The term structure of equity option implied volatility

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Abstract

This paper investigates the relationship between the slope of the implied volatility (IV) term structure and future option returns. In Fama-Macbeth regressions we demonstrate that implied volatility slopes are positively correlated with future returns on short-term at-the-month straddles. A strategy that buys straddles with high IV slopes and short sells straddles with low IV slopes returns seven percent per month, with an annualized Sharpe ratio just less than two. Risk-adjustment using Fama-French, Carhart, and S&P 500 Index straddle factors only increases the return spread. Surprisingly, we find no relation between IV slopes and the returns on longer-term straddles, even though the correlation between the returns on portfolios of short-term and long-term straddles generally exceeds 0.9. Furthermore, we find no time-series predictability in average straddle returns or in the returns on the long-short strategy identified above. We interpret these results as evidence that the return predictability we document is unrelated to systematic risk premia. We believe that our results point to two possible explanations. One is that temporary hedging pressure pushes option prices away from efficient levels. The other is that short-term options are more likely to be mispriced by noise traders than long-term options.

JEL classification: G12, G13

Keywords: options, implied volatility, return predictability

1 Introduction

Option-implied volatilities reflect risk-neutral expectations of the future future volatility of the underlying asset. Because these expectations are computed under an equivalent martingale measure, they embody expectations under the true probability measure as well as premia on risk factors such as jumps or stochastic volatility. One might therefore suppose that implied volatilities have some predictive ability to forecast the future returns on options and their underlying assets.

This prediction has been confirmed directly in several recent papers and indirectly in a number of others. Bollerslev et al. (2009) show that the spread between implied and realized volatility forecasts stock market returns. Specifically, when implied volatility is high relative to realized volatility, then future stock returns tend to be higher. Goyal (2009) find that a similar variable has strong predictive power in the cross section of at-the-money straddle returns, with high volatilities forecasting negative straddle returns. Other papers, such as Jones (2003), that estimate stochastic volatility and/or jump models using both stock and implied volatility series generally find that nonzero premia on volatility and/or jump risk are necessary to fit both series, which implies that option expected returns will vary with the level of actual or implied volatility.

In the fixed income literature, it is well known that the slope of the term structure has significant predictive power for future bond returns, with positive slopes associated with high excess returns on intermediate and long-term bonds. Work in this area goes back to seminal papers such as Fama and Bliss (1987) and Campbell and Shiller (1991). The importance of the term structure slope can be attributed to the fact that risk premia have relatively minor effects on the discounting of short-maturity cash flows and much larger effects for long maturities. Subtracting the short maturity yield from the long maturity yield seems to isolate the component of yields that is driven by risk premia rather than expected future interest rates.

In this paper we ask whether the slope of the implied volatility term structure is a predictor of future stock and option returns. When predicting option returns, we focus on the returns on at-the-money (ATM) straddle, which is a portfolio of one ATM call and one ATM put, both with the same maturity. The straddle portfolio is naturally close to zero-delta, which means that it primarily represents a bet on volatility (or time varying jump risk) rather than being a directional bet on the underlying asset. We examine predictability both in the time series and in the cross section, and we examine both indexes and individual equities.

Our primary finding is that the slope of the implied volatility term structure has strong and highly significant predictive power for future short-term straddle returns. For straddles with one month remaining until expiration, a one percentage point increase in the difference between long and short IV results in a 0.5 to one percent decrease in expected straddle returns. in expected return per year. This effect remains significant after controlling for the volatility difference measure of Goyal (2009), which is the difference between implied and historical volatility, as well as numerous other controls. A long-short strategy that buys straddles with high IV slope and sells straddles with low IV slope results in an average monthly return of 7.0%, which is accompanied by a t-statistic of 7.7. Risk adjustment with a multifactor model increases both numbers.

The strength of these results makes it surprising, therefore, that we find almost no predictability in longer-term straddle returns. When we examine the one-month returns on straddles with as few as two months until expiration, the predictive ability of the IV slope vanishes almost completely.

Furthermore, the return on a long-short strategy that buys high IV slope straddles and shorts low IV slope straddles generates essentially zero returns when implemented with longer maturity straddles. This is even more puzzling given that the large correlations between portfolios of short-term and long-term straddles, which range from 0.91 to 0.94.

We find no predictability in the pure time-series component of straddle returns. The average IV slope across all equity options does not predict the average return on equity straddles. In addition, the implied volatility slope constructed from S&P 500 index options has no predictive power for future index straddle returns.

For two reasons, we believe that it is unlikely that the predictability of short-term straddle returns is the result of cross-sectional variation in risk. Primarily, this is because of the extremely high correlations between the returns on portfolios of long and short straddles and the fact that long-term straddles show little predictability. A risk-based reconciliation of these findings would require an extremely large Sharpe ratio on the component of short straddle returns that is orthogonal to long straddle returns. This Sharpe ratio is too large to be consistent either with common sense or the "good deal" bounds of Cochrane and Saa-Requejo (2000). The second reason is the lack of time series predictability. The finance literature has been relatively conclusive in showing that factor risk premia in equity, fixed income, and option markets all vary significantly through time. If the return on short-term straddles represents some systematic factor, then its lack of predictability would make it somewhat unique among risk factors.

We proceed in Section 2 by describing our data sources. Section 3 reports the results of cross-sectional regressions of straddle returns on the IV slope and various controls. We analyze trading strategies and time-series predictability in Section 4. In Section 5 we attempt to refine the slope measure by decomposing slope into expectation and risk premium components. Section 6 concludes.

2 Data

Our study's primary focus is on option prices, which we obtain from the IvyDB database of Optionmetrics. This database contains end-of-day quotes on equity, index, and ETF options in addition to option-level contractual characteristics (strike price, expiration date), trading data (volume and open interest), implied volatilities, and "Greeks" (delta, vega, etc.). Our primary sample is restricted to options on common equity and not ETFs or indexes, though we analyze index options separately. Our sample period starts in January of 1996, which is the start of the Optionmetrics dataset, and ends in December of 2010.

Although we use daily data to construct many explanatory variables, the straddle returns we analyze are monthly. Our short-term straddle is an investment that is initiated on the Monday following expiration week, which is either the third or fourth Monday of the month. On that day (or the first day after it if that Monday is a holiday), one call and one put on each underlying are purchased. The contracts chosen are those with one month remaining until expiration, with a strike price that is closest to the current spot price. The cost of each option is assumed to be the midpoint of each option's bid-ask spread. The short-term straddle is held until expiration, so the terminal value is determined based solely on the difference between stock and strike prices. We do not allow for early exercise.

Long-term straddle returns are computed similarly, except that they are not held until expiration. The long-term straddle is defined as the straddle with the longest maturity available subject to being no longer than four months and considering only those options that are part of the traditional monthly expiration calenday. (I.e., we do not consider "weeklys.") Regardless of the maturity, the straddle is held for one month and sold at a price determined by option bid-ask midpoints. The schedule on which new options are introduced ensures that in any given month the cross-section of long-term straddles will be approximately equally divided between two-month, three-month, and four-month maturities. Thus, while there is significant heterogeneity in the cross-section of long-term straddles, the degree of that heterogeneity is essentially constant over time.

Our primary predictive variable is the slope of the implied volatility term structure, computed as the long-maturity IV minus the short-maturity IV. The long-maturity IV is from the longest maturity options that are available subject to being no more than four months until expiration. The short-maturity IV is from the pair of options with just above one month until expiration. In both cases, IVs are taken from at-the-money options, defined as those with the smallest distance between strike and spot prices.

To reduce the effects of noise in the IV slope, we compute the slope daily over the two weeks prior to expiration Friday and then take the average of these values. We follow the same approach with other explanatory variables that are based on option prices. Results are slightly weaker when we compute slopes from just one day of data.

We augment the Optionmetrics data with stock prices, volume, and market capitalization data from CRSP and book values from Compustat. We obtain data on the Fama-French (1993) factors as well as the "up-minus-down" momentum factor suggested by Carhart (1997) from the website of

Ken French. We augment these factors with an SPX (S&P 500 index) straddle return factor used by Goyal (2009). We construct this factor identically to the short-term straddles described above except that it is based on S&P 500 index options.

3 The relation between IV slope and straddle returns

3.1 The determinants of the IV slope

We begin our empirical analysis with an examination of the variables associated with the level of the implied volatility slope. Although it might be argued that some of the variables we examine can be viewed as exogenous, this is not generally the case. The results we present should be regarded as establishing associations, not causality.

The explanatory variables we consider fall into three broad categories. The first consists of stock market variables. This includes the prior stock return and stock return volatility computed over two horizons, the previous month and the 11 months prior to that one. This group also includes the market capitalization of the stock, the stock's book-to-market ratio, and the Amihud (2002) measure of liquidity in the underlying stock. The second category consists of contemportaneous variables that are also based on the prices of options on the same stock. This includes the at-the-money implied volatility of the option, the risk-neutral implied skewness and kurtosis from options with just more than one month until expiration, and the slopes of the same skewness and kurtosis measures constructed from the same short and long options used to compute the IV slope measure. The third category consists of option trading variables. These include option trading volume and open interest, both computed by summing across all contracts for a given underlying stock, and then dividing the total by the trading volume of the stock. In addition to reporting totals for volume and open interest, we also compute corresponding "slope" measures by taking the difference between volume and open interest for long and short dated options. Finally, this category also includes the average bid-ask spread and the slope of the bid-ask spread for options on a given underlying stock.

Table 2 reports the results of Fama-Macbeth regressions of the IV slope variable on subsets of these explanatory variables. T-statistics, which appear in parentheses, are computed using the method of Newey and West (1987). Here and in all results to follow, we apply the automatic lag truncation method derived by Andrews (1991). Average R-squares are time-series averages of cross-sectional regression r-squares.

The first regression considers the effects of different stock market variables on the IV slope. By far the most significant predictors are the two volatility measures. The short-term measure is computed from daily returns over the previous month, while the long-term measure is based on returns during the 11 months prior to that. High recent volatility makes the IV slope more negative, while long-term volatility makes it more positive. One explanation is that volatility appears to have short-run and long-run components (e.g., Brandt and Jones (2006)), and recent volatility mainly reflects a short-run component with a relatively short half-life. Short-run volatility has a strong impact on short-term implied volatility, but its fast mean reversion means that the impact on long-run implied volatility is minimal. The persistence of the long run component of volatility, on the other hand, means that it has a stronger effect on long-term implied volatility.

The coefficients on lagged returns have a similar interpretation given that negative returns are predictors of higher future volatility. When lagged one-month returns are negative, this points to a more transient increase in volatility, leading mainly to an increase in short-term implied volatility. Low long-run past returns suggest a more persistent increase in volatility, implying higher long-term implied volatilities. Finally, the coefficients on lagged book-to-market and the Amihud liquidity measure are significant, suggesting that growth stocks and illiquid stocks tend to have steeper IV slopes. These effects appear minor, however.

The second regression shows the relationship between the IV slope and other measures extracted from various options on the same underlying stock. The most important explanatory variable in this group appears to be the implied volatility level. This result merely follows from the fact that the one-month IV is the same IV that is used to represent the short end of the IV term structure when the slope is computed. The other pair of variables that appears to be important is the level and slope of risk neutral implied skewness. When skewness is high, the IV slope is greater. When the term structure of skewness is more upward sloping, the IV slope becomes more negative.

The third regression examines the relations between IV slope and variables related to option trading. Higher option trading volume is associated with lower IV slopes, particularly when the volume is heavier in longer-dated options. Higher spreads, especially in longer-term contracts, are also associated with lower IV slopes. Finally, more open interest in short-term options seems to make the slope higher, while open interest in long-term options appears to reduce the IV slope.

3.2 The IV slope and the cross-section of straddle returns

The cross-sectional relationship between the IV slope and future returns is established in Table 3. We report results from Fama-Macbeth regressions, where Newey-West t-statistics are in parentheses. The main result is easy to summarize. With or without controls, a high IV slope predicts high future straddle returns. The coefficient of 0.908 from the first regression means that if the IV slope increases by one percentage point, then the expected 1-month straddle return will increase by 0.908 percent.

The second regression in the table adds two closely related control variables. The first is a pure IV measure, specifically the lagged implied volatility on the same options being held in the short-term straddle. The second is the IV deviation measure of Goyal (2009), defined as the same lagged implied volatility minus the standard deviation of daily stock returns over the previous year. While its coefficient declines in magnitude somewhat when Goya and Saretto's variable is included, the IV slope remains highly significant. Including IV by itself seems to have no effect on the other variables.

The third regression adds some of the stock-level variables from Table 2 as controls. While both size and the Amihud measure appear to offer some improvements in fit, including them along with the other controls only increases the magnitude and significance of the coefficient on IV slope. The fourth regression instead includes controls related to option trading acvivity, which has very minor effects on our main result.

Table 4 repeats these regressions, except now the short-term straddle is replaced with a long-term straddle, which is held over the same one month period as the short term straddle. This relatively minor change leads to completely different results. The IV slope is no longer statistically significant in any regression except the second, and in that regression its sign is negative, opposite the result from the previous table. Interestingly, the IV difference variable remains significant, and the IV level becomes significant as well. Coefficients on other control variables are broadly similar to before.

The stark contrast between the results of Tables 3 and 4 present something of a puzzle. The returns on short-term and long-term straddles are highly correlated. On average, the cross-sectional correlation between the two is 0.84, suggesting that loadings on systematic risk factors must be similar for short-term and long-term contracts. But if loadings are similar, and if the IV slope is a proxy for some systematic risk loading, then we should see similar predictability in both short-term and long-term contracts. Since we do not, the risk premia-based explanation appears tenuous at best,

Our last cross-sectional regression asks whether the IV slope can predict stock returns. The mechanism that would induce predictability at the stock level is the generally negative correlation that is found between volatility and returns. If the IV slope forecasts straddle returns, and if this is the result of a stochastic volatility risk premium, then it is possible that the equity return would inherit part of this risk premium through its correlation with the volatility process. The result, as shown in Table 5, is negative – there is no evidence at all that the IV slope or other IV-related variables forecasts future stock returns.

4 Trading strategies and time-series predictability

4.1 Risk adjustments and profitability of trading strategies

In this section we analyzed portfolios of straddles from different underlying stocks. This allows a clearer measure of the profitability of buying straddles with low IV slopes and also allows this profitability to be risk-adjusted using standard methods.

Table 6 analyzes the performance of five portfolios of short-term straddles formed on the basis of the IV slope. These portfolios are rebalanced monthly following expiration Friday, when the previous month's straddles expire and a new set of straddles is purchased. The top panel of the table reports the means, standard deviations, and Sharpe ratios of the five portfolios and of the long-short portfolio that buys high-slope straddles and shorts low-slope straddles. All of these numbers are reported on a monthly basis. This panel also includes the average IV slope of each portfolio. The second panel shows alphas and betas from a regression with the Fama-French and Carhart factors in addition to the SPX index straddle factor suggested by Goyal (2009). The third panel reports corresponding t-statistics.

In short, the table shows large gains from buying high-slope straddles relative to low-slope straddles. Most of the raw return comes from shorting the straddles with low IV slope, which on average lose about six percent of their value every month. When returns are risk-adjusted with the factor model, then the long leg turns out to be the source of more abnormal return. This is due primarily to the fact that all straddle returns load positively on the SPX straddle factor, which itself has a negative mean. The alpha of the long-short portfolio turns out to exceed eight percent per month, with a t-statistic of 7.84.

Consistent with the cross-sectional regressions, long-term straddle returns are unrelated to the IV slope variable. This result is shown in Table 7, which replicates the previous analysis with longer-term contracts. While all the portfolios now have positive alphas, the spread between high and low IV slope portfolios is insignificant, as is the spread in raw returns. The positivity of the alphas again follows from the positive loadings on the SPX straddle factor and that factor's negative mean.

The non-result here strongly undermines the risk premia explanation. The correlation between the portfolios of short-term and long-term straddles are generally above 0.9, implying that roughly 90% of the standard deviation of short-term straddle returns can be eliminated by hedging with long-term straddles. Since the expected return of the long-term straddle is close to zero, the hedge does not reduce the mean of the hedged portfolio, which implies that the Sharpe ratios of a hedged strategy may be larger by a factor of about 10. The Sharpe ratio of the low-IV slope portfolio, after this type of hedging, is well above 2. On an annualized basis, it is around 10, a number that is many times the Sharpe ratio of the stock market. As Cochrane and Saa-Requejo (2000) argue, "good deals" such as these should be ruled out by any reasonable asset pricing model.

4.2 Time series predictability

If high IV slopes predict high returns in the cross section, then do they predict returns in the time series as well? Suppose that IV slopes predict returns because they proxy for the beta with respect to some priced risk factor, i.e. the slope is generated by $\beta_i \lambda_t$. Then the cross-sectional average of the IV slope will provide a measure of the average beta multiplied by the ex ante price of risk λ_t. Variation in the ex post risk premium should therefore be forecastable using the average IV slope.

An increase in the ex ante price of risk should also increase the dispersion in IV slopes and in subsequent realized returns. This should make the return on the long-short strategy of buying high-IV slope straddles and selling low-IV slope straddles predictable based on the spread in IV slopes. We test both of these hypotheses in Table 8.

The dependent variable in the first two regressions is the cross sectional average of the returns on all short-term straddles. The independent variable that was motivated by the above discussion is the average IV slope, but the second regression also includes a measure of IV slope dispersion and the IV slope from S&P 500 Index options. The dispersion measure is the average IV slope of all stocks in the high-slope quintile minus the average IV slope of the low-slope quintile. The next two regressions are identical except that they replace the dependent variable with the average return on long-term straddles. The results of all four regressions are negative – there is no evidence of time series predictability in average straddle returns.

Regressions 5-8 examine predictability in the long-short spread portfolios. For this variable, the key predictor was hypothesized to be the spread in IV slopes. We run regressions with only this predictor, both for short-term and long-term straddles, and with all three predictors. Again, we find no evidence of time series predictability. Finally, regressions 9-12 examine predictability in short-term SPX straddle returns. Here, the key predictor is assumed to be the slope of the SPX IV term structure. No predictability is found here as well.

Failing to find evidence of predictability does not rule out the risk premia explanation by itself, as it is possible that the risk premia reflected in IV slopes is not time varying. This would appear to be the exception rather than the rule given the extensive research documenting predictability in most risk premia, but it is possible. Given that we believe we have already made a strong case against risk premia being the driver of IV slope-based predictability, we do not find the lack of time-series predictability to be surprising.

5 Controlling for expected realized volatility

To be completed.

6 Conclusion

This paper demonstrates a remarkable level of predictability in the returns on short-term equity options. Specifically, short-term options on stocks with an upward-sloping term structure of implied volatility have returns that far exceed those of stocks with downward-sloping term structures. The relationship between IV slope and straddle returns is highly significant in the cross section, even when many other variables, including the IV difference measure of Goyal (2009), are included. A trading strategy that buys short-term straddles on high-IV slope stocks and shorts straddles on low-IV slope stocks results in monthly returns that average seven percent, with a Sharpe ratio that exceeds that of the stock market by several times.

We believe that our results rule out the possibility that the IV slope predicts returns because it proxies for the loading on some systematic risk factor. In part this is because we find no evidence of any time series predictability in average straddle returns or in the returns on the high-slope minus low-slope strategy. If variation in slope is driven by the risk loading of some factor, then average slope should be related to that factor's risk premium. While there is no requirement that factor risk premia be time-varying, most risk premia appear to be at least somewhat predictable. Our finding of no time series predictability therefore makes the cross-sectional effect we document look more like mispricing.

More importantly, we rule out any risk-based explanation because straddles formed from options with expirations that are just a few more months longer display no predictability, their returns being essentially unrelated to the IV slope. This is problematic because these longer-term straddle returns are highly correlated with the short-term straddle returns. The average cross-sectional correlation between long and short straddle returns is above 0.8, while the time series correlations between the returns on portfolios of long and short straddles are all above 0.9. Such high correlations imply very similar risk loadings, implying that risk loadings cannot explain the predictability we document.

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Table 1

Summary Statistics for Implied Volatility Slopes

This table presents the summary statistics of the term structure slope of individual stock option implied volatility. For each stock, daily measures of implied volatility (IV) at each maturity are given by the averages of the IVs of at the money (ATM) put and call options with that maturity. Slopes are defined as the differences between the IV of the one-month contracts, which expire in one calendar month, and the IV of the longer term contracts, which are chosen to be the pair of ATM options with maturity between 2 to 4 months, and if there are multiple maturities available within this range, the contacts with the longest maturity are used. The maturity k (month) of long-term options is specified in the first column. We first obtain the time series average of the slope for each stock, then use these stock level measures to compute the statistics reported in the table. To be consistent with the predictive regressions in this paper, we only include the daily measures from the two weeks preceding the last trading day before each monthly option expiration day. The sample period is from January 1996 to December 2010.

k	Mean	Median	Std. Dev.	Minimum	Maximum
2.0000	0.0095	0.0073	0.0286	-0.3191	0.2578
3.0000	0.0200	0.0150	0.0361	-0.2467	0.5588
4.0000	0.0251	0.0183	0.0422	-0.2754	0.9034

Table 2

Determinants of Implied Volatility Slopes

In this table, we regress slopes of stock option implied volatility (IV) term structure on contemporaneous or lagged stock characteristics. For each stock, daily measures of implied volatility (IV) at each maturity are given by the averages of the IVs of at the money (ATM) put and call options with that maturity. Slopes are defined as the differences between the IV of the one-month contracts, which expire in one calendar month, and the IV of the longer term contracts, which are chosen to be the pair of ATM options with maturity between 2 to 4 months, and if there are multiple maturities available within this range, the contacts with the longest maturity are used. Monthly IV slopes are given by the averages of daily measures over the two weeks preceding the last trading day before the option expiration day of month t. We regress monthly measures of IV slopes on monthly measures of firm characteristics obtained using data preceding the expiration day of month t. "Lagged volatility in month $t-1(t-12$ to $t-2)$" refers to stock return volatility calculated using daily returns in the month (the year excluding the most recent month) preceding option expiration day of month t. Similarly, we include the one-month and one year lagged cumulative returns for each stock. Both market capitalization and book-to-market ratio are computed at the month end preceding month t expiration day. The Amihud liquidity measure is computed using data from the month preceding month t expiration. The rest of the independent variables are computed by first obtaining daily measures, then averaging daily measures over the two weeks preceding the last trading day before month t expiration day to obtain monthly measures. The intermediate maturity IV refers to the IV of one-month ATM contracts. Intermediate term skewness(kurtosis) is the risk-neutral skewness(kurtosis) estimated from the one-month contracts based the method in Bakshi, Kapadia, and Madan(2003). Total option volume (open interest) is the sum of the volume (open interest) of all options on a stock. The option spread is the average quoted spreads of all options on the stock. The "slopes" of the above variables are the differences between the variables measured from long-term contracts and one-month contracts. The sample period is from January 1996 to December 2010. All variables are winsorized at 1% and 99%. T-statistics are computed using Newey-West standard errors based on the data-dependent automatic bandwidth/lag truncation parameters derived in Andrews 1991.

Table 2, cont.

Determinants of Implied Volatility Slopes

Lagged volatility in month $t-1$	-0.6014		
	(-27.8900)		
Lagged volatility in months $t-12$ to $t-2$	0.2600		
	(8.0200)		
Lagged stock return in month $t-1$	0.0163		
	(7.5300)		
Lagged stock return in months $t-12$ to $t-2$	-0.0008		
	(-2.4900)		
Log market capitalization	0.0002		
	(1.3200)		
Book-to-market ratio	-0.0010		
	(-2.1500)		
Amihud illiquidity measure	0.1157		
	(2.2500)		
Intermediate maturity IV		-0.0629	
		(-21.3200)	
Intermediate term skewness		0.0037	
		(4.6100)	
Intermediate term kurtosis		-0.0001	
		(-0.4400)	
Skewness slope		-0.0063	
		(-9.0600)	
Kurtosis slope		0.0009	
		(3.5600)	
Total option volume			-2.9097
			(-11.3100)
Option volume slope			-0.7238
			(-5.4600)
Total open interest			0.1746
			(7.0100)
Open interest slope			-0.2305
			(-10.8500)
Option spread			-0.3105
			(-14.0200)
Option spread slope			-0.4172
			(-11.3700)
Adj. R-Squared (%)	11.1796	17.0727	7.4127

Table 3

Fama-Macbeth Regressions for One-Month Straddle Returns

This table presents the results of Fama-Macbeth regressions of one-month straddle returns on IV term structure slopes. Straddle returns are computed using at the money options that expire in one calendar month. These options are purchased at the end of the first trading day following the expiration day of month t and held to expiration in month t+1. Independent variables are computed using information before month t expiration. "Lagged stock return in month $t-1(t-12$ to $t-2)$" refers to cumulative stock returns in the month (the year excluding the most recent month) preceding month t expiration. Both market capitalization and book-to-market ratio are computed at the month end preceding month t expiration day. The Amihud liquidity measure is computed using data from the month preceding month t expiration. The rest of the independent variables are computed by first obtaining daily measures, then averaging daily measures over the two weeks preceding the last trading day before month t expiration day to obtain monthly measures. IV slope is the difference between long-term IV and one-month IV. IV refers to the IV of one-month ATM contracts. IV deviation is the difference between one-month IV and stock return volatility measured over the 250 trading days preceding month t expiration. Total option volume (open interest) is the sum of the volume (open interest) of all options on a stock. The option spread is the average quoted spreads of all options on the stock. The "slopes" of the above variables are the differences between the variables measured from long-term contracts and one-month contracts. We perform one cross-sectional regression for each month. The sample period is from January 1996 to December 2010. All dependent variables are winsorized at 1% and 99%. T-statistics are computed using Newey-West standard errors based on the data-dependent automatic bandwidth/lag truncation parameters derived in Andrews 1991.

IV slope	0.91	0.54		0.93	0.84
	(8.27)	(5.28)		(9.20)	(7.94)
IV deviation		-0.29	-0.35		
		(-7.43)	(-9.54)		
IV		-0.01			
		(-0.26)			
Lagged stock return in month $t-1$				-0.06	
				(-1.77)	
Lagged stock return in months $t-12$ to $t-2$				0.01	
				(0.92)	
Log market capitalization				-0.01	
				(-3.62)	
Book-to-market ratio				0.00	
				(0.01)	
Amihud illiquidity measure				-4.09	
				(-5.04)	
Total option volume					0.03
					(0.01)
Option volume slope					-1.35
					(-0.48)
Total open interest					-0.35
					(-1.80)
Open interest slope					-0.40
					(-1.25)
Option spread					-0.77
					(-2.16)
Option spread slope					-1.45
					(-2.25)
Adj. R-Squared (%)	0.24	1.41	0.46	1.90	0.98

Table 4

Fama-Macbeth Regressions for Long-Term Straddle Returns

This table presents the results of Fama-Macbeth regressions of long-term straddle returns on IV term structure slopes. Straddle returns are computed using at the money options that expire in 2 to 4 months. When multiple maturities are available in this range, the options with the longest maturities are used. The straddles are purchased at the end of the first trading day following the expiration day of month t and sold at the end of the expiration day in month t+1. Independent variables are computed using information before month t expiration. "Lagged stock return in month $t-1(t-12$ to $t-2)$" refers to cumulative stock returns in the month (the year excluding the most recent month) preceding month t expiration. Both market capitalization and book-to-market ratio are computed at the month end preceding month t expiration day. The Amihud liquidity measure is computed using data from the month preceding month t expiration. The rest of the independent variables are computed by first obtaining daily measures, then averaging daily measures over the two weeks preceding the last trading day before month t expiration day to obtain monthly measures. IV slope is the difference between long-term IV and one-month IV. IV refers to the IV of one-month ATM contracts. IV deviation is the difference between one-month IV and stock return volatility measured over the 250 trading days preceding month t expiration. Total option volume (open interest) is the sum of the volume (open interest) of all options on a stock. The option spread is the average quoted spreads of all options on the stock. The "slopes" of the above variables are the differences between the variables measured from long-term contracts and one-month contracts. We perform one cross-sectional regression for each month. The sample period is from January 1996 to December 2010. All dependent variables are winsorized at 1% and 99%. T-statistics are computed using Newey-West standard errors based on the data-dependent automatic bandwidth/lag truncation parameters derived in Andrews 1991.

IV slope	-0.01	-0.10		0.01	-0.03
	(-0.28)	(-2.82)		(0.29)	(-0.78)
IV deviation		-0.16	-0.17		
		(-9.36)	(-10.57)		
IV		-0.04			
		(-2.61)			
Lagged stock return in month $t-1$				0.01	
				(1.14)	
Lagged stock return in months $t-12$ to $t-2$				0.01	
				(1.71)	
Log market capitalization				0.00	
				(-1.96)	
Book-to-market ratio				0.00	
				(0.82)	
Amihud illiquidity measure				-1.43	
				(-4.57)	
Total option volume					-0.70
					(-0.84)
Option volume slope					-0.74
					(-0.67)
Total open interest					-0.15
					(-1.72)
Open interest slope					-0.42
					(-3.03)
Option spread					-0.51
					(-2.98)
Option spread slope					-0.04
					(-0.12)
Adj. R-Squared (%)	0.18	1.95	0.69	2.26	1.30

Table 5

Fama-Macbeth Regressions for Stock Returns

This table presents the results of Fama-Macbeth regressions of monthly stock returns on IV term structure slopes. The stock returns are cumulative returns from the first trading day following the expiration day of month t to the last trading day before option expiration in month t+1. Independent variables are computed using information before month t expiration. "Lagged stock return in month $t-1(t-12$ to $t-2)$" refers to cumulative stock returns in the month (the year excluding the most recent month) preceding month t expiration. Both market capitalization and book-to-market ratio are computed at the month end preceding month t expiration day. The Amihud liquidity measure is computed using data from the month preceding month t expiration. The rest of the independent variables are computed by first obtaining daily measures, then averaging daily measures over the two weeks preceding the last trading day before month t expiration day to obtain monthly measures. IV slope is the difference between long-term IV and one-month IV. IV refers to the IV of one-month ATM contracts. IV deviation is the difference between one-month IV and stock return volatility measured over the 250 trading days preceding month t expiration. Total option volume (open interest) is the sum of the volume (open interest) of all options on a stock. The option spread is the average quoted spreads of all options on the stock. The "slopes" of the above variables are the differences between the variables measured from long-term contracts and one-month contracts. We perform one cross-sectional regression for each month. The sample period is from January 1996 to December 2010. All dependent variables are winsorized at 1% and 99%. T-statistics are computed using Newey-West standard errors based on the data-dependent automatic bandwidth/lag truncation parameters derived in Andrews 1991.

IV slope	0.00	-0.01		0.04	0.01
	(0.09)	(-0.60)		(1.82)	(0.30)
IV deviation		-0.01	0.00		
		(-0.70)	(-0.20)		
IV		-0.02			
		(-1.21)			
Lagged stock return in month $t-1$				0.00	
				(-0.34)	
Lagged stock return in months $t-12$ to $t-2$				0.00	
				(-0.19)	
Log market capitalization				0.00	
				(0.15)	
Book-to-market ratio				0.00	
				(0.39)	
Amihud illiquidity measure				-0.17	
				(-1.00)	
Total option volume					-0.94
					(-1.37)
Option volume slope					0.16
					(0.28)
Total open interest					0.00
					(-0.04)
Open interest slope					0.00
					(0.04)
Option spread					-0.17
					(-1.45)
Option spread slope					0.05
					(0.33)
Adj. R-Squared (%)	0.98	7.34	1.33	7.77	3.95

Table 6

One-Month Straddle Portfolios

This table presents the returns of one-month straddle portfolios sorted by IV slopes. On the last trading day before month t option expiration day, stocks are sorted into quintiles based on their IV slopes. IV slopes used for sorting are the averages of daily IV slopes over the two weeks preceding the last trading day before the option expiration day of month t. Holding period straddle returns are computed using at the money options that expire in month t+1. These straddles are purchased at the end of the first trading day following the expiration day of month t and held to expiration in month t+1. The abnormal returns are given by monthly regressions on five risk factors: Carhart four factors and the returns of straddles formed by ATM SPX options. The returns of factors are computed over the same horizon as the stock straddle returns. The sample period is from January 1996 to December 2010. IV slopes are winsorized at 1% and 99%. T-statistics are computed using Newey-West standard errors based on the data-dependent automatic bandwidth/lag truncation parameters derived in Andrews 1991.

Portfolio	Mean Return	Return SD	Sharpe Ratio	Average IV IV Slope
1 (low IV slope)	-0.064	0.186	-0.342	-0.056
	(-4.410)			(-20.330)
2	-0.033	0.223	-0.146	-0.021
	(-1.830)			(-13.050)
3	-0.029	0.231	-0.126	-0.008
	(-1.610)			(-6.710)
4	-0.014	0.245	-0.058	0.002
	(-0.720)			(2.390)
5 (high IV slope)	0.006	0.244	0.026	0.026
	(0.340)			(26.610)
$5-1$	0.070	0.122	0.575	0.082
	(7.720)			(35.930)

	$\hat{\alpha}$	$\hat{\beta}_M$	$\hat{\beta}_{SMB}$	$\hat{\beta}_{HML}$	$\hat{\beta}_{UMD}$	$\hat{\beta}_{SPX}$	Adj. R^2
1 (low IV slope)	-0.035	-0.082	0.068	-0.014	0.038	0.202	0.510
	(-2.590)	(-1.500)	(1.040)	(-0.290)	(1.390)	(8.570)	
2	0.002	-0.060	0.017	-0.073	0.068	0.245	0.535
	(0.120)	(-0.880)	(0.200)	(-1.140)	(1.740)	(8.610)	
3	0.009	-0.104	0.020	-0.015	0.052	0.257	0.545
	(0.500)	(-1.610)	(0.270)	(-0.220)	(1.220)	(8.230)	
4	0.030	-0.124	0.042	-0.045	0.054	0.286	0.629
	(1.710)	(-1.810)	(0.570)	(-0.730)	(1.160)	(11.010)	
5 (high IV slope)	0.048	-0.110	0.054	-0.004	0.034	0.280	0.571
	(2.750)	(-1.620)	(0.640)	(-0.060)	(0.750)	(9.440)	
$5-1$	0.083	-0.027	-0.014	0.010	-0.004	0.078	0.201
	(7.840)	(-0.790)	(-0.310)	(0.210)	(-0.100)	(5.150)	

Table 7

Long-Term Straddle Portfolios

This table presents the returns of long-term straddle portfolios sorted by IV slopes. On the last trading day before month t option expiration day, stocks are sorted into quintiles based on their IV slopes. IV slopes used for sorting are the averages of daily IV slopes over the two weeks preceding the last trading day before the option expiration day of month t. Holding period straddle returns are computed using at the money options that expire in month t+2,t+3 or t+4. When multiple maturities are available in this range, the straddle with the longest maturities is used. These straddles are purchased at the end of the first trading day following the expiration day of month t and sold at the end of the expiration day in month t+1. The abnormal returns are given by monthly regressions on five risk factors: Carhart four factors and the returns of straddles formed by ATM SPX index options. The returns of factors are computed over the same horizon as the stock straddle returns. The sample period is from January 1996 to December 2010. IV slopes are winsorized at 1% and 99%. T-statistics are computed using Newey-West standard errors based on the data-dependent automatic bandwidth/lag truncation parameters derived in Andrews 1991.

Portfolio	Mean Return	Return SD	Sharpe Ratio
1 (low IV slope)	0.014	0.094	0.147
	(1.830)		
2	0.024	0.107	0.220
	(2.670)		
3	0.017	0.109	0.156
	(1.900)		
4	0.017	0.111	0.153
	(1.850)		
5 (high IV slope)	0.011	0.102	0.108
	(1.320)		
$5-1$	-0.003	0.045	-0.065
	(-0.840)		

	$\hat{\alpha}$	$\hat{\beta}_M$	$\hat{\beta}_{SMB}$	$\hat{\beta}_{HML}$	$\hat{\beta}_{UMD}$	$\hat{\beta}_{SPX}$	Adj. R^2
1 (low IV slope)	0.029	-0.027	0.038	-0.053	0.002	0.093	0.442
	(4.040)	(-0.820)	(0.880)	(-1.800)	(0.120)	(7.780)	
2	0.039	-0.025	-0.002	-0.056	0.034	0.109	0.521
	(4.970)	(-0.750)	(-0.030)	(-1.560)	(1.650)	(8.610)	
3	0.036	-0.055	-0.022	-0.041	0.017	0.111	0.533
	(4.210)	(-1.860)	(-0.540)	(-1.150)	(0.930)	(7.960)	
4	0.037	-0.057	-0.002	-0.052	0.021	0.118	0.569
	(4.460)	(-1.830)	(-0.040)	(-1.640)	(1.040)	(9.300)	
5 (high IV slope)	0.026	-0.030	0.018	-0.030	0.021	0.106	0.513
	(3.410)	(-1.100)	(0.380)	(-0.960)	(1.160)	(8.410)	
$5-1$	-0.003	-0.003	-0.019	0.023	0.019	0.014	0.070
	(-0.590)	(-0.200)	(-1.100)	(1.430)	(1.980)	(2.240)	

Table 8

Time Series Predictability

This table presents the predictive regressions of straddle returns on term structure slopes. Straddle returns in column "All one-month (long-term)" are the equal-weighted cross-sectional averages of one-month (long-term) ATM straddle returns of all stocks. Straddle returns in column "5-1 one-month (long-term)" are returns of the zero-investment portfolios that buy one-month (long-term) ATM straddles on stocks with high past IV slopes and sell one-month (long-term) ATM straddles on stocks with low past IV slopes. SPX one-month straddles are formed using ATM SPX index options with one month to maturity. All straddle returns are computed over the horizon that starts on the first trading day following month t option expiration and ends on the last trading day before month t+1 expiration. We consider three independent variables: "average IV slope" is the cross-sectional average of the IV slopes of all stocks; "high slope minus low slope" is the difference between the average IV slope of stocks in the high IV slope quintile and the stocks in the low IV slope quintile; "SPX IV slope" is the difference between the IV of the two month ATM SPX index options and the IV of the one month ATM SPX index options. Monthly observations of independent variables are computed by averaging over the daily observations over the two weeks preceding the last trading day before month t expiration. T-statistics are computed using Newey-West standard errors based on the data-dependent automatic bandwidth/lag truncation parameters derived in Andrews 1991.

Type of straddle return:	All one-month		All long-term		5-1 one-month		5-1 long-term		SPX one-month	
Regression #:	1	2	3	4	5	6	7	8	9	10
Intercept	-0.034	0.009	0.006	0.034	0.086	0.086	-0.006	0.003	-0.122	0.218
	(-1.780)	(0.100)	(0.720)	(0.890)	(1.760)	(1.760)	(-0.430)	(0.150)	(-2.110)	(0.860)
Average IV slope	-0.725	-1.873	-0.873	-1.808		0.725		-0.220		-3.419
	(-0.570)	(-0.800)	(-1.520)	(-1.890)		(0.670)		(-0.620)		(-0.500)
High (5) slope minus low (1) slope		-0.699		-0.485	0.725	-0.048	0.032	-0.101		-4.559
		(-0.500)		(-0.830)	(0.670)	(-0.070)	(0.200)	(-0.400)		(-1.220)
SPX IV slope		0.769		0.866		-0.360		-0.049	-4.743	-6.841
		(0.300)		(0.710)		(-0.250)		(-0.080)	(-0.780)	(-0.940)
Adjusted R-square (%)	-0.250	-1.120	1.530	1.280	-0.030	-0.910	-0.540	-1.410	-0.070	-0.180