehat{r}_{P,t} + \varepsilon^*_{tb}$. The bootstrapped $r^*_{P,tb}$ are regressed on the fixed $[R_{m,t}, R_{o,t}, R_{f,t}, SMB_t, HML_t, UMD_t]$ to get bootstrap regression coefficients $b^*_b = [\alpha^*_p, \beta^*_{ib}]$. From the 50,000 bootstrapped alphas, we form the

the alpha is positive and significantly different from zero.

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 similar magnitude as the raw returns of the long-short straddle portfolio reported in Panel A of Table 2. The most important factors are the market and the S&P 500 straddle returns that report significant coefficients in all regressions.

4.3 Volatility Measures, Higher Moments, Jump Risk, and the Slope of the Volatility Term Structure

We now use the modified Fama and MacBeth (1973) regressions proposed by Brennan, Chordia, and Subrahmanyam (1998) and two-way sorts to confirm that the slope of the volatility term structure is positively related with straddle returns in the cross section.

We estimate the modified two-stage Fama and MacBeth (1973) regressions. 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

$$r_{i,t} - \widehat{\beta}_i F_t = \gamma_{0,t} + \gamma'_{0,t} Z_{i,t-1} + \varepsilon_{i,t} \tag{4}$$

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 week t, a regression is run with the option return and the factors on the left hand side and the slope of the volatility term

95% bootstrap confidence interval.

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.[13]

[Insert Table 3 here]

We control for volatility risk premium ($RV_{1M} - IV_{1M}$), investor misreaction to volatility changes ($IV_{1M}^{avg} - IV_{1M}$ and $IV_{1M}^{\max} - IV_{1M}$), option anomalies ($HV - IV_{1M}$), risk neutral moments (Volatility, skewness, and kurtosis), and risk neutral jump (as in Yan (2011)). We only use the most relevant control variables given that the results remain unchanged for the other ones. The results for the remaining control variables are reported in the Internet Appendix.[14]

Table 3 reports the regression results of the risk adjusted straddle returns on the slope of the volatility term structure and selected control variables. The first column presents the result of the regression of the straddle return on the slope of the volatility term structure. The coefficient associated with the slope of the volatility term structure is 0.217 with a Newey-West t-statistic of 15.56, confirming the positive and significant relation between the slope of the volatility term structure and future straddle returns. In column two to five, we add HV, RV_{1M}, IV_{1M}^{avg}, and $IV_{1M}^{\max}$ (minus IV_{1M}), and the coefficient of the slope of the volatility term structure remains unchanged. Adding the risk neutral moments and risk neutral jump in column six confirms the results. The most important finding is that the slope of the volatility term structure outperforms each individual measure of volatility (minus IV1M) in explaining future straddle returns.

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

[14] To control for the volatility risk premium, we also use realized volatility over 1-day and 1-week. To control for volatility misreaction we also use the 1-month, 3-month, and 6-month lagged volatility. We also include idiosyncratic volatility since Cao and Han (2013) find that it is related to delta-hedged call returns. Tables IA.2 and IA.3 in the Internet Appendix contain the results for the modified Fama and MacBeth (1973) regressions and the two-way sorts, respectively.

We report the 95% confidence interval for the coefficient of the slope of the volatility term structure using bootstrap. The bootstrap procedure implemented for the regression model is extended to the modified Fama-MacBeth regression. Our original sample contains observations, $z_{i,t} = [r_{i,t} - \widehat{\beta}_i F_t, Z_{i,t-1}]$, for individual stock i over week t. The observations $[z_{1,1}, .., z_{n_1,1}; z_{1,2}, .., z_{n_1,2}; ..; z_{1,837}, .., z_{n_{837},837}]$ are resampled with replacement b times within each week t, where $b = 50,000$ and $t = 837$. We assume that each week t contains n_t stocks. For each bootstrap sample, $[z^*_{1,1b}, .., z^*_{n_1,1b}; z^*_{1,2b}, .., z^*_{n_2,2b}; ..; z^*_{1,837b}, .., z^*_{n_{837},837b}]$, we run the modified Fama-MacBeth regression to produce a set of bootstrap regression coefficients $\gamma^*_{0,b}$. From the $50,000$ bootstrapped coefficients, we extract the 2.5% and 97.5% percentiles to form the 95% bootstrap confidence interval. We find that the 95% bootstrap confidence interval for the coefficient of the slope of the volatility term structure is positive and different from zero for all regressions.

[Insert Table 4 here]

To ensure that the slope of the volatility term structure is related with straddle returns, we implement the double sorting methodology. With the two-way sorts, we can examine whether the cross-sectional variation in returns holds across different levels of the control variables. 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, its 95% bootstrap confidence interval, and the t-statistics for each characteristic. All the long-short straddle returns are positive and significant. The 95% bootstrap confidence intervals confirm this conclusion. The long-short straddle returns are between 2.2% and 3.51%, while the t-statistics are between 12.48 and 21.48.

Using modified Fama-MacBeth regressions and two-way sorts, we conclude that the slope of the volatility term structure predicts straddle returns over and above the volatility risk premium, investor misreaction to volatility changes, option anomalies, risk neutral moments, and risk neutral jump. 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 one week (FV), defined as the standard deviation of the underlying stock return, is greater (lower) than the implied volatility over the same period of time. Since the options are (on average) 5 weeks away from maturity, the implied volatility of the option (IV_{1M}) contains information of the future volatility over the following week and the remaining 4 weeks.

We explore whether implied volatility (IV_{1M}) and future volatility (FV) are related with straddle returns with an in-sample exercise. We form ten straddle portfolios based on the difference between future volatility (FV) and short-term implied volatility, $FV - IV_{1M}$, and examine contemporaneous straddle returns. Sorting by $FV - IV_{1M}$ produces a long-short weekly straddle return of 21.4% with a t-statistic of 60.36 as reported on Table IA.1 in the Internet Appendix. This result shows that straddle returns are closely related with the spread between future realized volatility and short-term 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 minus implied volatility on several volatility measures minus IV_{1M}. Each week, 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 week. 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]

In addition to the slope of the volatility term structure, we include volatility measures related to option anomalies, the volatility risk premium, and volatility overreaction. For the volatility risk premium, we include the one-day, one-week and one-month realized volatility measures since Corsi (2009) and Busch, Christensen, and Nielsen (2011) show that they are good predictors of future volatility.

In Table 5, we only report the most relevant volatility measures: $IV_{LT} - IV_{1M}$, $HV - IV_{1M}$, $RV_{1M} - IV_{1M}$, $IV_{1M}^{t-6} - IV_{1M}$, $IV_{1M}^{avg} - IV_{1M}$, and $IV_{1M}^{\max} - IV_{1M}$. The results remain unchanged for the other volatility measures (RV_{1d}, RV_{1w}, IV_{1M}^{t-1}, IV_{1M}^{t-3}, and $IdioVol$) and are therefore reported in Table IA.4 of the Internet Appendix.

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 0.217 with a Newey-West t-statistic of 7.79. In addition, this coefficient is statistically significant 42% of the time. In columns 2 to 6, we run bivariate regressions between the slope of the volatility term structure and one alternative volatility factor at a time. The coefficient associated with the slope of the volatility term structure ranges from 0.092 to 0.259, and the Newey-West t-statistic is above 3.25 for all regressions. The coefficient of most volatility measures ($HV - IV_{1M}$, $RV_{1M} - IV_{1M}$, and $IV_{1M}^{t-6} - IV_{1M}$) is also positive and significant. Finally, the multivariate regression in column 7 confirms the positive relation between the slope of the volatility term structure and future volatility.

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 also explain future realized volatility.

4.5 Alternative Forecast Horizons

Thus far the empirical analysis has been based on one-week straddle returns. In this section we study two-week, three-week, and one-month holding periods. Two-week option returns are constructed like the one-week returns. Three-week and one-month options returns are constructed with options that are three weeks and one month away from expiration and are held until maturity. One-month options are available on the second trading day (usually a Tuesday) after the expiration of the previous one-month options, which occurs on the Saturday following the third Friday of the month.

[Insert Table 6 here]

Table 6 contains the results for the two-week, three-week, and one-month straddle returns. We report the average straddle returns of decile portfolios, the long-short return, their t-statistic, standard deviation, skewness and kurtosis. For all holding horizons, the long-short straddle return is positive and significant. Given that the long-short returns are highly non-normal, we compute 95% bootstrap confidence intervals similar to the one in Panel A of Table 2. The 95% bootstrap confidence intervals confirm that the two-week, three-week, and one-month long-short returns are positive and significant.

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

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 5.8% and 7.1% for portfolios 1 and 10. Hence, the bid-ask spreads will eliminate the one-week long-short straddle return of 5.1%. For this reason we assess the impact of transaction costs on the one-month straddle returns. The long-short one-month straddle return of 16.5% and the fact that options are held until maturity might mitigate the impact of the bid-ask spread. When the one-month option expire, 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.[15]

Financial research has reported that the effective-to-quoted spread ratio is lower than 50% (De Fontnouvelle, Fisher, and Harris (2003) and Mayhew (2002)), but in some cases it can be as large as 100% (Battalio, Hatch, and Jennings (2004)). Recent work by Muravyev and Pearson (2014) shows that average investors and algorithmic traders execute their trades at an effective-to-quoted spread ratio of 50% and 12.5% based on daily closing quotes. An effective-to-quoted spread ratio of 50% (12.5%) is equivalent to paying half (one-eighth) the bid-ask quoted spread when executing the option trading strategy.

[Insert Table 7 here]

Panel A of Table 7 reports the long-short one-month straddle returns for effective-to-quoted spread ratios 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. The first three quartile portfolios (Q1, Q2 and Q3) report a positive and significant return for all effective-to-quoted spread ratios (Q2 is not significant when the ratio is 100%). For example, the

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

portfolio with the lowest bid-ask spread (Q1) reports a long-short straddle return of 16.7% with a t-statistic of 4.88 when the effective-to-quoted 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-to-quoted spread ratio is 100%. 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-to-quoted spread 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-to-quoted 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 7 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 that 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 one-month 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.

4.7 Possible Explanations

We now explore potential explanations of our results. We provide evidence that links our results with risk-based and behavioral explanations.

The large straddle return differential across decile portfolios might be compensating investors for some risk. In the first test, we compute standard risk measures for each decile portfolio. If straddle returns are explained by risk, higher levels of risk should translate into higher returns. Table IA.6 in the Internet Appendix reports, for each decile portfolio, the value-at-risk and the expected shortfall at the 5 percent level using historical weekly straddle returns. We find that portfolio 1, the one with the lowest return, is riskier than portfolio 10, the one with the highest return using both risk measures. However, the volatility, skewness, and kurtosis across portfolios provide a different picture. As reported in Panel A of Table 2, portfolio 1 has the lowest volatility, skewness, and kurtosis across all portfolios, and portfolio 10 has the highest volatility. Therefore, value-at-risk and expected shortfall are mainly driven by the average return of the portfolio. Given that transaction costs reduce the returns of all portfolios, higher moments become more important to assess their risk. We conclude that there is mixed evidence that standard risk measures explain our results.

A second risk-based explanation is that the slope of the volatility term structure is measuring the volatility risk premium. We define the ex-post volatility risk premium as $FV - IV_{1M}$ following Carr and Wu (2008). According to Panel B of Table 1, the correlation between the slope of the volatility term structure and the ex-post volatility risk premium is -3.0%, and the correlation with the ex-ante volatility risk premium, $RV_{1M} - IV_{1M}$, is 17.6%. These correlations indicate a weak relation between the slope of the volatility term structure and the volatility risk premium.

However, the two measures are good predictors of the long-short straddle returns. An in-sample exercise where we sort by $FV - IV_{1M}$ produces a long-short weekly straddle return of 21.4% with a t-statistic of 60.36 (see Panel B of Table IA.1 in the Internet Appendix). The correlation between these long-short straddle returns and the ones sorted by the volatility risk premium is 92%. This large correlation and the fact that the slope of the volatility term structure is a good predictor of the ex-post volatility risk premium (see Table 5) indicate that both measures might be measuring something similar. Overall, we find mixed evidence that the slope of the volatility term structure is measuring the volatility risk premium.

Finally, we provide a behavioral based explanation: volatility over-reaction. Poteshman (2001) and Stein (1989) document that investors can under- or over-react to changes in short-term volatility. Investor under- and over-reaction 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), and by demand pressures of the type studied by Garleanu, Pedersen, and Poteshman (2009).

We examine several measures of volatility over-reaction following Cao and Han (2013): $IV_{1M}^{t-1} - IV_{1M}$, $IV_{1M}^{t-3} - IV_{1M}$, $IV_{1M}^{t-6} - IV_{1M}$, 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 under-reacted (over-reacted) compared to its historical average and such options are potentially underpriced (overpriced). According to Panel A of Table 1, the magnitude of the slope of the volatility term structure and the measures of volatility overreaction is very similar across portfolios ranked by the slope of the volatility term structure. For example, the slope of the volatility term structure is -13.4%, -1.7%, and 5.6% for portfolios 1, 5 and 10, while $IV_{1M}^{avg} - IV_{1M}$ is -6.9%, -0.1%, and 4.3% for the same portfolios. The correlation matrix on Panel B of Table 1 reports a high correlation (ranging from 51.4% to 57.8%) between the slope of the volatility term structure and the measures of volatility misreaction. The correlation among the four measures of volatility over-reaction is between 34.8% and 80.9%. This evidence tentatively supports an under- and over-reaction explanation of our results.

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. Since the results presented do not change the conclusions of the paper, we describe them in this section and report the tables in the Internet Appendix.

5.1 Controlling for Alternative Measures of Jump Risk

In Section 4.3, we showed that the positive relation between the slope of the volatility term structure and future straddle returns is robust to jump risk as defined by Yan (2011). We now investigate the robustness of our results to three additional measures of jump risk. The first proxy for jump risk is the slope of the volatility smile, $OptionSkew$, defined as the difference between out-of-the-money and at-the-money volatilities by Xing, Zhang and Zhao (2010). The other two proxies are the model-free left tail ($RNJump\ Left$) and right tail ($RNJump\ Right$) risk-neutral jump measures derived by Bollerslev and Todorov (2011).

Table IA.2 in the Internet Appendix reports the modified Fama and MacBeth (1973) regression proposed by Brennan, Chordia, and Subrahmanyam (1998) with the three measures of jump risk. The coefficient of the slope of the volatility term structure remains positive and significant. Table IA.3 in the Internet Appendix reports two-way sorts for the jump risk measures and the slope of the volatility term structure. The conclusions are confirmed.

5.2 Controlling for Stock Characteristics

Table IA.2 in the Internet Appendix reports the results of the modified Fama and MacBeth (1973) regressions proposed by Brennan, Chordia, and Subrahmanyam (1998) of straddle returns on firm characteristics. 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, book-to-market, and historical volatility, skewness and kurtosis.

The coefficient of the slope of the volatility term structure is positive and significant for all regressions. The slope of the volatility term structure effect is not explained by option liquidity or historical moments.

Table IA.3 in the Internet Appendix reports the long-short straddle returns and the t-statistics for each firm characteristic using the two-way sort methodology. All of the long-short straddle returns are positive and significant.

We conclude that the slope of the volatility term structure is not a proxy for option illiquidity or firm characteristics such as size, book to market, or historical moments.

5.3 Moneyness

In our study, the moneyness level for call and put options is between 0.95 and 1.05. Table IA.5 in the Internet Appendix shows that when the moneyness bounds are changed to 0.975 and 1.025, the long-short straddle return remains positive and significant. In this case, the number of stocks decreases from 486 to 309. If the moneyness is not bounded, the number of stocks per week increases from 486 to 680, and the magnitude of the straddle returns and the t-statistics remains very similar to those reported in the primary analysis.

5.4 Sub-samples

We divide the sample into two sub-periods: 1996 to 2003 and 2004 to 2012. The long-short straddle return decreases from the first to the second period as reported in Table IA.5 in the Internet Appendix. 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. Table IA.5 in the Internet Appendix shows that results are robust for the two groups.

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. The results are not driven by the January effect.

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

5.5 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. 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 IA.5 in the Internet Appendix. Options that violate arbitrage bounds only account for 0.6% of the sample data.

5.6 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 within the week that the options are included in the analysis. As reported on Table IA.5 in the Internet Appendix, the long-short straddle returns are positive and significant, and the magnitude is larger for firms with earnings announcements than for firms not making an announcement. Therefore, the long-short straddle returns are robust to earnings announcements.

5.7 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 IA.5 in the Internet Appendix, the results are robust to the weighting methodology.

5.8 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. As shown in Table IA.5 in the Internet Appendix, the long-short straddle returns for the 3-month, 6-month and 9-month definitions of the slope of the volatility term structure are positive and significant. We conclude that the definition of the slope of the volatility term structure does not change the results.

6 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 week, we rank stocks according to the slope of the volatility term structure and study subsequent one week straddle returns. We find that as the slope of the volatility term structure increases, so does the one-week 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 5.1% per week.

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.

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Appendix A: Volatility measures

As is standard, all volatility measures are annualized.

- Short-term implied volatility, IV_{1M}, is defined as the average of the one-month ATM put and call implied volatilities.
- Long-term implied volatility, IV_{LT}, is the average volatility of the ATM put and call options that have the longest time-to-maturity.
- Lagged implied volatility, IV_{1M}^{t-i}, is defined as the average of the one-month ATM put and call implied volatilities i months ago. We estimate implied volatility for different lags: 1 month, 3 months, and 6 months.
- Average implied volatility, IV_{1M}^{avg}, is defined as the average of daily observations of IV_{1M} over the last six months.
- Maximum implied volatility, $IV_{1M}^{\max}$, is defined as the maximum short-term volatility IV_{1M} over the last six months.
- Historical volatility for stock i on day t is defined as

$$HV_{i,t} = \left(\frac{252}{N} \sum_{s=0}^{N} (r_{i,t-s} - \mu_i)^2 \right)^{1/2}, \tag{5}$$

  where N is the number of trading days, $r_{i,t-s}$ is the daily log-return of stock i on day $t-s$, μ_i is the mean for stock i, and μ_i is the mean of stock i. We estimate historical volatility using 12 months of daily returns.

- Future volatility for stock i on day t is defined as

$$FV_{i,t} = \left(\frac{252}{T} \sum_{s=1}^{T} (r_{i,t+s} - \mu_i)^2 \right)^{1/2}, \tag{6}$$

  where T is the number of trading days until the option expiration, $r_{i,t+s}$ is the daily log-return of stock i on day $t+s$, and μ_i is the mean of stock i. We estimate future volatility over 1 week ($T = 5$).

- Realized volatility for stock i on day t is defined as

$$RV_{i,t} = \left(\frac{252}{N} \sum\nolimits_{i=0}^{N-1} \sum\nolimits_{j=1}^{I} r^2_{t-i,\frac{j}{I}} \right)^{1/2}, \tag{7}$$

  where $r^2_{t-i,\frac{j}{I}}$ is the jth intraday return on day $t-i$ and I is the number of return observations in a trading day. We use five-minute returns so that in 6.5 trading hours we have $I = 78$, and we estimate realized volatility over 1 day ($N = 1$), 1 week ($N = 5$), and 1 month ($N = 22$).

- Idiosyncratic volatility is defined as

$$idvol_{i,t} = (252 * var(\varepsilon_{i,t}))^{1/2}, \tag{8}$$

where $\varepsilon_{i,t}$ is the error term of the three-factor Fama and French (1993) regression. The regression is estimated with daily returns over the previous 22 trading days.

Figure 1: Time Series of Straddle Returns

Straddle returns are generated as in Table 2. The figures below display the returns of the long-short portfolio 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 for OptionMetrics stocks is January 1996 to January 2012.

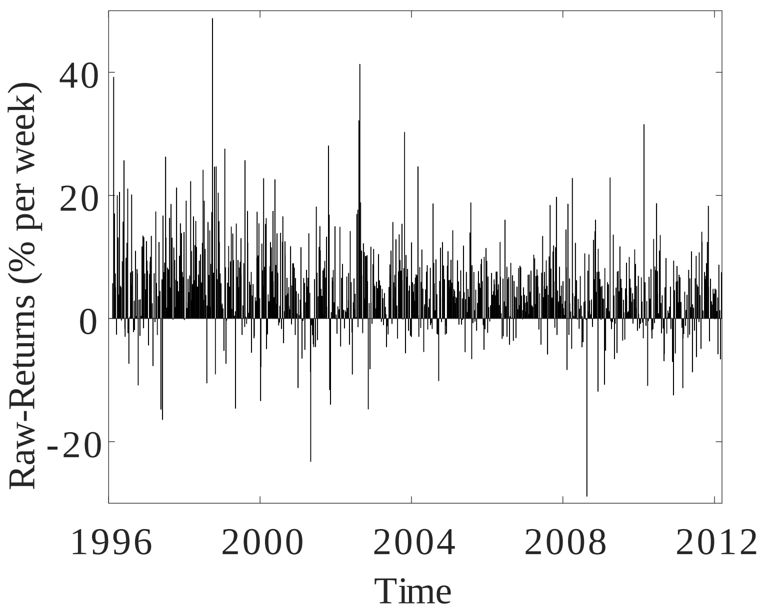

Figure 2: QQ-plot of Straddle Returns

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 for OptionMetrics stocks is January 1996 to January 2012.

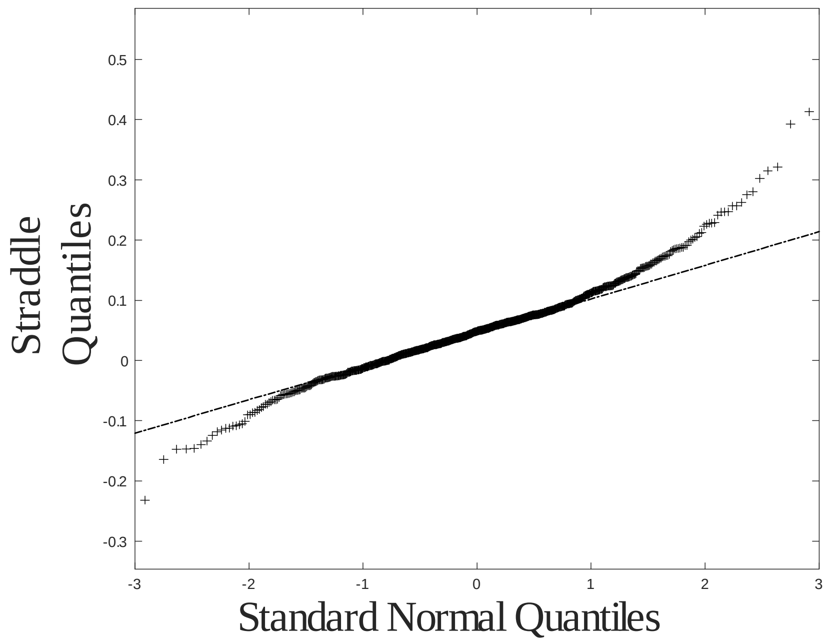

Table 1
Characteristics of Portfolios Sorted by the Slope of the Volatility Term Structure

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 stocks in the OptionMetrics database 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), volatility measures minus IV_{1M} (Volatility measures are future volatility (FV) over the following week, 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 average (IV_{1M}^{avg}) and maximum ($IV_{1M}^{\max}$) implied volatilities over the previous 6-months, and idiosyncratic volatility ($idioVol$)), \$ Size Options (Open interest of the ATM call and put multiplied by their respective mid price, in \$ thousands), 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), and risk-neutral jump ($RNjump$) as in Yan (2011). Panel B reports the correlations of the volatility variables minus IV_{1M}. See Appendix A for volatility measures definitions.

Panel A: Portfolio Characteristics

Deciles	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10
Volatility Measures										
Slope VTS	-0.134	-0.063	-0.041	-0.027	-0.017	-0.008	0.000	0.009	0.020	0.056
IV_{1M}	0.740	0.578	0.512	0.466	0.429	0.402	0.383	0.377	0.385	0.461
IV_{LT}	0.606	0.516	0.471	0.439	0.413	0.394	0.384	0.385	0.405	0.517
$FV-IV_{1M}$	-0.076	-0.051	-0.042	-0.040	-0.038	-0.037	-0.035	-0.036	-0.038	-0.050
$HV-IV_{1M}$	-0.084	-0.014	0.002	0.012	0.017	0.023	0.029	0.039	0.054	0.095
$RV_{1d}-IV_{1M}$	-0.059	-0.038	-0.035	-0.032	-0.032	-0.031	-0.027	-0.026	-0.018	-0.004
$RV_{1w}-IV_{1M}$	-0.059	-0.030	-0.027	-0.024	-0.025	-0.023	-0.018	-0.017	-0.008	0.011
$VRP(=RV_{1M}-IV_{1M})$	-0.078	-0.034	-0.027	-0.021	-0.021	-0.018	-0.011	-0.007	0.004	0.031
$IV_{1M}^{t-1}-IV_{1M}$	-0.110	-0.043	-0.024	-0.012	-0.003	0.004	0.012	0.020	0.032	0.064
$IV_{1M}^{t-3}-IV_{1M}$	-0.123	-0.044	-0.023	-0.009	0.001	0.008	0.016	0.024	0.037	0.072
$IV_{1M}^{t-6}-IV_{1M}$	-0.138	-0.051	-0.027	-0.013	-0.002	0.008	0.016	0.026	0.039	0.072
$IV_{1M}^{avg}-IV_{1M}$	-0.069	-0.025	-0.013	-0.006	-0.001	0.004	0.008	0.013	0.021	0.043
$IV_{1M}^{\max}-IV_{1M}$	0.072	0.063	0.060	0.060	0.060	0.060	0.063	0.068	0.080	0.128
$IdioVol-IV_{1M}$	-0.195	-0.152	-0.136	-0.123	-0.114	-0.107	-0.100	-0.095	-0.091	-0.094
Option and Firm Characteristics										
\$ Size Options	876	800	933	977	957	964	960	1046	1115	952
Put-Call Spread IV_{1M}	0.016	0.009	0.007	0.007	0.007	0.007	0.007	0.007	0.008	0.013
Bid to Mid Spread IV_{1M}	0.058	0.057	0.057	0.057	0.057	0.057	0.058	0.059	0.061	0.071
Delta call	0.558	0.551	0.548	0.546	0.542	0.538	0.534	0.528	0.525	0.530
Delta put	-0.443	-0.451	-0.455	-0.458	-0.462	-0.468	-0.472	-0.478	-0.481	-0.475
Gamma	0.173	0.177	0.179	0.183	0.186	0.187	0.196	0.199	0.210	0.245
Vega	8.64	10.57	12.00	13.23	14.31	15.43	15.86	17.29	17.6	13.61
Size	5.56	9.58	12.79	16.21	19.51	21.67	23.92	25.46	23.02	13.16
BE/ME	0.842	0.918	0.866	0.846	0.825	0.853	0.831	0.744	0.743	0.727
Risk Neutral Measures										
RNVol	0.683	0.582	0.526	0.485	0.451	0.425	0.406	0.399	0.407	0.481
RNSkew	-0.383	-0.436	-0.482	-0.522	-0.558	-0.596	-0.623	-0.646	-0.664	-0.597
RNKurt	3.637	3.814	3.984	4.128	4.262	4.396	4.476	4.593	4.696	4.614
RNJump	0.017	0.009	0.008	0.007	0.007	0.007	0.007	0.008	0.009	0.014

Table 1 (Continued)

Panel B: Correlation Matrix

	Slope VTS	FV-IV$_{1M}$	HV$-$IV$_{1M}$	RV$_{1d}$-IV$_{1M}$	RV$_{1w}$-IV$_{1M}$	VRP (=RV$_{1M}$-IV$_{1M}$)	IV$^{t-1}_{1M}$-IV$_{1M}$	IV$^{t-3}_{1M}$-IV$_{1M}$	IV$^{t-6}_{1M}$-IV$_{1M}$	IV$^{avg}_{1M}$-IV$_{1M}$	IV$^{\max}_{1M}$-IV$_{1M}$	IdioVol-IV$_{1M}$
FV-IV$_{1M}$	-3.0											
HV-IV$_{1M}$	42.4	-3.5										
RV$_{1d}$-IV$_{1M}$	2.0	13.3	1.3									
RV$_{1w}$-IV$_{1M}$	4.3	14.1	3.3	68.1								
VRP (=RV$_{1M}$-IV$_{1M}$)	17.6	7.5	14.6	51.3	77.1							
IV$^{t-1}_{1M}$-IV$_{1M}$	55.8	-5.4	43.0	-0.8	1.6	26.1						
IV$^{t-3}_{1M}$-IV$_{1M}$	53.4	-6.4	60.4	-1.8	-2.9	7.0	49.1					
IV$^{t-6}_{1M}$-IV$_{1M}$	51.4	-5.9	69.3	-1.2	-2.5	4.7	37.4	62.9				
IV$^{avg}_{1M}$-IV$_{1M}$	57.8	-4.7	40.5	-0.9	8.1	37.3	80.9	44.3	34.8			
IV$^{\max}_{1M}$-IV$_{1M}$	9.0	-1.8	13.9	1.3	12.7	31.1	44.7	3.6	-4.8	59.9		
IdioVol-IV$_{1M}$	25.8	0.1	20.8	18.6	29.2	39.8	26.4	15.5	16.7	32.2	19.2	

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 weekly 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). We report the 95% bootstrap confidence interval for the long-short ($P10 - P1$) straddle return. 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). We report the 95% bootstrap confidence interval for the alpha (α_P). Adjusted R^2 is reported at the bottom of the table. The sample period for OptionMetrics stocks is January 1996 to January 2012.

Panel A: Straddle Returns

Deciles	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P10-P1
Mean	-0.029	-0.015	-0.010	-0.010	-0.008	-0.005	-0.003	-0.001	0.006	0.022	0.051
t-stat	(-11.2)	(-6.06)	(-4.12)	(-3.78)	(-3.24)	(-1.76)	(-1.03)	(-0.45)	(2.02)	(7.35)	(19.9)
Mean - 95% Bootstrap CI											[0.046, 0.055]
StDev	0.074	0.074	0.073	0.073	0.074	0.077	0.078	0.081	0.085	0.086	0.073
Skewness	0.7	0.8	0.6	0.5	1.0	1.5	0.8	1.2	1.4	1.3	0.6
Kurtosis	4.1	5.8	4.1	3.8	10.1	12.2	7.3	7.9	12.0	9.4	3.8

Panel B: Bootstrapped Critical Values for the t-statistic

Percentile (%)	Bootstrapped t-statistic
1	-2.367
2.5	-1.997
5	-1.673
10	-1.308
90	1.265
95	1.631
97.5	1.937
99	2.300

Table 2 (Continued)

Panel C: Risk-Adjusted Returns

	(1)	(2)	(3)	(4)
Alpha	0.056	0.054	0.053	0.054
	(21.53)	(18.77)	(15.46)	(15.71)
Alpha - 95% Bootstrap CI	[0.050, 0.061]	[0.046, 0.061]	[0.044, 0.061]	[0.044, 0.062]
R_m - R_f	-0.069	-0.079	-0.052	-0.058
	(-7.93)	(-7.91)	(-4.57)	(-4.86)
SMB	-0.038			-0.017
	(-2.38)			(-1.08)
HML	-0.022			-0.018
	(-1.60)			(-1.31)
UMD	-0.009			-0.019
	(-1.00)			(-2.12)
$R_o - R_f$		0.082	0.069	0.063
		(3.70)	(2.65)	(2.42)
$R_m^2 - R_f$		0.03	-0.03	-0.02
		(2.41)	(-1.21)	(-0.83)
$R_o^2 - R_f$		0.008	0.202	0.183
		(0.25)	(1.76)	(1.59)
$R_m R_o - R_f$		-0.028	-0.087	-0.100
		(-0.71)	(-1.18)	(-1.36)
$R_o^3 - R_f$			-0.195	-0.185
			(-2.35)	(-2.23)
$R_m^3 - R_f$			-0.01	-0.02
			(-0.59)	(-0.84)
$R_m R_o^2 - R_f$			-0.081	-0.080
			(-0.76)	(-0.75)
$R_m^2 R_o - R_f$			0.193	0.207
			(2.68)	(2.83)
Adj. R^2	0.077	0.118	0.143	0.147

Table 3
Modified Fama-MacBeth Cross-Sectional Regressions

This table reports the results from the modified Fama-MacBeth weekly 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 the slope of the volatility term structure, 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 month (RV_{1M}), the average (IV_{1M}^{avg}) and maximum ($IV_{1M}^{\max}$) implied volatilities over the previous 6-months), risk-neutral volatility, skewness and kurtosis (Bakshi, Kapadia, and Madan (2003)), and risk-neutral jump (Yan (2011)). The first row gives the coefficients of the regression and the second row gives the Newey-West t-statistics (in parentheses). We report the 95% bootstrap confidence interval for the coefficient of the slope of the volatility term structure. Adjusted R^2 is reported at the bottom of the table. The sample period for OptionMetrics stocks is January 1996 to January 2012.

	(1)	(2)	(3)	(4)	(5)	(6)
Intercept	0.007	0.006	0.007	0.006	0.007	0.000
	(3.91)	(3.20)	(3.80)	(3.38)	(3.61)	(-0.01)
Slope VTS	0.217	0.192	0.202	0.184	0.221	0.222
	(15.56)	(12.64)	(14.62)	(11.37)	(15.27)	(15.84)
95% Bootstrap CI	[0.198, 0.241]	[0.168, 0.217]	[0.182, 0.227]	[0.159, 0.213]	[0.202, 0.246]	[0.200, 0.249]
HV-IV$_{1M}$		0.029				
		(4.06)				
VRP (=RV$_{1M}$-IV$_{1M}$)			0.032			
			(4.27)			
IV$_{1M}^{avg}$-IV$_{1M}$				0.065		
				(4.14)		
IV$_{1M}^{\max}$-IV$_{1M}$					-0.015	
					(-1.58)	
RNVol						0.002
						(0.40)
RNSkew						0.003
						(1.29)
RNKurt						0.0016
						(2.53)
RNJump						-0.0163
						(-0.98)
Adj. R^2	0.0067	0.0099	0.0095	0.0099	0.0096	0.016

Table 4
Double Sorting on Firm Characteristics and the Slope of the Volatility Term Structure

Each week, firms are first sorted into quintiles based on volatility measures (minus IV_{1M}), and then, within each quintile, firms are sorted into quintiles 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 to form $P1_{avg}$ to $P5_{avg}$. $P1_{avg}$ ($P5_{avg}$) averages the portfolios with the lowest (highest) slope of the volatility term structure for each quintile characteristic portfolio. The characteristics included are volatility measures minus IV_{1M} (Volatility measures are the one-year historical volatility of daily returns (HV), realized volatility computed with 5-minute returns over 1 month (RV_{1M}), the average (IV_{1M}^{avg}) and maximum ($IV_{1M}^{\max}$) implied volatilities over the previous 6-months), risk-neutral volatility, skewness and kurtosis (Bakshi, Kapadia, and Madan (2003)), and risk-neutral jump (Yan (2011)). This table reports the average straddle return for portfolios $P1_{avg}$ to $P5_{avg}$, the difference between $P1_{avg}$ and $P5_{avg}$, the 95% bootstrap confidence interval for $P5_{avg} - P1_{avg}$, and the t-statistics (in parentheses). The sample period for OptionMetrics stocks is January 1996 to January 2012.

Control	P1$_{avg}$	P2$_{avg}$	P3$_{avg}$	P4$_{avg}$	P5$_{avg}$	P5$_{avg}$−P1$_{avg}$	95% Bootstrap CI for P5$_{avg}$−P1$_{avg}$
HV-IV$_{1M}$	-0.016	-0.010	-0.005	-0.002	0.006	0.022	[0.019, 0.025]
	(-6.47)	(-4.29)	(-2.10)	(-0.76)	(2.36)	(12.48)	
VRP (=RV$_{1M}$-IV$_{1M}$)	-0.020	-0.010	-0.006	-0.002	0.011	0.031	[0.028, 0.035]
	(-8.26)	(-4.14)	(-2.49)	(-0.83)	(4.19)	(17.45)	
IV$_{1M}^{avg}$-IV$_{1M}$	-0.017	-0.009	-0.005	-0.002	0.006	0.023	[0.020, 0.027]
	(-7.17)	(-3.56)	(-2.02)	(-0.71)	(2.25)	(14.22)	
IV$_{1M}^{\max}$-IV$_{1M}$	-0.021	-0.011	-0.005	0.000	0.010	0.031	[0.028, 0.035]
	(-8.90)	(-4.58)	(-2.02)	(0.16)	(3.61)	(16.90)	
RNVol	-0.024	-0.011	-0.006	-0.001	0.014	0.038	[0.034, 0.041]
	(-10.28)	(-4.42)	(-2.19)	(-0.45)	(5.05)	(21.48)	
RNSkew	-0.022	-0.011	-0.006	-0.001	0.013	0.0349	[0.031, 0.039]
	(-9.21)	(-4.63)	(-2.41)	(-0.38)	(4.71)	(18.40)	
RNKurt	-0.022	-0.011	-0.006	-0.002	0.013	0.0350	[0.031, 0.039]
	(-9.37)	(-4.56)	(-2.23)	(-0.62)	(4.67)	(18.40)	
RNJump	-0.022	-0.011	-0.006	-0.002	0.013	0.0351	[0.031, 0.039]
	(-9.13)	(-4.43)	(-2.53)	(-0.58)	(4.74)	(17.80)	

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 week, 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 one week. 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 month (RV_{1M}), implied volatility lagged by 6 months (IV_{1M}^{t-6}), and the maximum ($IV_{1M}^{\max}$) and average (IV_{1M}^{avg}) implied volatilities over the previous 6-months. 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 for OptionMetrics stocks is January 1996 to January 2012.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Intercept	-0.043	-0.045	-0.035	-0.044	-0.042	-0.035	-0.025
	(-9.87)	(-10.29)	(-9.46)	(-10.83)	(-10.43)	(-9.03)	(-7.94)
IV_{LT}-IV_{1M}	0.217	0.142	0.092	0.198	0.248	0.259	0.077
	(7.79)	(4.62)	(3.25)	(7.26)	(7.97)	(9.03)	(2.79)
HV-IV_{1M}		0.086					0.094
		(7.22)					(7.07)
VRP (=RV_{1M}-IV_{1M})			0.196				0.193
			(13.7)				(15.5)
IV_{1M}^{t-6}-IV_{1M}				0.027			-0.033
				(2.39)			(-2.89)
IV_{1M}^{avg}-IV_{1M}					-0.027		0.123
					(-1.08)		(3.37)
$\mathrm{IV}_{1M}^{\max}$-IV_{1M}						-0.138	-0.255
						(-9.53)	(-13.5)
Adj. R^2	2%	3%	4%	3%	3%	3%	7%
Pct. of t$\geqslant$1.96 (IV_{LT}-IV_{1M})	42%	33%	28%	35%	36%	44%	20%
Pct. of t$\geqslant$1.96 (HV-IV_{1M})		25%					19%
Pct. of t$\geqslant$1.96 (RV_{1M}-IV_{1M})			42%				40%
Pct. of t$\geqslant$1.96 (IV_{1M}^{t-6}-IV_{1M})				20%			11%
Pct. of t$\geqslant$1.96 (IV_{1M}^{avg}-IV_{1M})					16%		23%
Pct. of t$\geqslant$1.96 ($\mathrm{IV}_{1M}^{\max}$-IV_{1M})						7%	6%

Table 6
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, 3-week, and one-month 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). We report the 95% bootstrap confidence interval for the long-short portfolio straddle return. The sample period for OptionMetrics stocks 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	-0.050	-0.025	-0.020	-0.019	-0.012	-0.013	-0.008	-0.005	0.003	0.030	0.079
t-stat	(-8.45)	(-4.02)	(-3.52)	(-3.39)	(-2.05)	(-1.99)	(-1.27)	(-0.79)	(0.48)	(4.41)	(13.20)
Mean - 95% Bootstrap CI											[0.067, 0.091]
StDev	0.120	0.126	0.118	0.115	0.122	0.131	0.131	0.139	0.138	0.138	0.122
Skewness	1.1	1.1	0.9	1.2	0.9	2.0	1.6	2.1	1.6	1.6	0.3
Kurtosis	3.4	3.4	2.3	5.2	2.7	10.4	5.8	11.0	6.1	6.3	5.1

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)
Mean - 95% Bootstrap CI											[0.092, 0.179]
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

Panel C: One-Month Horizon

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)
Mean - 95% Bootstrap CI											[0.135, 0.201]
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

Table 7
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 an effective-to-quoted spread ratio of 25%, 50%, 75%, and 100%. 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 for OptionMetrics stocks is January 1996 to January 2012.

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

	Effective-to-Quoted Spread Ratio			
Bid/Ask Spread Quartiles	25%	50%	75%	100%
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%

Internet Appendix for

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

Table IA.1
Straddle Returns for Alternative Definitions of the Slope of the Volatility Term Structure and Future Volatility

This table reports weekly equal-weighted straddle returns along with the t-statistics (t-stat) of decile portfolios for different definitions of the slope of the volatility term structure and future volatility. Panel A reports on alternative definitions of the slope of the volatility term structure ($IV_{LT} - IV_{1M}$) use variance, the square-root of volatility, volatility cubed, the cubed root of volatility, and the logarithm of each volatility measure. Panel B reports straddle returns when sorting on future volatility, FV, minus short-term implied volatility, IV_{1M}. The last column displays the difference between decile portfolio 10 and decile 1. The sample period for OptionMetrics stocks is January 1996 to January 2012.

Panel A: Alternative Definitions of the Slope of the Volatility Term Structure

Deciles	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P10-P1
Variance	-0.026	-0.014	-0.011	-0.010	-0.009	-0.006	-0.002	-0.001	0.007	0.020	0.046
	(-10.23)	(-5.59)	(-4.14)	(-4.02)	(-3.65)	(-2.19)	(-0.82)	(-0.22)	(2.26)	(6.57)	(18.20)
Sqr Root	-0.030	-0.015	-0.011	-0.008	-0.009	-0.004	-0.003	-0.001	0.006	0.021	0.051
	(-12.10)	(-5.87)	(-4.21)	(-3.31)	(-3.41)	(-1.55)	(-0.93)	(-0.37)	(2.03)	(7.10)	(20.43)
Cubed	-0.026	-0.013	-0.011	-0.010	-0.010	-0.005	-0.003	-0.001	0.008	0.018	0.043
	(-9.71)	(-5.07)	(-4.36)	(-3.77)	(-3.93)	(-2.05)	(-1.24)	(-0.19)	(2.75)	(5.86)	(17.08)
Cubed Root	-0.027	-0.016	-0.009	-0.011	-0.008	-0.006	-0.001	-0.001	0.006	0.020	0.047
	(-10.41)	(-6.31)	(-3.60)	(-4.30)	(-3.28)	(-2.16)	(-0.51)	(-0.28)	(2.05)	(6.77)	(18.59)
Log	-0.031	-0.014	-0.011	-0.008	-0.007	-0.004	-0.003	0.000	0.005	0.020	0.051
	(-12.89)	(-5.60)	(-4.33)	(-3.17)	(-2.84)	(-1.74)	(-1.00)	(-0.01)	(1.87)	(6.66)	(20.58)

Panel B: Sorting by Future Volatility minus IV_{1M}

Deciles	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P10-P1
Mean	-0.067	-0.047	-0.039	-0.032	-0.025	-0.017	-0.009	0.006	0.032	0.147	0.214
t-stat	(-28.20)	(-20.12)	(-15.63)	(-13.39)	(-9.84)	(-6.52)	(-3.32)	(2.16)	(10.85)	(38.69)	(60.36)
StDev	0.069	0.068	0.071	0.069	0.073	0.075	0.078	0.080	0.086	0.110	0.103
Skewness	0.7	0.7	1.4	0.7	1.1	0.8	0.8	0.9	0.9	0.6	0.7
Kurtosis	7.3	9.0	19.8	7.3	10.4	7.4	5.3	5.2	3.8	1.1	0.9

Table IA.2
Controlling for Volatility Measures, and Firm Characteristics

This table reports the results from the modified Fama-MacBeth 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}), realized volatility computed with 5-minute returns over 1 day (RV_{1d}), and 1 week (RV_{1w}), implied volatility lagged by one month (IV_{1M}^{t-1}), 3 months (IV_{1M}^{t-3}), and 6 months (IV_{1M}^{t-6}), and idiosyncratic volatility ($idioVol$)), option skew (Xing, Zhang and Zhao (2010)), the right-tail and left-tail risk neutral jumps (Bollerslev and Todorov (2011)), option dollar volume ($\$Vol$), option volume contracts (Vol), option open interest (OI), bid-to-mid option spread (BM), size (market capitalization in $ billions), book-to-market ratio (BE/ME), historical volatility (HV), skewness ($HSkew$) and kurtosis ($HKurt$). 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 for OptionMetrics stocks is January 1996 to January 2012.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Intercept	0.001	0.0001	-0.001	-0.001	-0.001	-0.002	-0.004	0.013	0.004
	(0.57)	(0.14)	(-0.38)	(-0.48)	(-0.27)	(-0.74)	(-1.89)	(2.65)	(1.47)
Slope VTS	0.209	0.215	0.210	0.165	0.189	0.230	0.202	0.211	0.225
	(14.90)	(15.25)	(13.18)	(11.30)	(12.81)	(16.45)	(13.72)	(15.85)	(16.22)
RV_{1d}-IV_{1M}	0.032								
	(7.85)								
RV_{1w}-IV_{1M}		0.026							
		(4.49)							
IV_{1M}^{t-1}-IV_{1M}			0.016						
			(1.69)						
IV_{1M}^{t-3}-IV_{1M}				0.059					
				(7.29)					
IV_{1M}^{t-6}-IV_{1M}					0.034				
					(4.98)				
IdioVol-IV_{1M}						-0.012			
						(-2.39)			
OptionSkew							0.143		
							(9.52)		
RNJump Right							0.059		
							(4.22)		
RNJump Left							-0.082		
							(-5.09)		
Ln($Vol)								-0.005	
								(-3.00)	
Ln(Vol)								0.006	
								(3.21)	
Ln(OI)								-0.003	
								(-4.50)	
Ln(BM)								0.076	
								(3.35)	
Ln(size)									-0.0001
									(-2.38)
BE/ME									-0.001
									(-0.67)
HV									-0.010
									(-1.99)
HSkew									0.0005
									(0.95)
HKurt									-0.0001
									(-1.08)
Adj. R^2	0.0077	0.0078	0.0076	0.0082	0.0085	0.0074	0.0138	0.016	0.0143

Table IA.3
Double Sorting on Firm Characteristics and the Slope of the Volatility Term Structure

Each week, firms are first sorted into quintiles based on volatility measures (minus IV_{1M}), and then, within each quintile, firms are sorted into quintiles 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 to form P1$_{avg}$ to P5$_{avg}$. P1$_{avg}$ (P5$_{avg}$) averages the portfolios with the lowest (highest) slope of the volatility term structure for each quintile characteristic portfolio. The characteristics included are volatility measures minus IV_{1M} (Volatility measures are realized volatility computed with 5-minute returns over 1 day (RV_{1d}), and 1 week (RV_{1w}), implied volatility lagged by one month (IV_{1M}^{t-1}), 3 months (IV_{1M}^{t-3}), and 6 months (IV_{1M}^{t-6}), and idiosyncratic volatility ($idioVol$)), option skew (Xing, Zhang and Zhao (2010)), the right-tail and left-tail risk neutral jumps (Bollerslev and Todorov (2011)), option dollar volume ($\$Vol$), option volume contracts (Vol), option open interest (OI), bid-to-mid option spread (BM), market capitalization in \$ billions (Size), book-to-market ratio (BE/ME), historical volatility (HV), skewness ($HSkew$) and kurtosis ($HKurt$). This table reports the average straddle return for portfolios P1$_{avg}$ to P5$_{avg}$, the difference between P1$_{avg}$ and P5$_{avg}$, and the t-statistics (in parentheses). The sample period for OptionMetrics stocks is January 1996 to January 2012.

Control	P1$_{avg}$	P2$_{avg}$	P3$_{avg}$	P4$_{avg}$	P5$_{avg}$	P5$_{avg}$−P1$_{avg}$
RV$_{1d}$-IV$_{1M}$	-0.021	-0.010	-0.006	-0.002	0.013	0.034
	(-8.75)	(-4.30)	(-2.54)	(-0.87)	(4.63)	(17.64)
RV$_{1w}$-IV$_{1M}$	-0.021	-0.011	-0.006	-0.003	0.013	0.034
	(-8.69)	(-4.50)	(-2.21)	(-1.05)	(4.74)	(18.19)
IV$_{1M}^{t-1}$-IV$_{1M}$	-0.018	-0.008	-0.006	-0.001	0.008	0.026
	(-7.60)	(-3.51)	(-2.55)	(-0.55)	(2.95)	(16.55)
IV$_{1M}^{t-3}$-IV$_{1M}$	-0.017	-0.009	-0.006	-0.002	0.008	0.025
	(-6.93)	(-3.86)	(-2.64)	(-0.87)	(2.93)	(14.77)
IV$_{1M}^{t-6}$-IV$_{1M}$	-0.017	-0.011	-0.006	-0.002	0.009	0.026
	(-7.27)	(-4.78)	(-2.28)	(-0.76)	(3.42)	(15.41)
IdioVol-IV$_{1M}$	-0.021	-0.010	-0.006	-0.002	0.013	0.034
	(-8.83)	(-4.39)	(-2.62)	(-0.72)	(4.66)	(19.31)
OptionSkew	-0.022	-0.010	-0.007	-0.001	0.013	0.035
	(-9.43)	(-4.16)	(-2.73)	(-0.42)	(4.66)	(17.84)
RNJump Right	-0.023	-0.010	-0.005	-0.001	0.013	0.036
	(-9.74)	(-4.08)	(-2.19)	(-0.50)	(4.63)	(19.90)
RNJump Left	-0.023	-0.010	-0.005	-0.001	0.013	0.036
	(-9.88)	(-4.03)	(-2.07)	(-0.58)	(4.66)	(20.25)
$Vol	-0.022	-0.009	-0.006	-0.002	0.013	0.035
	(-9.34)	(-3.86)	(-2.60)	(-0.66)	(4.51)	(17.21)
Vol	-0.021	-0.011	-0.006	-0.002	0.013	0.035
	(-8.95)	(-4.40)	(-2.51)	(-0.77)	(4.76)	(17.50)
OI	-0.022	-0.011	-0.006	-0.002	0.014	0.036
	(-9.29)	(-4.46)	(-2.38)	(-0.77)	(4.90)	(17.74)
BM	-0.022	-0.010	-0.006	-0.002	0.012	0.034
	(-9.29)	(-3.95)	(-2.27)	(-0.56)	(4.27)	(17.35)
Size	-0.023	-0.010	-0.006	0.000	0.014	0.037
	(-9.94)	(-4.22)	(-2.52)	(-0.15)	(4.86)	(18.80)
BE/ME	-0.023	-0.010	-0.007	-0.002	0.015	0.038
	(-9.80)	(-4.32)	(-2.66)	(-0.57)	(5.25)	(19.10)
HV	-0.024	-0.011	-0.005	0.000	0.013	0.037
	(-10.58)	(-4.60)	(-1.97)	(0.01)	(4.73)	(20.16)
HSkew	-0.022	-0.011	-0.006	-0.002	0.013	0.035
	(-9.19)	(-4.54)	(-2.46)	(-0.60)	(4.74)	(18.04)
HKurt	-0.022	-0.010	-0.006	-0.002	0.013	0.035
	(-9.08)	(-4.30)	(-2.35)	(-0.82)	(4.71)	(17.78)

Table IA.4
Forecasting Realized Volatility

This tables reports the average coefficients and Newey-West t-statistics from the two pass Fama-MacBeth (1973) regressions. Each week, 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 following week. Volatility measures are the long-term implied volatility (IV_{LT}), realized volatility computed with 5-minute returns over 1 day (RV_{1d}) and 1 week (RV_{1w}), implied volatility lagged by 1 month (IV_{1M}^{t-1}) and 3 months (IV_{1M}^{t-3}), 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 for OptionMetrics stocks is January 1996 to January 2012.

	(1)	(2)	(3)	(4)	(5)
Intercept	-0.035	-0.035	-0.043	-0.044	-0.038
	(-9.70)	(-10.3)	(-10.9)	(-11.0)	(-9.68)
IV_{LT}-IV_{1M}	0.164	0.133	0.231	0.195	0.198
	(6.29)	(5.02)	(7.80)	(7.50)	(7.70)
RV_{1d}-IV_{1M}	0.147				
	(21.05)				
RV_{1w}-IV_{1M}		0.190			
		(17.63)			
IV_{1M}^{t-1}-IV_{1M}			-0.001		
			(-0.07)		
IV_{1M}^{t-3}-IV_{1M}				0.029	
				(2.43)	
IdioVol-IV_{1M}					0.048
					(6.45)
Adj. R^2	4%	4%	3%	3%	3%
Pct. of $t \geqslant 1.96$ (IV_{LT}-IV_{1M})	36%	32%	37%	34%	39%
Pct. of $t \geqslant 1.96$ (RV_{1d}-IV_{1M})	51%				
Pct. of $t \geqslant 1.96$ (RV_{1w}-IV_{1M})		51%			
Pct. of $t \geqslant 1.96$ (IV_{1M}^{t-1}-IV_{1M})			18%		
Pct. of $t \geqslant 1.96$ (IV_{1M}^{t-3}-IV_{1M})				20%	
Pct. of $t \geqslant 1.96$ (IdioVol-IV_{1M})					27%

Table IA.5
Long-Short Straddle Returns for Different Sub-Samples

This table reports 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 arbitrage-bounds group includes stocks that violate arbitrage bounds as suggested by Duarte and Jones (2007). The earnings announcement (EA) group includes stocks that made the announcement during the life of the options. 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 sample period for OptionMetrics stocks is January 1996 to January 2012.

	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P10-P1
Baseline Portfolio	-0.029	-0.015	-0.010	-0.010	-0.008	-0.005	-0.003	-0.001	0.006	0.022	0.051
	(-11.18)	(-6.06)	(-4.12)	(-3.78)	(-3.24)	(-1.76)	(-1.03)	(-0.45)	(2.02)	(7.35)	(19.93)
Moneyness: 0.975 - 1.025	-0.030	-0.016	-0.013	-0.013	-0.007	-0.007	-0.003	-0.001	0.005	0.020	0.050
	(-10.49)	(-5.82)	(-4.66)	(-4.64)	(-2.58)	(-2.34)	(-1.10)	(-0.46)	(1.67)	(6.20)	(17.00)
Unbounded Moneyness	-0.031	-0.014	-0.009	-0.010	-0.007	-0.004	-0.003	0.000	0.008	0.019	0.050
	(-12.99)	(-6.02)	(-3.93)	(-4.16)	(-2.78)	(-1.68)	(-1.06)	(0.02)	(2.71)	(6.95)	(19.95)
Period 1996-2003	-0.027	-0.009	-0.003	-0.003	0.000	0.005	0.007	0.010	0.018	0.036	0.063
	(-6.83)	(-2.33)	(-0.95)	(-0.91)	(-0.04)	(1.35)	(1.85)	(2.60)	(4.46)	(8.38)	(15.31)
Period 2004-2012	-0.031	-0.022	-0.017	-0.016	-0.016	-0.014	-0.013	-0.012	-0.006	0.008	0.039
	(-9.18)	(-6.41)	(-4.95)	(-4.50)	(-4.52)	(-3.95)	(-3.35)	(-3.01)	(-1.48)	(1.96)	(13.30)
TWF Months	-0.044	-0.030	-0.023	-0.025	-0.018	-0.021	-0.017	-0.014	-0.009	0.007	0.049
	(-9.23)	(-5.95)	(-4.69)	(-5.45)	(-3.75)	(-4.11)	(-3.14)	(-2.51)	(-1.50)	(1.15)	(11.13)
Non TWF Months	-0.028	-0.013	-0.009	-0.005	-0.007	-0.002	-0.001	-0.001	0.007	0.022	0.048
	(-7.99)	(-4.05)	(-2.88)	(-1.58)	(-2.24)	(-0.69)	(-0.40)	(-0.33)	(1.75)	(5.63)	(14.54)
January	-0.037	-0.012	-0.020	-0.013	-0.009	-0.008	-0.005	-0.009	0.001	0.017	0.054
	(-4.36)	(-1.41)	(-2.61)	(-1.45)	(-1.11)	(-0.94)	(-0.57)	(-0.99)	(0.10)	(1.55)	(5.66)
Non-January	-0.028	-0.016	-0.010	-0.009	-0.008	-0.004	-0.003	-0.001	0.006	0.022	0.050
	(-10.37)	(-5.90)	(-3.55)	(-3.51)	(-3.06)	(-1.57)	(-0.90)	(-0.19)	(2.09)	(7.23)	(19.12)
Arbitrage Bounds	-0.032	-0.017	-0.016	-0.012	-0.009	-0.007	-0.005	-0.005	0.002	0.018	0.050
	(-8.62)	(-5.01)	(-4.10)	(-3.29)	(-2.47)	(-1.82)	(-1.33)	(-0.96)	(0.69)	(4.54)	(13.38)
EA Months	-0.036	-0.005	-0.012	0.024	0.013	0.023	0.026	0.022	0.042	0.045	0.077
	(-4.12)	(-0.62)	(-1.69)	(2.77)	(1.63)	(3.32)	(3.57)	(3.13)	(5.61)	(5.88)	(6.85)
Non EA Months	-0.032	-0.017	-0.015	-0.014	-0.010	-0.007	-0.005	-0.004	0.006	0.020	0.052
	(-12.68)	(-6.67)	(-5.82)	(-5.26)	(-3.96)	(-2.70)	(-1.94)	(-1.47)	(1.84)	(6.55)	(20.77)
$ Volume Weighted	-0.032	-0.024	-0.018	-0.012	-0.007	-0.008	-0.008	-0.005	-0.005	0.011	0.044
	(-7.06)	(-6.06)	(-4.42)	(-2.95)	(-1.77)	(-2.07)	(-1.89)	(-1.19)	(-1.25)	(2.82)	(7.98)
$ Open Interest Weighted	-0.034	-0.022	-0.016	-0.015	-0.013	-0.007	-0.005	-0.005	-0.004	0.009	0.043
	(-10.08)	(-6.55)	(-4.77)	(-4.14)	(-4.14)	(-2.15)	(-1.32)	(-1.48)	(-1.23)	(2.44)	(10.46)
Slope VTS = IV_{3M}-IV_{1M}	-0.028	-0.011	-0.011	-0.013	-0.009	-0.007	-0.004	0.003	0.009	0.022	0.050
	(-9.53)	(-3.83)	(-3.77)	(-4.66)	(-3.40)	(-2.53)	(-1.20)	(1.09)	(2.90)	(6.64)	(15.13)
Slope VTS = IV_{6M}-IV_{1M}	-0.029	-0.016	-0.012	-0.009	-0.008	-0.007	-0.004	0.000	0.006	0.021	0.049
	(-11.39)	(-6.11)	(-4.39)	(-3.56)	(-2.83)	(-2.52)	(-1.32)	(0.11)	(2.11)	(7.04)	(20.50)
Slope VTS = IV_{9M}-IV_{1M}	-0.030	-0.016	-0.010	-0.010	-0.009	-0.005	-0.004	-0.001	0.004	0.019	0.050
	(-11.22)	(-6.03)	(-3.85)	(-3.86)	(-3.27)	(-1.67)	(-1.23)	(-0.39)	(1.43)	(6.31)	(18.11)

Table IA.6
Portfolio Risk Measures

This table reports two risk measures, the one-week 5% value-at-risk and the 5% expected shortfall computed with historical simulation for each decile portfolio of straddles sorted by the slope of the volatility term structure. The sample period for OptionMetrics stocks is January 1996 to January 2012.

	Portfolio									
Risk Measures	1	2	3	4	5	6	7	8	9	10
Value at Risk - 5%	0.131	0.119	0.116	0.116	0.107	0.101	0.109	0.102	0.099	0.084
Expected Shortfall - 5%	0.176	0.162	0.160	0.167	0.161	0.159	0.170	0.164	0.168	0.150