ESSAYS ON THE OPTIONS MARKET

by

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A dissertation submitted to the Graduate Faculty in Business in partial fulfillment of the requirements for the degree of Doctor of Philosophy, The City University of New York

2012

This manuscript has been read and accepted for the Graduate Faculty in Business in satisfaction of the dissertation requirement for the degree of Doctor of Philosophy.

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Abstract

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This dissertation consists of a collection of two essays examining the pricing of risk in the options market. In the first essay, I develop a methodology for calculating returns on portfolios that contain short option positions. The main insight is that short option positions carry a large amount of risk, and entering into such positions therefore requires a substantial margin requirement to protect against large losses. This margin requirement, therefore, not the initial price of the portfolio, constitutes the basis of the return calculation. The second essay examines the pricing of skewness risk in the options market. I examine the returns of portfolios of skewness assets (assets comprised of option and stock positions in a manner such that they isolate the effect of skewness) and find a negative relation between option implied skewness and the returns of the skewness assets. The result empirically confirms the theoretical prediction of a preference for positively skewed assets.

Advisor: Prof. Turan Bali

ACKNOWLEDGEMENTS

I would like to thank my dissertation advisor Dr. Turan Bali for his invaluable guidance and support, and for keeping me on track to complete my dissertation on schedule. I thank my committee, Drs. Armen Hovakimian, Lin Peng, and Joseph Weintrop for their meticulous review of my work. I would also like to thank Dr. Linda Allen and the rest of the faculty at Baruch College for their continuous support and encouragement during the dissertation writing process. Last, but not least, I thank my beautiful wife, my parents, and the rest of my family for always being by my side.

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Chapter 1

A Margin Requirement Based Return Calculation for Portfolios of Short Option Positions

Short option positions carry significant risk of losses well in excess of 100% of the initial price of the option. This risk requires investors with short option positions to hold a cash reserve (margin requirement) sufficient to cover potential losses. The commonly used price return calculation is therefore not reflective of the return an investor realizes on short option positions. Short positions in options may also be hedged with other option positions or a position in the underlying security, significantly decreasing the potential losses. The objectives of this paper are to develop a methodology for calculating margin requirement-based option portfolio returns that realistically represent the returns realized by investors, and to demonstrate the effects of this methodology on analyses of option returns.

The results indicate that accounting for margin requirements reduces the returns associated with simple short option strategies such as selling calls, puts, and straddles by up to 92%. A simple estimate of the price of volatility risk is 61% lower using margin rather than price-based returns. In long/short portfolio analyses, margin requirement-based returns must be accompanied by volatility hedging, which necessitates allocating a different amount of capital to the long and short portfolios. The end result is a portfolio more reflective of returns realized by investors, and a test with more power to detect cross-sectional option return patterns.

Issues concerning calculation and analysis of option returns are not new to the literature. Broadie, Chernov, and Johannes (2009) propose comparing historical option returns to returns generated by option pricing models. Cao and Han (2009) use the stock price as the denominator for calculating daily delta-hedged option returns. Their methodology is based on Merton (1973), who finds that option prices are homogeneous of degree one in the stock price. Santa-Clara and Saretto (2009) demonstrate that daily CME and CBOE margin requirements have a significant impact on the returns of investors short selling S&P 500 index options.

The Chicago Mercantile Exchange (CME) and the Chicago Board Options Exchange (CBOE), the two primary options exchanges, each have their own methods for determining margin requirements on short option positions. The CME uses a system known as CME SPAN, which "evaluates overall portfolio risk by calculating the worst possible loss that a portfolio of derivative and physical instruments might reasonably incur over a specified time period (typically one trading day.)."[1] The CBOE margin requirements for individual short index (equity) option positions are 100% of the market price of the option plus 15% (20%) of the price of the underlying security, less the amount that the option is out-of-the-money.[2] Both systems are daily margin requirements designed with the goal of protecting against the worst case one day loss on a portfolio. Investors also face margin requirements from their broker-dealers (BD). While each BD has its own system for determining margin requirements, these requirements will be at least as stringent as those imposed by the exchanges.

Despite numerous papers on the topic and the transparency of the option exchange margin requirements, a consensus has yet to be reached on a methodology for calculating returns on buy and hold (or more appropriately sell and hold) option portfolios. Such a methodology is necessary to understand the true risks taken and rewards earned by investors implementing

[1] Quote taken from the CME website. The worst possible loss is taken to be the margin requirement. For more details on the calculation of the worst possible loss and CME margin requirements, see the CME website, www.cmegroup.com.

[2] For calls (puts) that are far out-of-the-money, the minimum margin requirement is the market value of the option plus 10% of the value of the underlying security (10% of the strike). For combination positions such as short straddles, the margin requirement is the maximum of the margin requirements for each of the two individual options. For more details on CBOE margin requirements, visit the CBOE website, www.cboe.com.

short options based investment strategies.

The daily nature of exchange imposed margin requirements make them inappropriate for analyzing buy and hold portfolio returns because margin calls are quite frequent.[3] BD margin requirements form a lower bound on the amount of cash the investor must supply, but may fall well short of the amount the investor needs to hold the positions to expiration.[4] To correctly calculate the returns realized by an investor with short option positions, one must have knowledge of the amount of cash held in reserve by the investor, either in her own accounts or in the form of a margin requirement posted to the exchange or broker-dealer, to cover potential required payouts. The sum of the amounts held in reserve in the investor's own accounts or in margin accounts with a BD or exchange will hereafter be referred to as the margin requirement. The margin requirement-based return calculation developed in this paper is focusses on generating a reasonable estimate of this amount for a representative option seller.

The return calculation is based on a margin requirement sufficient to cover any *reasonably probable* loss the portfolio may realize at expiration. While the actual return realized by any specific investor depends not only on the initial amount held in reserve by that investor, but also on her choice of action when losses exceed the amount held in reserve, the purpose of this paper is not to replicate the returns realized by any specific investor. Instead, the goal is to develop a simple methodology capable of calculating a return similar to that realized by a representative investor implementing a short option based investment strategy. Though developed in a very general setting, the methodology is designed for use on portfolios held for

[3]When a margin call occurs, the investor must produce enough cash to satisfy the call, or the position will be liquidated. This means that the investor must have been holding some cash in reserve to satisfy potential margin calls. It is unreasonable to assume that a margin call can be covered by profits from some other trading strategy implemented by the investor, as margin calls that cannot be met by investors tend to happen at the worst possible times (see Santa-Clara and Saretto (2009)).

[4]Broker-dealer margin requirements also vary substantially across brokers and clients.

relatively short periods of time, for example one month.[5] Given the prevalence of one-month studies, the methodology represents a significant improvement over previously used methods (primarily the price return).

The remainder of this paper is organized as follows. Section 1 presents reasons for, and issues associated with, the margin requirement for short option positions. Section 2 presents the model for calculating the margin requirement of an option portfolio. Section 3 calibrates the margin requirement model. Section 4 demonstrates the effect of margin requirements on the distribution of returns for common short option positions. Section 5 explains methodological and empirical ramifications of the margin requirement-based return in long/short portfolio return analyses. Section 6 concludes.

1 Why a Margin Requirement?

Take the hypothetical situation of a non-dividend paying stock with spot price of \$50 and risk-neutral volatility of 0.5. Assume, for simplicity, a risk-free rate of 0. The Black and Scholes (1973) price for a call option with strike \$55 and time to expiration 1 year is \$8.05. To purchase this option, an investor must supply the \$8.05, and the worst case loss is the \$8.05 investment. Now, imagine an investor who shorts this option. A two standard deviation up move in the stock over the next year makes the stock price at expiration $\$50e^{2\times 0.5} = \$135.91$. The option is exercised, and the investor must buy shares at the market price, deliver them for \$55, realizing a loss of \$80.91 per share. Accounting for the \$8.05 sale price of the option, the loss is \$72.86. To cover such potential losses, the investor must hold at least this amount in reserve, either in her own accounts or in the form of margin requirements on deposit with a BD or exchange.

[5] Taking a margin requirement equal to the worst case *reasonably probable* loss at expiration on a long term option portfolio will result in a very large margin requirement, creating a calculated return that may be smaller in magnitude than that realized by an investor.

The simple price return for this short position is $\frac{-\$72.86}{\$8.05} = -905.14\%$. However, for a reasonable investor who held enough in reserve to cover an up move of two-standard deviations or less (\$72.86), the realized return is $\frac{Profit}{Margin} = \frac{-\$72.86}{\$72.86} = -100\%$.[6] For a long position in the same option however, the only cash required is the \$8.05 used to purchase the option, thus the return on the long position is 905.14%. The concept of having a short return that is not equal to the negative of the long return seems unnatural at first, but hopefully this example is sufficient to convince the reader that in the case of short option positions, calculating returns as described above provides a more realistic assessment of the actual returns realized by an investor.

Imagine now that the investor sells the \$55 strike call and buys a \$60 strike call for \$6.55, realizing a net cash inflow of \$1.50 from the trades. A 2 standard deviation up move results in a \$72.86 loss on the short call position, and a profit of $\$135.91 - \$60 - \$6.55 = \$69.36$ on the long call position. The total payout and loss at expiration are \$5.00 and $\$72.86 - \$69.36 = \$3.50$ respectively. This worst case scenario for the combined portfolio will result from any expiration stock price greater than \$60 (the strike of the long call). For such a portfolio the investor would adjust the margin requirement accordingly, most likely to \$3.50. This \$3.50 plus the \$1.50 received from the initial trades cover the investor in the worst case scenario, a required payout of \$5.00.

The situation becomes more complicated as more option positions or positions in the underlying security are added to the portfolio. To correctly calculate returns of such portfolios requires estimating the margin requirement for such portfolios, and using the margin requirement (not the price) as a basis for return calculations. The next section formally develops such a return calculation.

[6] It is important to note that the margin requirement does not include the initial proceeds from the sale. It is assumed that the initial proceeds are also available to cover potential required payouts. It is irrelevant to the investor whether the margin requirement is held in her own accounts or in a margin account with a broker-dealer or an exchange.

2 Return Calculation Methodology

In this section, I present a general framework for calculating returns for portfolios comprised of option positions and a position in the underlying security, where all the options have the same underlying security and expiration. All positions are to be held until option expiration, at which time the portfolio is liquidated. The methodology is intended to replicate the returns that an actual investor would realize when trading any general stock option portfolio that meets these criteria.

As is the case with any return calculation, the numerator is determined by the profit or loss realized by the investor. The difference between the methodology presented here and the standard price return methodology is that here I determine the amount of cash held in reserve (margin requirement) by a reasonable investor to cover potential payouts from short option positions. The margin requirement is designed to cover any loss that may be realized by the portfolio. In many cases, for example the case of a portfolio consisting of only a short call position, the maximum loss on the portfolio is infinite. As an infinitely large margin requirement is not reasonable, I use the term *reasonably probable* to describe the situations that the margin requirement must cover. Section 3 is devoted to calibration of the parameters that determine what is *reasonably probable*.

2.1 Definitions

Before presenting the methodology for calculating returns, a few definitions are necessary. Let t_0 be the date on which the portfolio is formed, t_1 be the expiration date of the options in the portfolio, and t be the time, in years, between t_0 and t_1 ($t = t_1 - t_0$).[7] Let n be the number of options held in the portfolio, P_i be the position held in the ith option, K_i be the strike of the ith option, S_0^i be the price of the ith option on date t_0, and C_i be an indicator

[7] To be precise, t_1 is the last trading day before the option expiration. Option expiration dates fall on Saturdays, thus in most cases t_1 is the Friday before expiration.

with value 1 for a call option and 0 for a put option, where $i \in \{1, 2, ..., n\}$. Let P_S be the position in the underlying security and let S_0 be the price of the underlying security on day t_0. Let V represent the annualized volatility of the underlying security (how the volatility is determined will be discussed in section 3), and r represent the risk-free rate of return for a deposit made on date t_0 and withdrawn on date t_1. Finally, let $PVDivs$ be the present value, on date t_0, of all dividends paid on the underlying stock that have an ex-date between t_0 (exclusive) and t_1 (inclusive).[8] If the underlying security is an index, let y be the dividend yield of the index. It is assumed that either y or $PVDivs$, or both, is equal to 0.

The payoff function for the portfolios defined in the previous section can be written as

$$S_t^P(S_t) = P_S e^{yt}\left(S_t + PVDivs \times e^{rt}\right) + \sum_{i=1}^{n} P_i S_t^i(S_t) \tag{1}$$

where S_t is the price of the stock at expiration, and $S_t^i(S_t)$ is the payoff of the ith option in the portfolio if the stock price at expiration is S_t.[9] Specifically, $S_t^i(S_t) = max(0, S_t - K_i)$ if $C_i = 1$ and $S_t^i(S_t) = max(0, K_i - S_t)$ if $C_i = 0$. We can define the price of the portfolio on date t_0 as

$$S_0^P = P_S S_0 + \sum_{i=1}^{n} P_i S_0^i. \tag{2}$$

An important feature of the payoff function of the portfolio is that it is linear for expiration stock prices below the lowest strike price, between each successive strike price, and above the highest strike price. The importance of this is that the minimum payoff for the portfolio must come at an expiration stock price that is either equal to one of the strikes, below the lowest strike, or above the highest strike. Thus, in evaluating the minimum *reasonably probable* payoff for the portfolio, only payoffs for the lowest and highest *reasonably*

[8] See Appendix 1A for the details of the calculation of $PVDivs$ and r.

[9] The term $PVDivs \times e^{rt}$ assumes that dividends are invested at the risk free rate from the payment date until expiration. The risk free rate at which the the dividends are invested is determined by the theoretical forward rate calculated at the time of portfolio inception. Equivalently, the dividends are considered to be sold at time t_0 for their present value ($PVDivs$), with the proceeds invested in the risk free asset.

probable expiration stock prices, and the strikes of the options in the portfolio, need to be evaluated.

2.2 What is *Reasonably Probable*?

To determine the lowest and highest *reasonably probable* expiration stock prices, I begin with the assumption that stock returns follow a log-normal distribution. I calculate the lowest (highest) *reasonably probable* expiration price for the stock, denoted S_t^d (S_t^u), to be the price associated with a SD_d (SD_u) standard deviation down (up) move in the stock. Thus, the lowest and highest *reasonably probable* stock prices at option expiration are $S_t^d = (S_0 - PVDivs)\, e^{\left((r-y)t - SD_d V\sqrt{t}\right)}$ and $S_t^u = (S_0 - PVDivs)\, e^{\left((r-y)t + SD_u V\sqrt{t}\right)}$. While the veracity of the log-normal assumption has been debated vigorously in the literature, with much evidence, including evidence to be presented later in this paper, indicating that stock returns exhibit negative skewness, I choose to employ this simple model and adjust for skewness (and higher order moments) by letting the parameters SD_u and SD_d take on different values.

2.3 Cash-Flow Assumptions

The final items that need to be addressed before presenting the methodology are the assumptions behind the return calculation. First, all positions are assumed to be financed. If the portfolio has a positive price at inception, the investor borrows the money at the risk-free rate. If the portfolio has a negative price, resulting in a positive cash flow, that cash earns the risk-free rate until the options expire. Thus, in addition to the difference between the payoff and the initial price of the portfolio, the investor will have to pay $S_0^P\left(e^{rt} - 1\right)$ in interest.[10]

[10] The payment is negative if the initial price of the portfolio, S_0^P, is negative (assuming a positive risk-free rate).

Second, the investor sets aside enough cash to cover any *reasonably probable* loss at expiration. This amount, which I call the margin requirement and denote with $MARGIN$, earns the risk-free rate until expiration. Thus, when calculating the returns, the investor will earn an additional $MARGIN\left(e^{rt}-1\right)$. With the details of the assumed cash-flows in order, I proceed to the development of the model.

2.4 Return Calculation

The first part of calculating any return is to calculate the profit or loss (PnL) realized by the investor. In the case of the option portfolios of the type discussed in this paper, there are three components of the PnL. First, there is the difference between the payoff of the portfolio and the initial price of the portfolio ($S_t^P\left(S_t\right)-S_0^P$), the second is the loss from interest paid to finance the position ($-S_0^p\left(e^{rt}-1\right)$), and the third is interest received on the margin requirement ($MARGIN\left(e^{rt}-1\right)$). Thus, the total PnL from the portfolio can be defined as $PnL\left(S_t\right)=S_t^P\left(S_t\right)-S_0^P-S_0^P\left(e^{rt}-1\right)+MARGIN\left(e^{rt}-1\right)$, or equivalently

$$PnL\left(S_t\right)=S_t^P\left(S_t\right)-S_0^Pe^{rt}+MARGIN\left(e^{rt}-1\right). \tag{3}$$

The denominator of the return calculation will be the margin requirement. A few things are worth remembering here. First, the purpose of the margin requirement is to cover any *reasonably probable* losses. As the margin requirement will earn interest, the amount of margin is the *present value* of the absolute value of the worst case *reasonably probable* loss on the positions. As discussed above, in evaluating the worst case *reasonably probable* loss, one must only evaluate the payoff function at stock prices equal to the lowest and highest *reasonably probable* prices, as well as the strikes of the options in the portfolio ($S_t \in$

$\{S_t^d, S_t^u, K_i; 1 \leq i \leq n\})$. Thus, I define the margin requirement as

$$MARGIN = |min_{S_t \in \{S_t^d, S_t^u, K_i; 1 \leq i \leq n\}} S_t^P (S_t) - S_0^P e^{rt}| e^{-rt}. \quad (4)$$

With the margin requirement for the option portfolio defined, I calculate the return on the option portfolio to be $R = \frac{PnL(S_t)}{MARGIN} = \frac{S_t^P(S_t) - S_0^P e^{rt} + MARGIN\left(e^{rt}-1\right)}{MARGIN}$. Rearranging gives a form that looks very much like the traditional return calculation, except with $MARGIN$ in the denominator instead of the price.

$$R = \frac{S_t^P (S_t) - S_0^P e^{rt}}{MARGIN} + e^{rt} - 1 \quad (5)$$

Removing the $e^{rt} - 1$ from the end of the return formula gives the excess return. If the margin requirement is equal to the initial price of the portfolio, as is the case for most portfolios with long positions only, then this return calculation is the standard price-based return calculation.[11]

This completes the presentation of the margin-based return calculation methodology for option portfolios. In the next section, I turn my attention to calibrating the values of SD_u and SD_d, and determining how to find an appropriate value for V.

3 Calibration of Model Parameters

Implementation of the margin-based option portfolio return calculation requires calibration of parameters V, SD_u, and SD_d. The goal in fitting these parameters is to find values such that in all *reasonably probable* scenarios, the stock price at expiration is between $S_t^d =$

[11] A portfolio comprised of only long positions of well in the money options may not have a reasonable probability of having a 0 payoff. Likewise, a portfolio with a long position in a call with strike K and a long position in a put with a strike higher than K would have a 0 probability of a payoff of 0. Such portfolios, however, are of little interest to researchers and of little practical use to investors.

$(S_0 - PVDivs)\, e^{\left((r-y)t - SD_d V\sqrt{t}\right)}$ and $S_t^u = (S_0 - PVDivs)\, e^{\left((r-y)t + SD_u V\sqrt{t}\right)}$.

The parameter V is defined as the annualized volatility of log stock returns over the holding period. The natural place to look for a forward looking measure of volatility is the options market. Therefore, I take V to be the average implied volatility of the at-the-money (ATM) call and put contracts with the same expiration as the options in the portfolio.[12] The ATM call (put) is taken to be the contract with delta closest to 0.5 (-0.5).[13]

To calibrate the parameters SD_u and SD_d, I analyze the distribution of the standardized log excess returns in the cross-section of stocks. I define the standardized log excess return for a stock to be

$$R_{Std} = \frac{ln \frac{S_t}{(S_0 - PVDivs)e^{rt}}}{V\sqrt{t}}. \quad (6)$$

Each month from February 1996 through December 2010, the standardized returns for the past 1, 2, 3, and 6 months are calculated for all stocks using stock and option data from the OptionMetrics database.[14] For entry into the sample, I require that a valid stock return be available in the OptionMetrics database for all days during the holding period. I also require that the absolute deltas of the options used to calculate V be between 0.4 and 0.6. The holding periods begin on the second trading day following each monthly expiration, and end when the options expire. V is calculated at the beginning of the holding period.

I calculate monthly cross-sectional means, as well as selected percentiles of the monthly cross-sectional distributions of R_{Std} for each holding period. Table 1.1 presents the time-series average of monthly cross-sectional percentiles (row *Mean CS Pctls*), along with the time-series distribution of the cross-sectional mean (*TS of Means*) R_{Std}. A more complete presentation of the time-series and cross-sectional distribution of R_{Std} is available in Ap-

[12]All analyses performed in the calibration of the parameters SD_d and SD_u have also been done using 1, 2, 3, 6, and 12 month historical volatility as the value for V. The results are qualitatively similar.

[13]The strike of the ATM call and ATM put contracts may not be the same.

[14]Due to data availability, for 2, 3, and 6 month standardized returns, the analysis starts in March, April, and July 1996 respectively.

pendix 1B.

Table 1.1: Distribution of Standardized Excess Returns (R_{Std})
The table below presents selected percentiles of the distribution of standardized excess returns for $k \in \{1, 2, 3, 6\}$ month holding periods. The standardized excess return is defined as $R_{Std} = \frac{ln \frac{S_t}{(S_0 - PVDivs)e^{rt}}}{V\sqrt{t}}$, where S_0 and S_t are the stock prices at the beginning and end of the holding period, $PVDivs$ is the present value, at the beginning of the period, of all dividends paid on the stock during the holding period, r is the risk-free rate, t is the length in years of the holding period, and V is the implied volatility of the stock at the beginning of the holding period, calculated as the average of the ATM call and put implied volatilities of the k month options. The holding periods begin at the close of the second trading day following each monthly expiration and end on the expiration k months in the future. Each month, the mean and selected percentiles of the cross-sectional distribution of k month standardized excess returns are calculated. The rows labeled *Mean CS Pctls* in the tables below presents the time series average of the monthly cross-sectional mean (column **Mean**) and selected percentiles of standardized excess returns. The rows labeled *TS of Means* present the time-series distribution of monthly cross-sectional means of standardized excess returns. The column labeled **Months** indicates the length of the holding period. The sample covers holding periods ending in February, March, April, and July 1996 through October of 2010 for the 1, 2, 3, and 6 month holding periods.

Months		**Mean**	**Min**	**1%**	**2%**	**3%**	**4%**	**5%**	**25%**	**50%**	**75%**	**95%**	**96%**	**97%**	**98%**	**99%**	**Max**
1	*Mean CS Pctls*	-0.01	-5.84	-2.43	-1.98	-1.74	-1.58	-1.45	-0.53	0.01	0.55	1.36	1.46	1.57	1.73	2.00	3.23
	TS of Means	-0.01	-2.32	-1.67	-1.35	-1.21	-0.89	-0.83	-0.29	0.07	0.36	0.66	0.67	0.72	0.74	0.78	0.86
2	*Mean CS Pctls*	-0.04	-6.56	-2.48	-2.04	-1.80	-1.64	-1.51	-0.56	0.00	0.54	1.32	1.40	1.52	1.67	1.92	3.07
	TS of Means	-0.04	-2.94	-1.78	-1.44	-0.99	-0.86	-0.84	-0.34	0.06	0.31	0.63	0.72	0.79	0.81	0.85	0.95
3	*Mean CS Pctls*	-0.06	-4.80	-2.49	-2.07	-1.84	-1.67	-1.55	-0.58	-0.01	0.53	1.31	1.40	1.50	1.65	1.89	2.70
	TS of Means	-0.06	-2.99	-1.78	-1.54	-1.25	-1.18	-1.07	-0.29	0.02	0.32	0.64	0.65	0.65	0.74	0.81	0.92
6	*Mean CS Pctls*	-0.10	-5.23	-2.73	-2.26	-2.02	-1.84	-1.70	-0.65	-0.05	0.52	1.33	1.42	1.53	1.69	1.93	2.80
	TS of Means	-0.10	-2.76	-2.07	-1.88	-1.58	-1.48	-1.41	-0.30	-0.02	0.26	0.69	0.72	0.79	0.81	0.84	0.93

The average cross-sectional percentiles cover the case of an undiversified investor who takes a position in only 1 stock each month. Here, I consider the *reasonably probable* outcomes to be the middle 98% of the distribution in the average month. Thus, for an investor who will realize large losses when the underlying stock is down (up), I look at 1st (99th) percentile of R_{Std} in the average month (*Mean CS Pctls*). The average 1st percentile 1, 2, 3, and 6 month standardized returns are -2.43, -2.48, -2.49, -2.73. To cover all of these scenarios, SD_d must be set to at least 2.73. A similar analysis of the 99th percentile produces R_{Std} values of 2.00, 1.92, 1.89, and 1.93. SD_u must therefore be at least 2.00.

I also examine the time-series of cross-sectional means to determine reasonably probable outcomes for a diversified investor who takes a similar short option position in all stocks each month (diversified). For this investor, I examine the minimum (maximum) of the time-series of cross-sectional mean R_{Std} (*TS of Means*) to find appropriate values of SD_d and SD_u. The minimum mean R_{Std} for 1, 2, 3, and 6 month holding period are -2.32, -2.94, -2.99, and -2.76 respectively. Thus, SD_d must be set to at least 2.99. The maxima are 0.86, 0.95, 0.92, and 0.93, thus the value of 2.00 for SD_u found in the previous paragraph still holds.

Taking the most extreme values from the undiversified and diversified investor scenarios, I arrive at values of 3.00 (rounding 2.99 slightly) for SD_d and 2.00 for SD_u. In choosing these values, I acknowledge that my choice of the cases that cover what is *reasonably probable* are somewhat arbitrary. However, a more in-depth analysis of the time-series and cross-sectional distribution of R_{Std} supports my choice of parameters. For the reader who wishes to expand the definition of *reasonably probable*, appropriate values of SD_d and SD_u can be found by examining the more complete presentation of the time-series and cross-sectional distribution of R_{Std} presented in Appendix 1B. Expanding the definition of *reasonably probable* would result in larger values of SD_d and SD_u, leading to higher margin requirements. The effect of higher margin requirements on analyses presented in the subsequent sections would be even more dramatic differences between price and margin requirement-based returns.

4 Distribution of Option Returns

4.1 Stock Options

In this section, I compare the margin-based returns of short positions in common option portfolios to the standard price returns. Each month, for each stock, I calculate the price and margin-based return of a short position in a 1 month at-the-money (ATM) call, out-of-the-money (OTM) call, ATM put, OTM put, and ATM straddle. The ATM (OTM) positions are found by taking the contract with absolute delta closest to 0.5 (0.2) at the beginning of the holding period. The straddle position is created by taking the call option with delta closest to 0.5 and the put option with the same strike. The holding period starts at the close of the second trading day following each monthly expiration and ends on the next monthly expiration, when the options expire. For entry into the sample, I require that the options used to calculate V have absolute deltas between 0.4 and 0.6, that return data for the underlying stock be available for all days during the holding period, and that the delta of the actual option shorted be within 0.1 of the targeted delta (either 0.5 or 0.2). For the straddle positions, I require that the absolute delta of both options be between 0.4 and 0.6.

Panel A of Table 1.2 presents the time-series average of selected percentiles of the cross-sectional distribution of monthly price and margin-based returns for each type of short option position.[15] The results indicate that in the average month more than 5% of positions in all strategies have price-based returns less than -100%. Using the margin based return, less than 1% (2%) of puts and OTM calls (ATM calls and straddles) realize losses in excess of 100% of the margin requirement. More importantly, the column labeled **Mean** presents the average monthly excess return of the equal weighted portfolio with a short option position on all stocks. The results indicate that the magnitude of the average monthly margin-based returns are dramatically lower than the price-based returns for all strategies. Margin-based returns are between 54% and 91% lower than price-based returns for these common option positions.

The time-series distributions of monthly cross-sectional mean returns are presented in Panel B of Table 1.2. The results show that for each of the single option based strategies, more than 5% of months have price-based losses in excess of 100%. The margin-based loss,

[15] A more complete presentation of the time-series and cross-sectional distribution of option position returns is available in Appendix 1B. Results for 2, 3, and 6 month returns are also available.

Table 1.2: Distribution of 1 Month Short Call, Put, and Straddle Excess Returns
The table below shows the selected statistics from the distribution of short 1 month ATM and OTM call and put, and ATM straddle price and margin-based excess returns. Each month, on the second trading day following the monthly expiration, the ATM (OTM) call and put for each are stock defined to be the 1 month options with delta closest to 0.5 and -0.5 (0.2 and -0.2) respectively. The straddle is comprised of the ATM call and the put with the same strike. The mean, as well as selected percentiles of the cross-sectional distribution of the price and margin based returns are calculated each month. Panel A presents the time-series means of the monthly cross-sectional means and percentiles. Panel B presents the time-series distribution of monthly cross-sectional means. The column labeled **Reduction%** presents the percentage reduction in average cross-sectional mean excess return achieved by using the margin return as compared to the price return. The sample covers holding periods ending from February 1996 through October 2010. All values are in percent.

Panel A: Time-Series Average of Cross-Sectional Excess Return Distribution

Position	**ATM/OTM**	**Return**	**Mean**	**Reduction%**	**Min**	**1%**	**2%**	**3%**	**4%**	**5%**	**25%**	**50%**	**75%**	**95%**	**96%**	**97%**	**98%**	**99%**	**Max**
Short Call	**ATM**	*Price*	-5.5		-1054	-529	-428	-369	-328	-296	-54	53	97	100	100	100	100	100	100
		Margin	-1.2	78.4	-195	-101	-83	-72	-64	-58	-12	9	19	24	24	25	25	26	36
	OTM	*Price*	4.6		-2755	-1254	-889	-695	-550	-451	62	100	100	100	100	100	100	100	100
		Margin	1.0	77.4	-350	-96	-70	-55	-45	-37	3	7	9	12	12	13	15	23	265
Short Put	**ATM**	*Price*	11.4		-942	-386	-308	-264	-233	-210	-28	54	90	99	100	100	100	100	100
		Margin	2.4	79.4	-174	-80	-64	-55	-49	-44	-7	10	19	26	26	27	28	30	39
	OTM	*Price*	17.1		-2512	-888	-612	-464	-364	-297	36	87	98	100	100	100	100	100	100
		Margin	1.6	90.7	-175	-71	-49	-38	-30	-25	1	6	9	12	12	13	13	15	82
Short Straddle	**ATM**	*Price*	3.6		-522	-241	-195	-170	-153	-138	-35	19	61	93	95	97	98	99	100
		Margin	1.7	54.1	-237	-111	-90	-78	-70	-63	-16	9	28	43	44	45	46	48	52

Panel B: Time-Series Distribution of Monthly Cross-Sectional Mean Excess Return

Position	ATM/OTM	Return	Mean	Reduction%	Min	1%	2%	3%	4%	5%	25%	50%	75%	95%	96%	97%	98%	99%	Max
Short Call	**ATM**	*Price*	-5.5		-182	-141	-129	-124	-118	-113	-47	1	44	78	83	88	91	92	99
		Margin	-1.2	78.4	-32	-29	-26	-24	-23	-21	-9	-0	8	15	16	16	17	18	19
	OTM	*Price*	4.6		-424	-249	-192	-175	-171	-155	-36	28	71	91	95	97	98	98	100
		Margin	1.0	77.4	-41	-24	-18	-14	-13	-12	-2	3	6	9	9	10	11	12	25
Short Put	**ATM**	*Price*	11.4		-349	-252	-183	-158	-131	-110	-15	32	58	77	78	81	82	86	88
		Margin	2.4	79.4	-74	-51	-40	-34	-24	-22	-3	6	12	17	17	17	18	19	19
	OTM	*Price*	17.1		-759	-518	-304	-244	-209	-162	9	51	79	91	94	95	96	96	98
		Margin	1.6	90.7	-64	-39	-25	-21	-16	-12	0	4	7	8	8	9	9	12	16
Short Straddle	**ATM**	*Price*	3.6		-141	-93	-55	-49	-42	-33	-4	8	16	27	29	30	33	34	41
		Margin	1.7	54.1	-66	-42	-25	-22	-19	-14	-2	4	8	13	13	14	15	16	19

however, never exceeds the margin requirement. It appears as if margin requirement serves its intended purpose, as losses in excess of the margin requirement are mitigated.

4.2 Index Options

Here I investigate the impact of the margin requirement on index option returns. Several authors have found that the returns associated with selling puts or selling straddles on an index are very large. Coval and Shumway (2001) show that calls (puts) are expected to have positive (negative) returns for underliers with positive correlation to the market, and find that S&P index options returns, while exhibiting these characteristics, under-perform their expectations. They interpret this result as evidence of a negative price of volatility risk. Bondarenko (2003) finds very large negative returns associated with selling ATM and OTM S&P 500 index puts, and concludes that the returns are too large in magnitude to be associated with any reasonable investor preferences.

Table 1.3 presents the time-series distribution of monthly returns associated with selling ATM and OTM calls and puts, and ATM straddles for the S&P 500 and Nasdaq 100 indices.[16] The positions are constructed in exactly the same manner as the stock option positions.

The results indicate that margin requirements reduce the magnitude of short index option returns by 59% to 92%. The percentage of months that realize losses in excess of 100%, and the size of losses in these months is also substantially decreased. Consistent with results of previous studies, selling S&P and Nasdaq puts produces very large price-based returns. When margin requirements are introduced, the returns associated with selling ATM (OTM) S&P puts are only 3.20% (3.40%) per month, compared to returns of 18.83% (44.02%) using the price-based measure. The results for short Nasdaq put positions are similar.[17]

Finally, the results demonstrate that price-based returns may exaggerate estimates of the gains realized by shorting index straddles. S&P straddle returns are frequently used as estimates of the price of volatility risk. The results indicate that accounting for margin requirements may reduce straddle return-based estimates of the price of volatility risk by as much as 61%.

4.3 Summary of Effects of Margin Requirements

In summary, the margin requirement-based return calculation performs as designed. Diversified short option portfolios (index option portfolio) never (rarely) realize losses in excess of 100% of the margin requirement. The margin requirement-based returns associated with such strategies are more reflective of the returns realized by investors than the price-based

[16] Results for the 2, 3, and 6 month index option strategies are presented in Appendix 1B.

[17] Contrary to the theoretical and empirical results of Coval and Shumway (2001), short positions in ATM S&P calls produce a positive average monthly price (margin) based return of 1.32% (0.63%). This departure from theory is due to the sample period. Unreported results from the subperiod 1996 through 2006 show negative returns. The market turmoil of 2007-2009 has a large impact on the full-sample results in table 1.3, as selling calls during this later period produced very high returns.

Table 1.3: Distribution of Index Option Returns

The table below presents the time-series distribution of short 1 month ATM and OTM call and put, and ATM straddle price and margin-based excess returns for S&P 500 (S&P) and Nasdaq 100 (Nasdaq) index options. Each month, on the second trading day following the monthly expiration, the ATM (OTM) call and put for each index are defined to be the 1 month options with delta closest to 0.5 and -0.5 (0.2 and -0.2) respectively. The straddle is comprised of the ATM call and the put with the same strike. The table presents the mean and selected percentiles of the time-series distribution of monthly price and margin-based excess returns. The column labeled **Reduction%** presents the percentage reduction in average cross-sectional mean excess return achieved by using the margin return as compared to the price return. The sample covers holding periods ending from February 1996 through October 2010. All values are in percent.

Position	**ATM/OTM**	**Index**	**Return**	**Mean**	**Reduction%**	**Min**	**1%**	**2%**	**3%**	**4%**	**5%**	**25%**	**50%**	**75%**	**95%**	**96%**	**97%**	**98%**	**99%**	**Max**
Short Call	**ATM**	**S&P**	*Price*	1.32		-367	-310	-292	-265	-260	-257	-80	61	100	100	100	100	100	100	101
			Margin	0.28	78.7	-83	-70	-64	-61	-59	-55	-18	13	22	24	24	24	25	25	27
		Nasdaq	*Price*	-12.88		-615	-401	-360	-350	-329	-302	-105	76	100	100	100	100	100	101	101
			Margin	-2.78	78.5	-125	-81	-74	-72	-69	-66	-23	16	21	23	23	23	24	25	28
	OTM	**S&P**	*Price*	12.84		-1050	-873	-637	-618	-570	-522	100	100	100	100	100	100	101	101	101
			Margin	1.08	91.6	-75	-59	-52	-47	-43	-40	6	7	8	9	9	9	9	10	10
		Nasdaq	*Price*	-14.19		-1813	-999	-809	-733	-705	-647	100	100	100	100	100	100	101	101	101
			Margin	-1.11	92.1	-134	-75	-66	-62	-60	-53	6	7	8	10	10	10	11	11	22
Short Put	**ATM**	**S&P**	*Price*	18.83		-639	-565	-463	-347	-284	-282	-21	100	100	100	100	100	100	101	101
			Margin	3.20	83.0	-106	-94	-80	-64	-50	-47	-3	15	17	19	19	19	19	20	21
		Nasdaq	*Price*	20.93		-630	-528	-345	-281	-274	-266	-9	100	100	100	100	100	100	101	101
			Margin	3.73	82.2	-108	-92	-62	-54	-51	-49	-1	16	18	20	21	21	22	23	24
	OTM	**S&P**	*Price*	44.02		-1244	-1121	-900	-566	-361	-314	100	100	100	100	100	100	101	101	101
			Margin	3.40	92.3	-109	-91	-73	-51	-29	-26	7	8	8	10	10	10	10	10	11
		Nasdaq	*Price*	36.70		-1488	-1157	-589	-478	-422	-405	100	100	100	100	100	100	101	101	101
			Margin	3.42	90.7	-111	-89	-50	-37	-35	-32	7	8	8	9	9	10	10	11	100
Short Straddle	**ATM**	**S&P**	*Price*	10.33		-274	-235	-193	-148	-120	-98	-30	18	67	93	96	98	98	99	99
			Margin	4.03	61.0	-107	-92	-77	-58	-47	-40	-11	7	26	37	37	38	39	39	41
		Nasdaq	*Price*	4.64		-290	-244	-188	-133	-115	-111	-37	16	61	92	95	97	98	99	99
			Margin	1.88	59.5	-110	-102	-80	-59	-49	-47	-14	7	25	38	39	40	41	41	43

returns. In the next section, I turn my attention the effects of margin requirements on long/short option portfolio return analyses.

5 Effect of Margin on Long/Short Portfolio Analysis

Several recent studies have analyzed the cross-section of option returns. Most notably, Goyal and Saretto (2009) (GS hereafter) use a long/short portfolio analysis to detect a positive cross-sectional relation between $HV - IV$ (historical minus implied volatility) and price-based ATM straddle returns.[18] In this section, I replicate the GS results, and demonstrate that using margin-based returns results in a lower, more realistic, high-low (10-1) portfolio return, while maintaining the level of statistical significance. En-route, I develop additional methodological modifications, necessitated by the the use of margin-based returns, to the standard portfolio analysis.

5.1 Replication of Goyal-Saretto Results

I begin by replicating the results of GS. Each month, on the first trading day after option expiration, $HV - IV$ is calculated. HV is the 1-year historical stock volatility, calculated as $HV = \sigma_{R,Daily}\sqrt{252}$, where $\sigma_{R,Daily}$ is the standard deviation of daily log returns over the past year.[19] IV is calculated using 1 month options in exactly the same way as V in the margin requirement calculation. For a stock/month pair to gain entry into the sample, I require that return data be available for all trading days during the HV calculation period, and that the absolute deltas of the options used to calculate IV be between 0.4 and 0.6.

On the second trading day following expiration, I form decile portfolios of 1-month strad-

[18]In another such study, Cao and Han (2009) find a negative cross-sectional relation between volatility and covered call returns.

[19]In calculating HV, stock data from OptionMetrics is augmented by stock data from the Center for Research in Security Prices (CRSP) for dates prior to January 1996, as OptionMetrics does not provide data prior to this time. CRSP PERMNOs are matched to OptionMetrics SecurityIDs using CUSIPs.

Table 1.4: Relation Between $HV - IV$ and Straddle Returns

Goyal and Saretto (2009) demonstrate a positive relation between HV-IV and straddle returns. Panel A presents a replication of the main result of Goyal and Saretto (2009). Each month, portfolios of straddle positions are formed by sorting stocks into deciles of historical volatility minus implied volatility ($HV - IV$). HV is the realized volatility over the past 1 year. IV is the average of the ATM call and ATM put implied volatilities. The signal, $HV - IV$, is calculated on the first trading day after each monthly expiration. On the second trading day, portfolios of ATM straddles are formed based on the deciles of $HV - IV$. Panel A presents the decile portfolio excess returns for long ATM straddle positions, thus replicating the main result of Goyal and Saretto (2009). Panel B presents the portfolio excess returns for short ATM straddle positions using the margin requirement-based returns. The row labeled **Excess Ret** presents the excess returns for each of the decile portfolios. The rows labeled **CAPM**, **FF3**, and **FFC4** present the alphas from the capital asset pricing model (Sharpe (1964), Lintner (1965)), Fama and French 3-factor model (Fama and French (1993)), and Fama, French, and Carhart (Carhart (1997)) risk models. The column labeled **10-1** presents the difference in returns or alphas between the 10th and 1st decile portfolios. The column labeled **10-1 t-stat** presents the t-statistic testing the null hypothesis that the average return or alpha of the 10-1 portfolio is equal to 0. All t-statistics are calculated using the Newey and West (1987) adjustment with 6 lags. The sample covers holding periods ending from February 1996 through October 2010. All excess returns and are in percent.

Panel A: $HV - IV$ Decile Long Straddle Portfolio Excess Returns

	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**10-1**	**10-1 t-stat**
Excess Ret	-13.09	-9.72	-7.55	-5.10	-3.02	-2.30	-2.03	-0.18	1.08	5.52	18.61	8.38
CAPM	-12.47	-8.85	-6.69	-4.12	-1.89	-1.29	-1.05	0.78	2.14	6.51	18.98	8.87
FF3	-11.98	-8.44	-6.10	-3.63	-1.31	-0.60	-0.37	1.57	2.69	7.21	19.18	8.36
FFC4	-11.88	-8.50	-6.15	-3.63	-1.29	-0.80	-0.49	1.66	2.52	7.02	18.89	8.70

Panel B: $HV - IV$ Decile Short Straddle Portfolio Excess Returns

	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**10-1**	**10-1 t-stat**
Excess Ret	6.16	4.48	3.38	2.26	1.41	1.09	0.93	0.12	-0.48	-2.50	-8.67	-8.21
CAPM	5.86	4.07	2.98	1.81	0.89	0.63	0.49	-0.31	-0.97	-2.96	-8.82	-8.70
FF3	5.64	3.88	2.70	1.59	0.63	0.32	0.18	-0.67	-1.22	-3.28	-8.92	-8.20
FFC4	5.59	3.91	2.74	1.61	0.63	0.43	0.25	-0.69	-1.12	-3.17	-8.76	-8.59

dles sorted on $HV - IV$. The portfolios are held for 1 month, until the options expire. For a stock/month observation to enter the sample, I require that stock return data for all days during the portfolio holding period be available in OptionMetrics.

The results, presented in Table 1.4 Panel A, are very similar to those of GS Table 3. The 1st decile portfolio realizes an average monthly loss of 13.09% (GS find loss of 12.8%), and the 10th decile decile portfolio gains 5.52% per month (GS find gain of 9.9%). The cross-sectional difference in returns is a very statistically significant 18.61% (t-statistic is 8.38). The table shows that the results are not driven by any of the market, size, book-to-market, or momentum factors of Fama and French (1993) or Carhart (1997).[20] Panel A demonstrates that the sample I am working with exhibits the same cross-sectional pattern of straddle returns as the sample used by GS.

Panel B shows the margin based returns of decile portfolios of short straddle positions sorted into deciles of $HV - IV$. As the positions analyzed in Panel B are *short* straddle positions, the difference between the 10th decile and 1st decile returns takes a negative sign. Notice that due to margin requirements diluting the returns, the magnitude of the return difference between the 10th and 1st decile portfolios has decreased significantly to 8.67% a month, but the statistical significance of the difference, measured by the magnitude of the t-statistic, has changed very little.

5.2 Long/Short Straddle Portfolio Returns

Neither Panel A nor Panel B of Table 1.4 represent the returns realized by a tradable investment strategy. The results in Table 1.4 simply represent cross-sectional differences in the returns from long (Panel A) and short (Panel B) straddle positions.[21] An investor who is long straddles on certain stocks and short straddles on other stocks will be required to supply margin equal to the sum of the margin requirements on the long and short straddle positions.[22] For an investor who commits equal margin to long (short) straddles for the 10th (1st) decile of $HV - IV$, the realized return is therefore half of the 10th decile long return (10th decile from Table 1.4, Panel A), plus half the 1st decile short return (1st decile

[20] Daily risk factor data is taken from Kenneth French's online data library. As the holding periods for the option positions do not correspond to calendar months, monthly risk factor returns for the holding periods are calculated from the daily risk factor return data.

[21] For long straddle positions, the price return and the margin based return are exactly the same, as the maximum loss is the initial price of the straddle.

[22] One may argue that the long and short positions should have an offsetting effect on the amount of margin required, as one side will tend to profit when the other side loses. Conversations with industry practitioners indicate that for standard clients, broker-dealers are unlikely to reduce the margin requirement, but for large and preferred clients, the reduction can be substantial.

from Table 1.4, Panel B). The returns of this portfolio are shown in Table 1.5 Panel A.[23] The results demonstrate that the returns realized by an investor implementing this strategy are much lower than indicated in Table 1.4, and the t-statistics have dropped considerably. The drop in returns is an expected outcome of using margin requirements. The drop in t-statistics comes from increased risk due to unequal position sizes on the long and short sides of the portfolio. The next section discusses how to remedy this issue.

5.2.1 *Vega* Hedged Long/Short Straddle Portfolio Returns

Allocating equal margin to the long and short sides of the portfolio results in much smaller position sizes for the short side, and as a result a substantial long aggregate volatility exposure. Not only is this inconsistent with how a long/short investor would likely construct her portfolio, but it fails to isolate the targeted cross-sectional effect, in this case the relation between $HV - IV$ and straddle returns. To alleviate this issue, an investor would allocate the portfolios such that there is equal volatility (*vega*) exposure on the long and short sides.[24] To generate the returns of the volatility hedged portfolio, at the beginning of each holding period, I calculate the total *vega* exposure for the long and short portfolios as the sum of the option *vega*s times the size of the option positions. The amount of margin committed to the long and short sides of the portfolio is then inversely related to the side's total *vega* exposure.

Table 1.5, Panel B shows the average returns for a long/short portfolio with equal *vega* exposure on both sides of the portfolio, along with the average percentage of total margin required by each side. As the long and short returns from Panel A are roughly the same,

[23] Because of this *halving*, the magnitude of returns presented in Table 1.4 cannot be directly compared to those in Table 1.5.

[24] As straddle positions are primarily volatility positions, the risk to be hedged is volatility exposure. There are examples where it would be appropriate to allocate portfolios to hedge some other risk. For example, Bali and Murray (2011) form delta and vega hedged skewness positions on each stock. In this scenario, to isolate the cross-sectional skewness effect, the authors would want to allocate equal skewness exposure to the long and short portfolios. This would require an option pricing model that, unlike the Black and Scholes (1973) model and the Cox, Ross, and Rubinstein (1979) model used by OptionMetrics, accounts for skewness.

Table 1.5: Long and Short Straddle Portfolio Returns

This table presents monthly excess returns for a portfolios that is long straddles for decile 10 of $HV - IV$ and short straddles for decile 1 of $HV - IV$. Portfolios are formed exactly as in Table 1.4. Panel A presents the results for a portfolio where the long and short portions of the portfolio are allocated equal margin. Panel B presents the results for a portfolio where the long and short portions of the portfolio are allocated margin in a manner such that the total *vega* on the long and short sides is equal. The column labeled **Short Decile 1** presents the excess margin-based short excess returns of the first decile portfolio. The column labeled **Long Decile 10** presents the margin-based (same as price-based because these are long positions) long excess returns of the 10th decile portfolio. The column labeled **Portfolio Return** presents the average excess return of a portfolio with equal margin (Panel A) or volatility exposure (*vega*, Panel B) allocated to the long and short sides. The column labeled **t-stat** presents the t-statistic testing the null hypothesis that the average monthly portfolio excess return is 0. All t-statistics are calculated using the Newey and West (1987) adjustment with 6 lags. The row labeled **Standard Deviation** presents the standard deviation of monthly returns for each of the portfolios. In Panel B, the row labeled **Margin%** presents the average percentage of total portfolio margin requirement allocated to the long and short positions. All other rows are as in Table 1.4. The sample covers holding periods ending from February 1996 through October 2010. All excess returns and alphas are in percent.

Panel A: Equal Capital To Long and Short

	Short Decile 1	**Long Decile 10**	**Portfolio Return**	**t-stat**
Excess Ret	6.16	5.52	5.84	5.15
CAPM	5.86	6.51	6.18	5.85
FF3	5.64	7.21	6.42	5.61
FFC4	5.59	7.02	6.30	5.78
Standard Deviation	9.30	31.10	13.45	

Panel B: Equal $Vega$ To Long and Short

	Short Decile 1	**Long Decile 10**	**Portfolio Return**	**t-stat**
Excess Ret	6.16	5.52	5.75	8.45
CAPM	5.86	6.51	5.75	8.52
FF3	5.64	7.21	5.74	8.03
FFC4	5.59	7.02	5.64	8.53
Standard Deviation	9.30	31.10	7.39	
Margin%	72	28	100	

it is not surprising that the re-weighting does not substantially change the average return. What does change is the risk of the long/short portfolio. Each of the t-statistics increase by more than 2.4. The standard deviation of the monthly returns decreases from 13.45% per month for the equal margin portfolio to 7.39% per month for *vega* neutral portfolio. The increased t-statistic and lower standard deviation is evidence that removing undesired cross-sectional variation in portfolio returns gives the portfolio analysis more power to detect the cross-sectional pattern being studied.

To test whether the increase in performance is statistically significant, I standardize the returns by dividing each monthly portfolio return by the standard deviation of the monthly portfolio returns. I then perform a t-test to compare the average standardized returns of the two investment strategies. The test produces a t-statistic of 3.23, strong evidence that the risk-reward profile of the vega-hedged investment strategy is superior to that of the equal margin portfolio.

5.3 Summary of Long/Short Portfolio Results

There are two main conclusions to be drawn from this section. First, when analyzing option returns in the cross-section, the high-low (in this case decile 10 - decile 1) return does not represent the return of an investable portfolio, as it fails to account for the margin requirement associated with short option positions. Second, when creating long/short option portfolios, allocating equal margin to the long and short portfolios may fail to isolate the targeted cross-sectional effect, as the portfolio may be exposed to aggregate volatility risk. The long/short portfolio should be constructed such that it is neutral to volatility (or other) risk. Doing so requires different margin commitments on each side of the portfolio.

6 Conclusion

Margin requirements have a large effect on the returns realized by an investor who is short options. In this paper, I develop and calibrate a model for calculating the margin requirement on portfolios containing short option positions. The results indicate that a margin requirement equal to the worst case portfolio loss for expiration stock prices between 3 standard deviations below and 2 standard deviations above the stock price at portfolio inception provides a realistic assessment of the returns realized by investors.

Empirically, I demonstrate that there is a very substantial difference between the price and margin based returns for several common option strategies. Returns on standard short option positions can be reduced by as much as 91% when accounting for margin requirements. Furthermore, margin requirements reduce a straddle return-based estimate of the price of volatility risk by 61%.

In long/short portfolio analyses of option returns, generating realistic return estimates while effectively isolating the targeted cross-sectional effect requires allocating margin to the long and short portfolios in quantities such that unwanted risk exposure is hedged. When studying the cross-section of volatility portfolios, such as straddles, it is optimal to allocate margin such that there is an equal amount of volatility exposure on each side of the portfolio. Doing so removes exposure to aggregate volatility changes, resulting in increased power to detect the targeted pattern in option returns.

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Appendix 1A Calculation of Risk Free Rate and Present Value of Dividends

The present value of dividends ($PVDivs$) on date t_0 for an option expiring on date t_1 is calculated to be the sum of the present values of all dividends paid on the underlying stock with ex-dates between date t_0 (exclusive) and t_1 (inclusive). Specifically, let $Div_{e,\tau}$ be a dividend paid on the underlying stock with ex-date e and pay-date τ, where $t_0 < e \leq t_1$, and let r_τ be the risk-free rate of return on a deposit made on date t_0 to be withdrawn on date τ, and t_τ be the time, in years, between dates t_0 and τ, then we have.

$$PVDivs = \sum_{t_0 < \tau \leq t_1} e^{-r_\tau t_\tau} Div_{e,\tau} \tag{7}$$

OptionMetrics provides zero-rate data for each date t_0 and a series of maturities. r_τ, for any specific value of t_0 and τ, is found by applying a cubic spline to the zero-rate data for date t_0 and finding the interpolated zero-rate for maturity t_τ.

Appendix 1B Additional Empirical Results

Table 1B.1: Distribution of Standardized Excess Returns (R_{Std})
The table below presents selected percentiles of the cross-sectional and time-series distribution of standardized excess returns for $k \in \{1, 2, 3, 6\}$ month (panels A, B, C, and D) holding periods. The standardized excess return is defined as $R_{Std} = \frac{ln\frac{S_t}{(S_0 - PVDivs)e^{rt}}}{V\sqrt{t}}$, where S_0 and S_t are the stock prices at the beginning and end of the holding period, $PVDivs$ is the present value, at the beginning of the period, of all dividends paid on the stock during the holding period, r is the risk-free rate, t is the length in years of the holding period, and V is the implied volatility of the stock at the beginning of the holding period, calculated as the average of the ATM call and put implied volatilities of the k month options. The holding periods begin at the close of the second trading day following each monthly expiration and end on the expiration k months in the future. Each month, the mean and selected percentiles of the cross-sectional distribution of k month standardized excess returns are calculated. Each column header represents a statistic from the monthly cross-sectional distribution of R_{Std}. Each row label represents a statistic from the time-series distribution of the monthly cross-sectional statistics of R_{Std}. For example, the value in the row labeled **5%** and the column labeled **25%** is calculated by taking the time-series of all of the monthly cross-sectional 25th percentiles, and then taking the 5th percentile of these values. The sample covers holding periods ending in February, March, April, and July 1996 through October of 2010 for the 1, 2, 3, and 6 month holding periods.

Panel A: 1 Month R_{Std}

	Mean	**StdDev**	**Min**	**1%**	**2%**	**3%**	**4%**	**5%**	**25%**	**50%**	**75%**	**95%**	**96%**	**97%**	**98%**	**99%**	**Max**	**n**
Mean	-0.01	0.91	-5.84	-2.43	-1.98	-1.74	-1.58	-1.45	-0.53	0.01	0.55	1.36	1.46	1.57	1.73	2.00	3.23	783
StdDev	0.51	0.17	4.62	0.91	0.78	0.73	0.70	0.68	0.55	0.51	0.47	0.45	0.46	0.46	0.47	0.49	0.89	211
Min	-2.32	0.60	-40.44	-5.98	-5.29	-4.86	-4.59	-4.36	-3.06	-2.21	-1.49	-0.45	-0.36	-0.30	-0.18	0.11	0.71	261
1%	-1.67	0.62	-27.28	-5.24	-4.44	-4.18	-3.88	-3.62	-2.30	-1.65	-0.93	0.12	0.23	0.39	0.55	0.85	1.43	311
2%	-1.35	0.65	-20.37	-4.91	-4.10	-3.83	-3.61	-3.37	-1.98	-1.27	-0.58	0.31	0.40	0.50	0.66	0.89	1.64	329
3%	-1.21	0.66	-12.88	-4.56	-4.03	-3.51	-3.30	-3.14	-1.79	-1.13	-0.51	0.41	0.49	0.59	0.75	0.95	1.72	344
4%	-0.89	0.69	-11.31	-4.29	-3.45	-3.15	-2.94	-2.87	-1.52	-0.92	-0.34	0.51	0.59	0.67	0.90	1.10	1.78	348
5%	-0.83	0.69	-10.68	-4.13	-3.38	-3.04	-2.83	-2.65	-1.49	-0.77	-0.20	0.63	0.70	0.80	0.95	1.17	1.81	367
25%	-0.29	0.82	-6.74	-2.83	-2.35	-2.13	-1.93	-1.79	-0.81	-0.27	0.28	1.08	1.18	1.29	1.47	1.72	2.67	651
50%	0.07	0.89	-4.64	-2.27	-1.84	-1.60	-1.46	-1.34	-0.43	0.09	0.63	1.41	1.49	1.58	1.73	1.98	3.19	781
75%	0.36	1.00	-3.46	-1.81	-1.44	-1.23	-1.08	-0.98	-0.15	0.38	0.87	1.69	1.76	1.90	2.05	2.35	3.75	948
95%	0.66	1.16	-2.41	-1.26	-0.97	-0.85	-0.73	-0.65	0.17	0.67	1.18	1.98	2.10	2.23	2.40	2.75	4.62	1103
96%	0.67	1.18	-2.30	-1.16	-0.94	-0.81	-0.68	-0.58	0.18	0.72	1.21	1.99	2.13	2.26	2.43	2.77	4.82	1108
97%	0.72	1.23	-2.08	-1.11	-0.89	-0.74	-0.65	-0.53	0.25	0.74	1.24	2.06	2.22	2.32	2.45	2.80	5.12	1129
98%	0.74	1.27	-2.02	-1.07	-0.84	-0.64	-0.55	-0.45	0.26	0.76	1.26	2.10	2.25	2.37	2.56	2.98	5.47	1143
99%	0.78	1.43	-1.78	-0.98	-0.79	-0.61	-0.44	-0.36	0.32	0.81	1.33	2.12	2.27	2.43	2.67	3.17	6.01	1158
Max	0.86	1.94	-1.50	-0.94	-0.70	-0.49	-0.33	-0.19	0.46	0.88	1.47	2.47	2.67	2.83	3.04	3.22	6.36	1419

Panel B: 2 Month R_{Std}

	Mean	**StdDev**	**Min**	**1%**	**2%**	**3%**	**4%**	**5%**	**25%**	**50%**	**75%**	**95%**	**96%**	**97%**	**98%**	**99%**	**Max**	**n**
Mean	-0.04	0.91	-6.56	-2.48	-2.04	-1.80	-1.64	-1.51	-0.56	0.00	0.54	1.32	1.40	1.52	1.67	1.92	3.07	1086
StdDev	0.54	0.17	4.48	1.01	0.88	0.82	0.78	0.75	0.59	0.53	0.48	0.46	0.46	0.48	0.48	0.51	0.89	286
Min	-2.94	0.55	-27.45	-7.92	-7.05	-6.35	-5.99	-5.74	-3.82	-2.76	-1.81	-0.63	-0.55	-0.38	-0.15	0.07	0.91	242
1%	-1.78	0.60	-23.33	-5.44	-4.73	-4.34	-4.14	-3.92	-2.45	-1.74	-1.00	-0.08	0.05	0.17	0.32	0.51	1.46	278
2%	-1.44	0.62	-21.86	-4.73	-4.03	-3.65	-3.41	-3.27	-2.03	-1.37	-0.72	0.19	0.25	0.36	0.53	0.86	1.68	292
3%	-0.99	0.64	-17.47	-4.64	-3.77	-3.33	-3.10	-2.94	-1.51	-0.88	-0.33	0.34	0.40	0.50	0.67	1.00	1.76	303
4%	-0.86	0.65	-17.00	-4.42	-3.66	-3.27	-3.03	-2.74	-1.44	-0.80	-0.22	0.60	0.68	0.80	0.87	1.12	1.88	314
5%	-0.84	0.66	-15.67	-4.34	-3.50	-3.16	-3.00	-2.68	-1.42	-0.76	-0.18	0.63	0.71	0.83	0.94	1.14	1.99	324
25%	-0.34	0.80	-7.17	-3.04	-2.51	-2.24	-2.03	-1.89	-0.88	-0.26	0.29	1.08	1.17	1.25	1.37	1.62	2.51	961
50%	0.06	0.89	-5.07	-2.31	-1.91	-1.68	-1.50	-1.40	-0.48	0.08	0.62	1.39	1.48	1.57	1.72	1.95	2.96	1110
75%	0.31	1.01	-3.83	-1.80	-1.47	-1.28	-1.13	-1.04	-0.19	0.33	0.86	1.63	1.71	1.84	1.96	2.23	3.47	1269
95%	0.63	1.22	-2.43	-1.15	-0.92	-0.76	-0.68	-0.55	0.23	0.68	1.17	2.00	2.07	2.18	2.34	2.72	4.57	1483
96%	0.72	1.23	-2.31	-1.10	-0.89	-0.73	-0.63	-0.52	0.30	0.73	1.19	2.03	2.13	2.29	2.44	2.77	4.85	1501
97%	0.79	1.27	-2.06	-1.05	-0.84	-0.70	-0.55	-0.45	0.33	0.81	1.25	2.10	2.18	2.34	2.56	2.81	4.95	1540
98%	0.81	1.31	-1.91	-0.97	-0.79	-0.60	-0.51	-0.39	0.34	0.84	1.31	2.13	2.26	2.43	2.61	2.93	5.09	1578
99%	0.85	1.39	-1.68	-0.89	-0.66	-0.55	-0.42	-0.31	0.38	0.86	1.34	2.25	2.37	2.56	2.89	3.39	5.75	1591
Max	0.95	1.66	-1.63	-0.68	-0.37	-0.16	-0.11	-0.05	0.57	1.00	1.47	2.54	2.72	2.90	3.08	3.52	8.30	1724

Panel C: 3 Month R_{Std}

	Mean	**StdDev**	**Min**	**1%**	**2%**	**3%**	**4%**	**5%**	**25%**	**50%**	**75%**	**95%**	**96%**	**97%**	**98%**	**99%**	**Max**	**n**
Mean	-0.06	0.92	-4.80	-2.49	-2.07	-1.84	-1.67	-1.55	-0.58	-0.01	0.53	1.31	1.40	1.50	1.65	1.89	2.70	448
StdDev	0.55	0.19	2.99	1.12	0.98	0.92	0.85	0.82	0.62	0.52	0.48	0.47	0.48	0.49	0.51	0.53	0.86	163
Min	-2.99	0.61	-20.00	-9.59	-8.19	-7.52	-6.61	-6.22	-4.02	-2.68	-1.76	-0.28	-0.21	0.01	0.12	0.46	0.96	154
1%	-1.78	0.63	-15.88	-5.62	-4.84	-4.49	-4.26	-4.04	-2.55	-1.64	-0.98	-0.06	0.04	0.16	0.29	0.56	1.21	163
2%	-1.54	0.64	-13.25	-5.04	-4.43	-4.08	-3.88	-3.79	-2.24	-1.38	-0.75	0.17	0.24	0.39	0.46	0.74	1.40	185
3%	-1.25	0.65	-12.63	-4.76	-4.05	-3.67	-3.48	-3.34	-1.95	-1.15	-0.51	0.26	0.37	0.47	0.60	0.88	1.49	195
4%	-1.18	0.66	-11.80	-4.60	-4.00	-3.54	-3.27	-3.09	-1.76	-1.06	-0.42	0.31	0.41	0.55	0.77	1.06	1.52	218
5%	-1.07	0.67	-11.04	-4.24	-3.82	-3.44	-3.24	-2.97	-1.66	-1.02	-0.39	0.53	0.63	0.75	0.86	1.11	1.54	232
25%	-0.29	0.79	-5.48	-2.97	-2.49	-2.20	-2.03	-1.89	-0.86	-0.24	0.30	1.11	1.17	1.26	1.39	1.57	2.15	348
50%	0.02	0.87	-4.09	-2.26	-1.94	-1.71	-1.56	-1.46	-0.51	0.09	0.59	1.30	1.39	1.48	1.60	1.87	2.58	420
75%	0.32	1.03	-2.90	-1.74	-1.38	-1.23	-1.11	-0.98	-0.18	0.34	0.88	1.61	1.71	1.80	1.95	2.19	3.03	521
95%	0.64	1.25	-1.94	-1.15	-0.91	-0.76	-0.64	-0.57	0.19	0.64	1.17	1.99	2.07	2.20	2.42	2.68	4.09	722
96%	0.65	1.29	-1.92	-1.13	-0.89	-0.75	-0.61	-0.54	0.21	0.67	1.18	2.03	2.17	2.35	2.49	2.75	4.14	728
97%	0.65	1.31	-1.72	-1.10	-0.88	-0.69	-0.61	-0.50	0.26	0.68	1.20	2.08	2.24	2.36	2.50	2.83	4.38	736
98%	0.74	1.35	-1.49	-0.99	-0.86	-0.66	-0.56	-0.43	0.33	0.77	1.26	2.15	2.28	2.42	2.66	2.95	4.82	807
99%	0.81	1.52	-1.39	-0.89	-0.64	-0.49	-0.42	-0.36	0.39	0.81	1.32	2.33	2.46	2.68	2.91	3.13	5.56	1045
Max	0.92	1.94	-1.06	-0.81	-0.51	-0.38	-0.25	-0.18	0.48	0.99	1.49	2.69	3.05	3.27	3.81	4.29	7.35	1236

Panel D: 6 Month R_{Std}

	Mean	StdDev	Min	1%	2%	3%	4%	5%	25%	50%	75%	95%	96%	97%	98%	99%	Max	n
Mean	-0.10	0.97	-5.23	-2.73	-2.26	-2.02	-1.84	-1.70	-0.65	-0.05	0.52	1.33	1.42	1.53	1.69	1.93	2.80	534
StdDev	0.59	0.24	3.05	1.30	1.13	1.06	1.01	0.97	0.68	0.56	0.48	0.46	0.47	0.48	0.50	0.54	0.76	190
Min	-2.76	0.57	-19.76	-8.66	-7.32	-6.79	-6.52	-6.18	-3.90	-2.57	-1.45	-0.08	-0.05	0.02	0.28	0.50	0.87	164
1%	-2.07	0.57	-14.57	-6.68	-5.87	-5.64	-5.38	-5.02	-2.92	-1.84	-1.02	0.00	0.13	0.24	0.43	0.62	1.21	176
2%	-1.88	0.59	-13.18	-6.16	-5.21	-4.77	-4.48	-4.23	-2.62	-1.72	-0.90	0.17	0.29	0.41	0.55	0.72	1.42	212
3%	-1.58	0.60	-11.95	-5.88	-4.95	-4.42	-4.21	-4.04	-2.32	-1.42	-0.71	0.31	0.40	0.50	0.62	0.84	1.55	234
4%	-1.48	0.61	-11.49	-5.53	-4.90	-4.28	-3.96	-3.82	-2.21	-1.34	-0.56	0.38	0.46	0.52	0.65	0.92	1.61	256
5%	-1.41	0.62	-11.12	-5.38	-4.45	-4.13	-3.79	-3.58	-2.18	-1.23	-0.52	0.46	0.53	0.63	0.75	0.98	1.68	293
25%	-0.30	0.83	-6.44	-3.20	-2.67	-2.43	-2.20	-2.04	-0.88	-0.26	0.33	1.09	1.17	1.30	1.43	1.63	2.30	418
50%	-0.02	0.93	-4.31	-2.54	-2.07	-1.84	-1.69	-1.52	-0.55	0.01	0.56	1.35	1.44	1.54	1.68	1.92	2.73	480
75%	0.26	1.08	-3.17	-1.84	-1.53	-1.34	-1.20	-1.11	-0.22	0.28	0.82	1.62	1.72	1.86	2.02	2.24	3.17	624
95%	0.69	1.39	-2.05	-1.12	-0.86	-0.71	-0.58	-0.46	0.25	0.74	1.18	1.97	2.06	2.20	2.44	2.77	4.17	860
96%	0.72	1.41	-1.98	-1.07	-0.83	-0.67	-0.55	-0.45	0.30	0.75	1.24	2.02	2.08	2.22	2.48	2.93	4.23	864
97%	0.79	1.47	-1.91	-1.00	-0.77	-0.62	-0.47	-0.39	0.37	0.78	1.25	2.04	2.15	2.27	2.52	2.97	4.34	917
98%	0.81	1.57	-1.67	-0.88	-0.64	-0.52	-0.42	-0.36	0.37	0.82	1.29	2.14	2.28	2.41	2.59	3.02	4.41	1016
99%	0.84	1.66	-1.39	-0.69	-0.50	-0.43	-0.29	-0.22	0.43	0.83	1.35	2.31	2.46	2.63	2.78	3.26	4.63	1243
Max	0.93	1.91	-1.10	-0.52	-0.39	-0.31	-0.18	-0.14	0.46	0.91	1.44	2.69	2.85	3.12	3.57	3.94	5.87	1374

Table 1B.2: Distribution of Call, Put, and Straddle Excess Returns

The table below presents selected percentiles of the cross-sectional and time-series distribution of price and margin excess returns for short ATM calls (Panels A1-A8), OTM calls (Panels B1-B8), ATM puts (Panel C1-C8), OTM puts, (Panel D1-D8), and ATM straddle (Panels E1-E8) positions for $k \in \{1, 2, 3, 6\}$ month holding periods. Each month, on the second trading day following the monthly expiration, the ATM (OTM) call and put for each are stock defined to be the k month options with delta closest to 0.5 and -0.5 (0.2 and -0.2) respectively. The straddle is comprised of the ATM call and the put with the same strike. The holding periods begin at the close of the second trading day following each monthly expiration and end on the expiration k months in the future. Each month, the mean and selected percentiles of the cross-sectional distribution of k month holding period excess returns are calculated for each type of position. Each column header represents a statistic from the monthly cross-sectional distribution of the holding period return. Each row label represents a statistic from the time-series distribution of the monthly cross-sectional statistics of the holding period returns. For example, the value in the row labeled **5%** and the column labeled **25%** is calculated by taking the time-series of all of the monthly cross-sectional 25th percentiles, and then taking the 5th percentile of these values. The sample covers holding periods ending in February, March, April, and July 1996 through October of 2010 for the 1, 2, 3, and 6 month holding periods.

Panel A1: 1 Month Short 50 Delta Call Price Excess Returns

	Mean	**StdDev**	**Min**	**1%**	**2%**	**3%**	**4%**	**5%**	**25%**	**50%**	**75%**	**95%**	**96%**	**97%**	**98%**	**99%**	**Max**	**n**
Mean	-5.5	149	-1054	-529	-428	-369	-328	-296	-54	53	97	100	100	100	100	100	100	755
StdDev	60	49	467	193	167	158	151	146	108	61	14	0	0	0	0	0	0	202
Min	-182	10	-4055	-1152	-1039	-919	-860	-802	-345	-137	-5	100	100	100	100	100	100	261
1%	-141	42	-2813	-1116	-797	-693	-637	-572	-265	-108	32	100	100	100	100	100	100	311
2%	-129	47	-2165	-1005	-756	-667	-598	-558	-251	-99	47	100	100	100	100	100	100	329
3%	-124	55	-1812	-855	-751	-651	-575	-534	-234	-91	54	100	100	100	100	100	100	344
4%	-118	65	-1685	-835	-732	-634	-570	-518	-231	-87	73	100	100	100	100	100	100	348
5%	-113	70	-1657	-809	-683	-611	-556	-510	-229	-72	78	100	100	100	100	100	100	367
25%	-47	115	-1272	-652	-542	-477	-427	-397	-137	11	100	100	100	100	100	100	100	617
50%	1	150	-988	-528	-423	-370	-334	-309	-55	94	100	100	100	100	100	100	100	749
75%	44	181	-780	-403	-315	-256	-227	-198	36	100	100	100	100	100	100	100	100	895
95%	78	217	-495	-236	-160	-101	-78	-57	100	100	100	100	100	100	100	100	100	1072
96%	83	226	-459	-233	-142	-79	-52	-26	100	100	100	100	100	100	100	100	100	1079
97%	88	230	-419	-153	-95	-50	-22	-3	100	100	100	100	100	100	100	100	100	1094
98%	91	245	-396	-134	-76	-16	9	37	100	100	101	101	101	101	101	101	101	1112
99%	92	273	-291	-126	-43	3	47	83	100	101	101	101	101	101	101	101	101	1122
Max	99	331	-106	100	100	100	100	100	100	101	101	101	101	101	101	101	101	1406

Panel A2: 1 Month Short ATM Call Margin Excess Returns

	Mean	**StdDev**	**Min**	**1%**	**2%**	**3%**	**4%**	**5%**	**25%**	**50%**	**75%**	**95%**	**96%**	**97%**	**98%**	**99%**	**Max**	**n**
Mean	-1.2	29	-195	-101	-83	-72	-64	-58	-12	9	19	24	24	25	25	26	36	755
StdDev	12	9	76	34	31	30	29	28	20	11	3	2	2	2	1	1	27	202
Min	-32	5	-557	-206	-182	-166	-148	-138	-64	-28	-1	19	20	20	21	22	25	261
1%	-29	9	-474	-195	-150	-133	-119	-108	-56	-24	6	20	20	21	21	22	26	311
2%	-26	10	-366	-169	-140	-128	-118	-107	-50	-20	10	20	21	21	22	23	26	329
3%	-24	11	-355	-158	-134	-122	-115	-102	-49	-17	10	20	21	22	22	23	26	344
4%	-23	12	-324	-156	-132	-117	-109	-100	-48	-16	13	21	21	22	23	24	26	348
5%	-21	14	-308	-154	-130	-117	-107	-99	-44	-13	14	21	21	22	23	24	26	367
25%	-9	23	-233	-125	-104	-92	-84	-79	-26	2	17	22	23	23	24	25	28	617
50%	-0	29	-187	-99	-81	-72	-66	-61	-11	15	19	24	24	25	26	26	29	749
75%	8	36	-148	-82	-64	-51	-45	-39	7	17	21	25	25	26	26	27	31	895
95%	15	42	-87	-46	-32	-21	-17	-12	17	19	22	26	26	27	27	28	100	1072
96%	16	44	-85	-39	-27	-15	-10	-5	17	19	22	26	26	27	27	28	100	1079
97%	16	45	-81	-31	-17	-10	-5	-1	17	20	23	26	26	27	27	28	100	1094
98%	17	45	-76	-26	-14	-3	2	6	17	20	23	26	27	27	28	28	100	1112
99%	18	49	-63	-24	-9	1	8	12	17	20	23	26	27	27	28	29	123	1122
Max	19	54	-11	8	11	12	12	13	18	20	24	27	27	28	28	29	279	1406

Panel A3: 2 Month Short ATM Call Price Excess Returns

	Mean	**StdDev**	**Min**	**1%**	**2%**	**3%**	**4%**	**5%**	**25%**	**50%**	**75%**	**95%**	**96%**	**97%**	**98%**	**99%**	**Max**	**n**
Mean	-5.8	154.8	-1187	-559	-449	-384	-339	-306	-54	58	97	101	101	101	101	101	101	1064
StdDev	64	58	647	244	209	187	175	167	111	63	18	0	0	0	0	0	0	276
Min	-194	13.7	-5013	-1730	-1338	-1173	-1092	-990	-345	-167	-42	100	100	100	100	100	100	242
1%	-162	38.0	-3718	-1555	-1275	-1003	-843	-758	-287	-128	21	100	100	100	100	100	100	278
2%	-156	51.1	-3347	-1055	-882	-750	-682	-618	-279	-120	31	100	100	100	100	100	100	292
3%	-149	56.0	-2666	-991	-785	-708	-640	-595	-263	-117	42	100	100	100	100	100	100	303
4%	-137	67.8	-2388	-965	-773	-657	-628	-590	-252	-92	44	100	100	100	100	100	100	314
5%	-121	72.6	-2297	-947	-748	-641	-591	-542	-241	-75	74	100	100	100	100	100	100	324
25%	-48	120.7	-1376	-673	-560	-489	-446	-412	-133	27	100	100	100	100	100	100	100	950
50%	0	155.4	-1026	-546	-456	-399	-345	-311	-58	100	101	101	101	101	101	101	101	1086
75%	41	185.4	-806	-425	-324	-273	-240	-208	46	101	101	101	101	101	101	101	101	1226
95%	78	238.9	-565	-238	-156	-125	-93	-66	101	101	101	101	101	101	101	101	101	1456
96%	80	240.3	-554	-222	-141	-116	-71	-50	101	101	101	101	101	101	101	101	101	1460
97%	88	255.7	-510	-183	-89	-28	-3	26	101	101	101	101	101	101	101	101	101	1512
98%	93	270.4	-455	-143	-34	10	31	66	101	101	101	101	101	101	101	101	101	1547
99%	95	381.6	-329	-47	20	74	100	100	101	101	101	101	101	101	101	101	101	1570
Max	100	409.0	-125	101	101	101	101	101	101	101	101	101	101	101	101	101	101	1716

Panel A4: 2 Month Short ATM Call Margin Excess Returns

	Mean	**StdDev**	**Min**	**1%**	**2%**	**3%**	**4%**	**5%**	**25%**	**50%**	**75%**	**95%**	**96%**	**97%**	**98%**	**99%**	**Max**	**n**
Mean	-1.2	28	-194	-97	-78	-68	-61	-55	-11	9	17	22	22	23	23	24	78	1064
StdDev	11	10	92	38	33	31	29	28	19	11	4	2	2	2	2	2	222	276
Min	-36	5	-688	-260	-201	-181	-167	-151	-64	-33	-8	17	18	18	19	20	22	242
1%	-30	7	-539	-226	-184	-146	-129	-120	-54	-25	3	17	18	19	19	21	23	278
2%	-29	10	-507	-169	-146	-131	-121	-111	-53	-22	6	18	19	19	20	21	24	292
3%	-26	11	-448	-167	-142	-126	-113	-107	-48	-21	7	18	19	19	20	21	24	303
4%	-23	12	-409	-163	-135	-122	-111	-102	-44	-18	8	18	19	20	20	21	25	314
5%	-22	12	-379	-159	-124	-114	-105	-100	-43	-14	11	19	19	20	20	22	25	324
25%	-7	21	-224	-117	-98	-89	-81	-75	-24	5	16	21	21	22	22	24	26	950
50%	-0	28	-176	-96	-80	-70	-64	-58	-10	13	17	22	22	23	24	25	28	1086
75%	7	34	-143	-74	-56	-49	-43	-39	8	16	19	23	24	24	25	26	32	1226
95%	14	43	-97	-41	-29	-22	-17	-13	15	18	21	24	25	25	26	26	128	1456
96%	15	44	-92	-36	-27	-21	-12	-10	15	18	21	24	25	25	26	27	276	1460
97%	15	46	-82	-33	-16	-5	0	5	15	18	21	25	25	25	26	27	432	1512
98%	17	57	-76	-25	-7	2	6	10	15	18	21	25	25	26	26	27	656	1547
99%	17	61	-62	-9	1	8	10	11	16	19	21	25	25	26	26	27	1032	1570
Max	18	67	-29	6	10	11	12	12	16	19	22	25	25	26	26	27	1965	1716

Panel A5: 3 Month Short ATM Call Price Excess Returns

	Mean	**StdDev**	**Min**	**1%**	**2%**	**3%**	**4%**	**5%**	**25%**	**50%**	**75%**	**95%**	**96%**	**97%**	**98%**	**99%**	**Max**	**n**
Mean	-7.5	163.7	-1087	-594	-474	-406	-359	-321	-54	61	98	101	101	101	101	101	101	440
StdDev	67	72	655	321	263	234	213	196	114	63	14	0	0	0	0	0	0	158
Min	-233	22.0	-5039	-2976	-2175	-1765	-1491	-1237	-374	-199	-12	100	100	100	100	100	100	154
1%	-181	30.3	-3179	-1621	-1353	-1171	-1075	-947	-315	-125	18	100	100	100	100	100	100	163
2%	-161	39.7	-2882	-1322	-1084	-938	-813	-731	-281	-115	47	100	100	100	100	100	100	185
3%	-150	42.0	-2691	-1256	-979	-831	-710	-673	-267	-78	66	100	100	100	100	100	100	195
4%	-139	63.0	-2627	-1082	-832	-749	-689	-648	-252	-72	68	100	100	100	100	100	100	218
5%	-130	69.5	-2477	-978	-824	-731	-641	-587	-239	-66	85	100	100	100	100	100	100	232
25%	-49	120.7	-1260	-702	-588	-519	-470	-426	-139	42	100	100	100	100	100	100	100	340
50%	7	157.8	-926	-547	-438	-373	-332	-302	-49	100	101	101	101	101	101	101	101	417
75%	38	193.5	-693	-413	-341	-281	-248	-224	38	101	101	101	101	101	101	101	101	508
95%	83	268.4	-405	-240	-146	-100	-64	-33	101	102	102	102	102	102	102	102	102	709
96%	87	281.7	-397	-229	-114	-42	9	38	101	102	102	102	102	102	102	102	102	714
97%	92	311.5	-390	-143	-63	-11	25	46	101	102	102	102	102	102	102	102	102	720
98%	93	335.1	-296	-106	-26	19	48	77	101	102	102	102	102	102	102	102	102	793
99%	97	404.7	-254	-33	46	96	101	101	101	102	102	102	102	102	102	102	102	998
Max	98	590.6	-189	-13	81	101	101	101	101	102	102	102	102	102	102	102	102	1229

Panel A6: 3 Month Short ATM Call Margin Excess Returns

	Mean	**StdDev**	**Min**	**1%**	**2%**	**3%**	**4%**	**5%**	**25%**	**50%**	**75%**	**95%**	**96%**	**97%**	**98%**	**99%**	**Max**	**n**
Mean	-1.2	36	-167	-95	-78	-67	-60	-54	-10	8	16	21	21	22	22	23	282	440
StdDev	12	117	91	43	39	34	32	30	18	10	3	2	2	2	2	2	3214	158
Min	-37	5	-663	-368	-314	-234	-199	-174	-65	-31	-2	16	16	17	17	19	20	154
1%	-28	7	-581	-219	-193	-167	-144	-131	-51	-20	3	16	17	17	18	19	21	163
2%	-25	8	-412	-196	-158	-135	-125	-114	-47	-19	6	17	17	17	18	20	22	185
3%	-22	9	-355	-174	-144	-132	-119	-107	-44	-14	9	17	17	18	19	20	22	195
4%	-22	10	-350	-159	-139	-127	-114	-104	-43	-12	11	17	18	18	19	20	22	218
5%	-21	12	-340	-155	-137	-116	-106	-100	-42	-12	12	17	18	19	19	20	22	232
25%	-9	20	-189	-115	-96	-88	-79	-73	-25	7	15	19	20	21	21	22	24	340
50%	0	26	-147	-91	-74	-63	-56	-51	-8	12	16	21	21	22	22	23	26	417
75%	6	33	-112	-71	-58	-49	-44	-38	6	15	18	22	23	23	24	25	28	508
95%	14	43	-70	-36	-24	-18	-10	-6	14	16	19	23	24	24	25	26	101	709
96%	15	45	-66	-33	-20	-8	2	6	14	17	20	23	24	24	25	26	101	714
97%	15	46	-59	-23	-12	-2	5	8	14	17	20	24	24	24	25	26	103	720
98%	16	51	-55	-16	-5	3	6	8	14	17	20	24	24	24	25	26	143	793
99%	16	70	-45	-6	6	7	8	9	15	18	20	24	24	25	25	26	349	998
Max	73	1571	-25	-2	8	9	10	10	15	18	21	24	25	25	26	27	42546	1229

Panel A7: 6 Month Short ATM Call Price Excess Returns

	Mean	**StdDev**	**Min**	**1%**	**2%**	**3%**	**4%**	**5%**	**25%**	**50%**	**75%**	**95%**	**96%**	**97%**	**98%**	**99%**	**Max**	**n**
Mean	-14.2	191.0	-1433	-727	-567	-482	-421	-374	-55	67	98	102	102	102	102	102	102	528
StdDev	72	91	913	453	328	292	256	228	120	64	16	1	1	1	1	1	1	186
Min	-250	18.0	-6353	-4007	-2637	-2359	-1849	-1438	-389	-164	2	100	100	100	100	100	100	164
1%	-213	35.3	-4982	-2594	-1741	-1433	-1215	-1088	-380	-143	22	100	100	100	100	100	100	176
2%	-191	47.6	-4309	-1979	-1348	-1176	-993	-898	-329	-124	30	100	100	100	100	100	100	212
3%	-187	52.5	-3829	-1574	-1261	-992	-860	-795	-325	-116	38	100	100	100	100	100	100	234
4%	-175	58.4	-3630	-1423	-1128	-958	-814	-733	-305	-113	51	100	100	100	100	100	100	256
5%	-168	67.5	-3255	-1322	-1029	-858	-771	-726	-288	-105	70	100	100	100	100	100	100	293
25%	-49	140.1	-1622	-867	-699	-603	-548	-496	-132	63	101	101	101	101	101	101	101	418
50%	1	182.4	-1240	-646	-536	-466	-403	-362	-42	101	102	102	102	102	102	102	102	476
75%	38	226.2	-874	-500	-398	-337	-287	-245	47	103	103	103	103	103	103	103	103	612
95%	86	329.7	-555	-212	-104	-69	-23	3	102	103	103	103	103	103	103	103	103	852
96%	90	351.9	-528	-173	-66	-23	7	30	102	103	103	103	103	103	103	103	103	856
97%	91	372.7	-523	-141	-65	-12	16	47	102	103	103	103	103	103	103	103	103	892
98%	93	433.9	-459	-115	-38	19	63	82	103	103	103	103	103	103	103	103	103	999
99%	96	562.4	-369	-52	8	80	99	101	103	103	103	103	103	103	103	103	103	1214
Max	99	721.6	-158	19	85	102	102	102	103	104	104	104	104	104	104	104	104	1347

Panel A8: 6 Month Short ATM Call Margin Excess Returns

	Mean	**StdDev**	**Min**	**1%**	**2%**	**3%**	**4%**	**5%**	**25%**	**50%**	**75%**	**95%**	**96%**	**97%**	**98%**	**99%**	**Max**	**n**
Mean	-2.3	28	-186	-100	-81	-69	-61	-55	-9	8	14	19	19	20	20	21	83	528
StdDev	10	13	91	50	40	36	32	30	17	8	3	2	2	2	2	2	386	186
Min	-33	5	-571	-401	-296	-247	-196	-174	-60	-24	0	12	12	13	14	15	17	164
1%	-30	7	-448	-255	-196	-164	-145	-133	-51	-20	3	13	13	14	14	16	18	176
2%	-26	8	-442	-223	-157	-138	-125	-114	-50	-19	4	14	14	15	15	16	19	212
3%	-25	8	-437	-204	-151	-130	-116	-106	-49	-18	5	14	14	15	16	17	19	234
4%	-24	10	-385	-183	-147	-121	-108	-101	-42	-16	7	15	15	15	16	17	20	256
5%	-23	11	-370	-167	-144	-118	-106	-100	-40	-13	8	15	15	16	16	17	20	293
25%	-8	20	-220	-122	-103	-90	-79	-73	-21	7	13	17	18	18	19	20	23	418
50%	-0	27	-166	-94	-77	-68	-61	-55	-6	10	15	19	20	20	20	22	25	476
75%	4	34	-129	-71	-58	-48	-43	-35	6	12	16	20	21	21	22	23	29	612
95%	12	44	-73	-26	-12	-10	-4	1	11	15	18	22	22	22	23	24	130	852
96%	13	46	-69	-24	-10	-4	1	4	12	15	18	22	22	23	24	24	211	856
97%	13	51	-64	-21	-9	-2	2	5	12	15	18	22	22	23	24	25	321	892
98%	13	53	-58	-14	-4	1	4	6	12	15	18	22	23	23	24	25	419	999
99%	14	71	-43	-9	1	5	6	7	12	16	19	23	23	24	25	25	837	1214
Max	17	134	-24	2	5	6	7	7	13	17	19	23	23	24	25	26	4912	1347

Panel B1: 1 Month Short OTM Call Price Excess Returns

	Mean	**StdDev**	**Min**	**1%**	**2%**	**3%**	**4%**	**5%**	**25%**	**50%**	**75%**	**95%**	**96%**	**97%**	**98%**	**99%**	**Max**	**n**
Mean	4.6	295	-2755	-1254	-889	-695	-550	-451	62	100	100	100	100	100	100	100	100	442
StdDev	83	157	1588	744	611	554	502	467	112	0	0	0	0	0	0	0	0	193
Min	-424	0	-9814	-3915	-3347	-2966	-2426	-2232	-679	100	100	100	100	100	100	100	100	147
1%	-249	30	-8486	-3322	-2419	-1905	-1703	-1586	-415	100	100	100	100	100	100	100	100	151
2%	-192	33	-7346	-2896	-2185	-1771	-1571	-1432	-304	100	100	100	100	100	100	100	100	167
3%	-175	47	-6144	-2606	-2013	-1727	-1528	-1379	-298	100	100	100	100	100	100	100	100	173
4%	-171	55	-5199	-2511	-1960	-1647	-1480	-1318	-218	100	100	100	100	100	100	100	100	181
5%	-155	74	-5194	-2456	-1909	-1595	-1420	-1267	-200	100	100	100	100	100	100	100	100	188
25%	-36	186	-3576	-1730	-1269	-1063	-902	-785	100	100	100	100	100	100	100	100	100	282
50%	28	271	-2400	-1200	-852	-649	-513	-416	100	100	100	100	100	100	100	100	100	423
75%	71	402	-1733	-775	-474	-227	-92	27	100	100	100	100	100	100	100	100	100	570
95%	91	560	-851	-158	71	100	100	100	100	100	100	100	100	100	100	100	100	772
96%	95	576	-737	38	100	100	100	100	100	100	100	100	100	100	100	100	100	801
97%	97	608	-601	100	100	100	100	100	100	100	100	100	100	100	100	100	100	814
98%	98	647	-437	100	100	100	100	100	101	101	101	101	101	101	101	101	101	820
99%	98	687	-332	100	100	100	100	100	101	101	101	101	101	101	101	101	101	833
Max	100	911	100	100	100	100	100	100	101	101	101	101	101	101	101	101	101	1126

Panel B2: 1 Month Short OTM Call Margin Excess Returns

	Mean	**StdDev**	**Min**	**1%**	**2%**	**3%**	**4%**	**5%**	**25%**	**50%**	**75%**	**95%**	**96%**	**97%**	**98%**	**99%**	**Max**	**n**
Mean	1.0	38	-350	-96	-70	-55	-45	-37	3	7	9	12	12	13	15	23	265	442
StdDev	7	83	1546	54	47	43	39	36	8	1	1	2	2	3	6	20	817	193
Min	-41	3	-20612	-264	-242	-232	-193	-179	-54	5	7	9	9	9	9	10	12	147
1%	-24	4	-1592	-243	-198	-159	-132	-118	-31	5	7	9	9	9	10	10	16	151
2%	-18	5	-895	-221	-172	-139	-123	-113	-24	6	7	9	9	10	10	10	17	167
3%	-14	7	-742	-204	-156	-137	-117	-107	-22	6	7	9	10	10	10	11	18	173
4%	-13	7	-527	-196	-150	-130	-114	-104	-17	6	7	10	10	10	10	11	19	181
5%	-12	8	-463	-179	-148	-128	-112	-103	-15	6	8	10	10	10	10	11	19	188
25%	-2	17	-292	-132	-101	-84	-74	-64	5	7	8	10	11	11	12	13	37	282
50%	3	24	-188	-90	-66	-52	-42	-35	6	7	9	11	12	12	13	17	100	423
75%	6	34	-130	-64	-37	-19	-8	2	6	8	9	13	14	15	17	23	150	570
95%	9	95	-65	-13	3	4	5	5	7	9	10	15	16	18	25	61	687	772
96%	9	134	-55	2	4	4	5	5	7	9	10	15	16	19	27	66	1104	801
97%	10	144	-46	3	4	5	5	5	7	9	10	16	17	20	28	70	1821	814
98%	11	155	-38	4	4	5	5	5	7	9	10	16	17	23	30	81	3406	820
99%	12	263	-32	4	4	5	5	5	7	9	11	18	21	26	35	95	3702	833
Max	25	1003	2	4	5	5	5	6	8	9	11	19	26	30	51	187	8114	1126

Panel B3: 2 Month Short OTM Call Price Excess Returns

	Mean	**StdDev**	**Min**	**1%**	**2%**	**3%**	**4%**	**5%**	**25%**	**50%**	**75%**	**95%**	**96%**	**97%**	**98%**	**99%**	**Max**	**n**
Mean	-0.4	307.0	-3346	-1287	-917	-719	-585	-478	57	100	101	101	101	101	101	101	101	701
StdDev	85	164	2008	748	614	552	503	458	117	9	0	0	0	0	0	0	0	229
Min	-291	0.0	-12394	-4263	-3031	-2562	-2258	-2006	-499	-22	100	100	100	100	100	100	100	134
1%	-266	32.9	-11954	-3331	-2544	-2080	-1825	-1649	-433	100	100	100	100	100	100	100	100	142
2%	-252	60.7	-10122	-2919	-2176	-1857	-1627	-1490	-397	100	100	100	100	100	100	100	100	154
3%	-238	71.9	-7994	-2835	-2119	-1802	-1570	-1432	-358	100	100	100	100	100	100	100	100	165
4%	-201	74.3	-7259	-2725	-2010	-1791	-1447	-1316	-267	100	100	100	100	100	100	100	100	183
5%	-159	79.0	-6367	-2594	-1964	-1649	-1392	-1170	-231	100	100	100	100	100	100	100	100	214
25%	-43	186.6	-4299	-1702	-1322	-1097	-954	-779	100	100	100	100	100	100	100	100	100	587
50%	16	292.9	-2925	-1249	-935	-758	-595	-477	100	101	101	101	101	101	101	101	101	688
75%	64	403.6	-2079	-776	-456	-310	-199	-95	101	101	101	101	101	101	101	101	101	828
95%	91	554.4	-986	-206	33	100	101	101	101	101	101	101	101	101	101	101	101	1096
96%	93	623.9	-966	-150	67	101	101	101	101	101	101	101	101	101	101	101	101	1121
97%	94	635.5	-933	62	100	101	101	101	101	101	101	101	101	101	101	101	101	1134
98%	96	678.1	-868	100	101	101	101	101	101	101	101	101	101	101	101	101	101	1154
99%	97	808.8	-448	101	101	101	101	101	101	101	101	101	101	101	101	101	101	1169
Max	101	955.7	101	101	101	101	101	101	101	101	101	101	101	101	101	101	101	1269

Panel B4: 2 Month Short OTM Call Margin Excess Returns

	Mean	**StdDev**	**Min**	**1%**	**2%**	**3%**	**4%**	**5%**	**25%**	**50%**	**75%**	**95%**	**96%**	**97%**	**98%**	**99%**	**Max**	**n**
Mean	0.1	24	-226	-93	-68	-54	-44	-37	3	7	8	10	10	11	11	12	103	701
StdDev	6	19	136	53	44	40	36	33	8	1	1	1	1	1	1	2	433	229
Min	-24	2	-958	-315	-222	-197	-180	-145	-41	-2	6	8	8	8	8	9	10	134
1%	-18	4	-712	-230	-186	-152	-124	-117	-33	5	6	8	8	9	9	9	11	142
2%	-18	4	-627	-212	-158	-136	-120	-109	-30	5	7	8	8	9	9	9	12	154
3%	-16	5	-603	-205	-156	-130	-113	-99	-26	5	7	9	9	9	9	10	12	165
4%	-15	6	-511	-196	-151	-120	-106	-96	-19	5	7	9	9	9	9	10	12	183
5%	-12	6	-466	-185	-137	-116	-104	-96	-18	5	7	9	9	9	10	10	12	214
25%	-3	14	-269	-120	-95	-79	-71	-58	5	6	8	10	10	10	10	11	18	587
50%	2	21	-197	-92	-69	-55	-45	-37	5	7	8	10	10	11	11	12	32	688
75%	5	29	-139	-56	-35	-24	-15	-9	6	7	9	11	11	11	12	13	101	828
95%	7	44	-88	-15	3	4	4	4	7	8	9	12	12	12	13	16	158	1096
96%	7	48	-72	-12	3	4	4	5	7	8	9	12	12	13	14	16	203	1121
97%	7	51	-60	1	3	4	4	5	7	8	9	12	12	13	14	17	226	1134
98%	8	56	-54	3	4	4	5	5	7	8	10	12	13	13	15	17	339	1154
99%	8	69	-36	4	4	5	5	5	7	8	10	12	13	14	15	19	1100	1169
Max	9	211	4	5	5	5	6	6	7	8	10	13	14	15	16	20	5387	1269

Panel B5: 3 Month Short OTM Call Price Excess Returns

	Mean	**StdDev**	**Min**	**1%**	**2%**	**3%**	**4%**	**5%**	**25%**	**50%**	**75%**	**95%**	**96%**	**97%**	**98%**	**99%**	**Max**	**n**
Mean	-4.6	320.2	-2856	-1356	-968	-756	-613	-509	55	100	101	101	101	101	101	101	101	338
StdDev	95	214	2313	970	736	630	558	512	118	11	0	0	0	0	0	0	0	151
Min	-425	0.0	-18859	-7548	-4426	-3919	-3237	-2900	-662	-50	100	100	100	100	100	100	100	73
1%	-303	0.0	-11182	-4225	-3247	-2563	-2058	-1733	-403	100	100	100	100	100	100	100	100	97
2%	-256	1.7	-8467	-3642	-2657	-2137	-1798	-1607	-363	100	100	100	100	100	100	100	100	119
3%	-241	30.3	-7340	-3142	-2365	-1878	-1647	-1461	-330	100	100	100	100	100	100	100	100	131
4%	-199	50.4	-6781	-2859	-2238	-1737	-1567	-1424	-266	100	100	100	100	100	100	100	100	145
5%	-180	72.7	-6197	-2713	-2166	-1714	-1490	-1369	-187	100	100	100	100	100	100	100	100	152
25%	-56	177.7	-3582	-1909	-1427	-1146	-995	-880	100	100	100	100	100	100	100	100	100	250
50%	27	286.6	-2392	-1179	-875	-687	-511	-415	101	101	101	101	101	101	101	101	101	308
75%	65	411.8	-1536	-719	-481	-329	-188	-82	101	101	101	101	101	101	101	101	101	399
95%	92	634.5	-598	-111	88	100	101	101	102	102	102	102	102	102	102	102	102	599
96%	93	662.0	-547	93	100	101	101	101	102	102	102	102	102	102	102	102	102	627
97%	98	720.0	-327	100	101	101	101	101	102	102	102	102	102	102	102	102	102	636
98%	100	801.0	70	101	101	101	101	101	102	102	102	102	102	102	102	102	102	640
99%	101	1019.1	101	101	101	101	101	101	102	102	102	102	102	102	102	102	102	869
Max	101	1642.0	101	101	101	101	101	101	102	102	102	102	102	102	102	102	102	1162

Panel B6: 3 Month Short OTM Call Margin Excess Returns

	Mean	**StdDev**	**Min**	**1%**	**2%**	**3%**	**4%**	**5%**	**25%**	**50%**	**75%**	**95%**	**96%**	**97%**	**98%**	**99%**	**Max**	**n**
Mean	-0.2	23	-181	-92	-67	-53	-44	-36	2	6	8	10	10	10	11	12	68	338
StdDev	6	15	141	66	47	42	37	34	8	1	1	1	1	1	1	2	260	151
Min	-27	2	-1093	-563	-261	-210	-165	-147	-52	-3	5	7	7	8	8	8	9	73
1%	-19	2	-773	-300	-205	-163	-138	-121	-26	4	6	7	8	8	8	8	10	97
2%	-15	3	-615	-222	-168	-147	-128	-113	-23	4	6	7	8	8	8	9	10	119
3%	-14	4	-454	-198	-161	-144	-119	-102	-21	4	6	8	8	8	9	9	11	131
4%	-12	4	-452	-192	-153	-134	-112	-98	-17	5	6	8	8	8	9	9	11	145
5%	-12	5	-391	-188	-148	-127	-111	-97	-15	5	6	8	8	8	9	9	11	152
25%	-4	12	-213	-122	-95	-80	-67	-59	4	6	7	9	9	10	10	10	13	250
50%	2	20	-149	-81	-60	-47	-38	-31	5	6	8	10	10	10	10	11	17	308
75%	4	29	-111	-49	-33	-22	-14	-6	5	7	8	10	10	11	11	12	67	399
95%	6	44	-39	-7	2	3	4	4	6	7	9	11	12	12	13	16	117	599
96%	6	46	-32	2	3	3	4	4	6	8	9	12	12	12	14	16	134	627
97%	7	48	-26	3	3	4	4	4	6	8	9	12	12	13	14	17	145	636
98%	7	73	1	3	3	4	4	4	6	8	9	12	12	13	14	19	173	640
99%	7	82	2	3	4	4	5	5	7	8	9	12	12	13	14	21	747	869
Max	8	110	3	3	4	4	5	5	7	8	10	12	13	13	17	25	2683	1162

Panel B7: 6 Month Short OTM Call Price Excess Returns

	Mean	**StdDev**	**Min**	**1%**	**2%**	**3%**	**4%**	**5%**	**25%**	**50%**	**75%**	**95%**	**96%**	**97%**	**98%**	**99%**	**Max**	**n**
Mean	-20.5	384.1	-3482	-1612	-1120	-868	-697	-571	49	102	102	102	102	102	102	102	102	323
StdDev	103	242	2537	1162	812	652	574	521	146	1	1	1	1	1	1	1	1	198
Min	-467	0.0	-13687	-6586	-4260	-2828	-2582	-2244	-707	100	100	100	100	100	100	100	100	36
1%	-355	7.7	-11710	-5610	-3755	-2614	-2250	-2137	-583	100	100	100	100	100	100	100	100	53
2%	-306	26.4	-10875	-4868	-3060	-2515	-2040	-1724	-468	100	100	100	100	100	100	100	100	61
3%	-279	44.1	-10164	-4740	-2926	-2275	-1924	-1705	-402	100	100	100	100	100	100	100	100	69
4%	-251	63.5	-9700	-4216	-2688	-2254	-1779	-1634	-325	100	100	100	100	100	100	100	100	77
5%	-235	70.5	-9470	-3511	-2624	-2026	-1712	-1471	-311	100	100	100	100	100	100	100	100	84
25%	-73	223.3	-4319	-2085	-1545	-1293	-1052	-911	100	101	101	101	101	101	101	101	101	179
50%	11	332.5	-2746	-1443	-1018	-819	-634	-473	102	102	102	102	102	102	102	102	102	286
75%	52	488.4	-1857	-910	-603	-439	-294	-186	103	103	103	103	103	103	103	103	103	411
95%	92	843.1	-751	82	101	101	101	102	103	103	103	103	103	103	103	103	103	660
96%	97	937.7	-677	94	101	101	101	102	103	103	103	103	103	103	103	103	103	666
97%	99	968.3	-567	101	101	101	102	102	103	103	103	103	103	103	103	103	103	672
98%	99	1075.8	-388	101	102	102	102	102	103	103	103	103	103	103	103	103	103	820
99%	101	1113.1	-10	102	102	102	102	103	103	103	103	103	103	103	103	103	103	1072
Max	102	1539.6	100	102	103	103	103	103	104	104	104	104	104	104	104	104	104	1191

Panel B8: 6 Month Short OTM Call Margin Excess Returns

	Mean	**StdDev**	**Min**	**1%**	**2%**	**3%**	**4%**	**5%**	**25%**	**50%**	**75%**	**95%**	**96%**	**97%**	**98%**	**99%**	**Max**	**n**
Mean	-1.3	24	-200	-98	-71	-56	-45	-37	1	6	7	9	9	9	10	11	47	323
StdDev	6	14	151	63	48	39	34	32	9	1	1	1	1	1	1	5	84	198
Min	-33	2	-1292	-351	-268	-181	-176	-172	-51	3	4	6	6	6	7	7	8	36
1%	-18	3	-710	-317	-219	-151	-113	-104	-34	3	4	6	6	7	7	7	9	53
2%	-16	3	-647	-302	-187	-126	-110	-98	-28	3	5	6	6	7	7	8	9	61
3%	-16	4	-545	-251	-158	-123	-109	-95	-24	4	5	6	7	7	7	8	9	69
4%	-15	4	-480	-203	-147	-120	-107	-93	-23	4	5	7	7	7	8	8	10	77
5%	-13	5	-424	-196	-145	-117	-103	-92	-22	4	5	7	7	7	8	8	10	84
25%	-5	14	-247	-128	-100	-85	-69	-59	3	5	7	8	9	9	9	10	12	179
50%	1	23	-164	-91	-68	-53	-38	-30	4	6	7	9	9	10	10	10	15	286
75%	3	32	-117	-58	-39	-27	-18	-10	5	6	8	10	10	10	11	11	51	411
95%	6	49	-47	2	2	3	3	3	6	7	9	11	11	11	12	14	104	660
96%	6	53	-39	2	3	3	3	3	6	7	9	11	11	11	12	14	117	666
97%	6	57	-36	2	3	3	3	3	6	7	9	11	11	11	12	15	198	672
98%	6	58	-25	2	3	3	3	3	6	7	9	11	11	11	12	17	239	820
99%	6	64	-3	2	3	3	3	4	6	7	9	11	11	12	12	25	458	1072
Max	6	79	1	3	4	4	4	5	6	8	10	12	12	12	13	73	755	1191

Panel C1: 1 Month Short ATM Put Price Excess Returns

	Mean	**StdDev**	**Min**	**1%**	**2%**	**3%**	**4%**	**5%**	**25%**	**50%**	**75%**	**95%**	**96%**	**97%**	**98%**	**99%**	**Max**	**n**
Mean	11.4	118	-942	-386	-308	-264	-233	-210	-28	54	90	99	100	100	100	100	100	762
StdDev	68	40	677	155	138	131	128	125	107	76	38	9	8	6	4	1	0	202
Min	-349	44	-4377	-922	-861	-785	-744	-725	-484	-332	-208	-12	-2	18	44	92	100	261
1%	-252	50	-4076	-910	-752	-681	-635	-593	-364	-236	-106	94	100	100	100	100	100	311
2%	-183	54	-3473	-787	-677	-627	-580	-559	-305	-168	-37	100	100	100	100	100	100	329
3%	-158	59	-2775	-748	-647	-577	-533	-487	-265	-146	-25	100	100	100	100	100	100	344
4%	-131	60	-2577	-693	-588	-520	-476	-457	-246	-116	17	100	100	100	100	100	100	348
5%	-110	62	-2095	-656	-550	-480	-457	-430	-222	-79	36	100	100	100	100	100	100	367
25%	-15	89	-1060	-468	-372	-325	-295	-270	-84	24	100	100	100	100	100	100	100	632
50%	32	115	-732	-363	-298	-241	-206	-187	-7	100	100	100	100	100	100	100	100	758
75%	58	142	-589	-279	-212	-170	-142	-122	56	100	100	100	100	100	100	100	100	900
95%	77	201	-403	-162	-120	-94	-72	-53	100	100	100	100	100	100	100	100	100	1075
96%	78	208	-391	-157	-114	-86	-64	-52	100	100	100	100	100	100	100	100	100	1079
97%	81	210	-373	-149	-100	-74	-50	-34	100	100	100	100	100	100	100	100	100	1095
98%	82	213	-338	-139	-90	-54	-37	-23	100	100	101	101	101	101	101	101	101	1123
99%	86	214	-302	-135	-84	-51	-16	0	100	101	101	101	101	101	101	101	101	1130
Max	88	249	-200	-107	-76	-31	0	29	100	101	101	101	101	101	101	101	101	1403

Panel C2: 1 Month Short ATM Put Margin Excess Returns

	Mean	**StdDev**	**Min**	**1%**	**2%**	**3%**	**4%**	**5%**	**25%**	**50%**	**75%**	**95%**	**96%**	**97%**	**98%**	**99%**	**Max**	**n**
Mean	2.4	25	-174	-80	-64	-55	-49	-44	-7	10	19	26	26	27	28	30	39	762
StdDev	14	8	113	29	27	26	26	25	22	15	9	4	4	4	4	4	9	202
Min	-74	10	-754	-180	-163	-153	-145	-139	-102	-74	-48	-3	-0	4	10	21	27	261
1%	-51	11	-690	-166	-140	-131	-125	-119	-76	-52	-23	17	18	21	22	24	29	311
2%	-40	12	-620	-149	-131	-124	-117	-111	-66	-40	-9	20	21	22	23	24	29	329
3%	-34	13	-542	-139	-129	-116	-111	-105	-58	-31	-6	20	21	23	23	24	29	344
4%	-24	13	-451	-137	-121	-105	-99	-97	-47	-22	3	22	22	23	24	25	30	348
5%	-22	14	-325	-137	-112	-103	-95	-90	-45	-17	8	22	22	23	24	25	30	367
25%	-3	19	-187	-96	-79	-71	-63	-59	-19	5	19	24	24	25	26	27	33	632
50%	6	23	-147	-77	-60	-52	-46	-40	-2	16	20	25	26	26	27	29	37	758
75%	12	30	-112	-60	-45	-35	-31	-26	12	18	22	28	28	29	30	32	42	900
95%	17	40	-77	-39	-26	-21	-16	-12	16	21	25	32	32	34	35	38	59	1075
96%	17	41	-77	-35	-26	-20	-15	-11	16	21	25	33	33	34	36	38	59	1079
97%	17	41	-68	-33	-23	-19	-12	-7	17	21	26	33	34	35	36	39	60	1095
98%	18	42	-67	-31	-20	-14	-8	-5	17	22	26	34	35	36	38	40	61	1123
99%	19	42	-56	-30	-18	-11	-4	0	18	22	27	36	36	37	39	43	64	1130
Max	19	46	-48	-26	-16	-9	0	5	18	23	28	39	40	42	43	46	76	1403

Panel C3: 2 Month Short ATM Put Price Excess Returns

	Mean	**StdDev**	**Min**	**1%**	**2%**	**3%**	**4%**	**5%**	**25%**	**50%**	**75%**	**95%**	**96%**	**97%**	**98%**	**99%**	**Max**	**n**
Mean	11.7	111.8	-873	-349	-285	-246	-220	-199	-33	52	90	99	100	100	100	100	101	1068
StdDev	66	39	601	141	130	124	121	119	100	75	40	12	10	8	5	1	0	277
Min	-352	33.0	-5585	-857	-792	-750	-728	-691	-472	-337	-223	-45	-29	2	37	82	100	242
1%	-243	44.4	-3013	-759	-678	-629	-605	-584	-356	-238	-113	55	82	96	100	100	100	278
2%	-185	47.4	-2620	-725	-633	-569	-536	-506	-283	-175	-63	100	100	100	100	100	100	292
3%	-116	52.2	-2263	-701	-566	-508	-471	-445	-221	-99	12	100	100	100	100	100	100	303
4%	-101	52.4	-1917	-634	-530	-473	-445	-412	-199	-83	39	100	100	100	100	100	100	314
5%	-90	54.0	-1763	-602	-504	-452	-419	-395	-192	-73	42	100	100	100	100	100	100	324
25%	-16	86.5	-1010	-413	-359	-307	-282	-264	-89	23	100	100	100	100	100	100	100	952
50%	29	109.8	-701	-330	-263	-228	-202	-181	-21	98	100	101	101	101	101	101	101	1089
75%	55	135.2	-555	-265	-214	-165	-144	-126	36	101	101	101	101	101	101	101	101	1237
95%	79	167.1	-362	-143	-103	-79	-60	-37	100	101	101	101	101	101	101	101	101	1460
96%	82	181.4	-356	-130	-99	-68	-51	-36	100	101	101	101	101	101	101	101	101	1467
97%	83	194.4	-350	-122	-90	-64	-42	-18	100	101	101	101	101	101	101	101	101	1518
98%	86	200.1	-311	-117	-72	-43	-23	-3	100	101	101	101	101	101	101	101	101	1560
99%	88	203.3	-280	-102	-54	-35	-11	6	101	101	101	101	101	101	101	101	101	1570
Max	93	336.5	-201	-76	-23	24	44	56	101	101	101	101	101	101	101	101	101	1714

Panel C4: 2 Month Short ATM Put Margin Excess Returns

	Mean	**StdDev**	**Min**	**1%**	**2%**	**3%**	**4%**	**5%**	**25%**	**50%**	**75%**	**95%**	**96%**	**97%**	**98%**	**99%**	**Max**	**n**
Mean	2.8	27	-179	-82	-68	-59	-53	-48	-9	10	21	30	31	32	34	37	56	1068
StdDev	16	8	105	29	28	28	27	27	24	17	11	6	6	6	6	7	18	277
Min	-91	9	-950	-192	-178	-168	-162	-158	-121	-94	-63	-14	-9	0	10	21	29	242
1%	-56	12	-578	-160	-145	-139	-133	-127	-82	-57	-28	15	20	22	24	26	33	278
2%	-45	12	-486	-145	-129	-119	-112	-108	-70	-45	-16	20	21	23	25	27	34	292
3%	-26	13	-417	-144	-121	-111	-104	-99	-51	-25	3	22	23	24	26	27	37	303
4%	-23	13	-388	-137	-119	-109	-102	-94	-48	-19	8	23	24	25	27	28	37	314
5%	-22	13	-352	-129	-113	-105	-101	-93	-47	-18	10	24	25	26	27	29	38	324
25%	-4	21	-199	-102	-85	-77	-69	-65	-25	6	20	27	28	28	30	32	43	952
50%	7	27	-153	-80	-66	-58	-51	-47	-6	17	23	29	30	31	33	35	51	1089
75%	13	32	-123	-61	-48	-41	-34	-31	9	20	25	34	35	35	38	41	64	1237
95%	20	39	-84	-36	-24	-19	-14	-11	18	23	29	40	41	42	45	49	93	1460
96%	21	41	-79	-33	-23	-18	-14	-8	19	24	30	40	41	44	46	49	95	1467
97%	21	41	-77	-30	-23	-15	-9	-4	19	24	30	41	42	45	48	55	98	1518
98%	22	43	-72	-29	-19	-11	-5	-1	20	25	31	45	47	50	53	56	104	1560
99%	23	45	-67	-25	-14	-8	-3	2	20	26	33	46	48	51	54	60	116	1570
Max	23	60	-61	-20	-6	5	11	14	21	26	34	49	50	51	56	62	130	1714

Panel C5: 3 Month Short ATM Put Price Excess Returns

	Mean	**StdDev**	**Min**	**1%**	**2%**	**3%**	**4%**	**5%**	**25%**	**50%**	**75%**	**95%**	**96%**	**97%**	**98%**	**99%**	**Max**	**n**
Mean	12.4	105.6	-587	-322	-266	-233	-209	-190	-33	51	89	100	100	101	101	101	101	442
StdDev	66	35	318	145	132	127	123	119	99	74	41	9	5	3	1	0	0	158
Min	-345	37.4	-2305	-1023	-900	-842	-792	-739	-478	-329	-201	2	40	63	100	100	100	154
1%	-208	41.0	-1423	-711	-611	-584	-548	-537	-305	-201	-98	55	75	97	100	100	100	163
2%	-186	50.0	-1361	-640	-577	-545	-520	-506	-295	-169	-64	100	100	100	100	100	100	185
3%	-153	50.7	-1286	-618	-556	-517	-488	-474	-271	-137	-25	100	100	100	100	100	100	195
4%	-133	51.3	-1261	-613	-539	-485	-461	-439	-220	-117	-7	100	100	100	100	100	100	218
5%	-120	53.9	-1234	-587	-530	-471	-445	-422	-215	-112	-3	100	100	100	100	100	100	232
25%	-9	81.3	-707	-390	-330	-295	-269	-247	-79	27	100	100	100	100	100	100	100	340
50%	28	105.0	-489	-298	-245	-212	-194	-171	-24	92	101	101	101	101	101	101	101	417
75%	56	125.3	-371	-227	-181	-144	-124	-110	38	101	101	101	101	101	101	101	101	508
95%	78	162.7	-244	-134	-101	-71	-52	-39	100	101	102	102	102	102	102	102	102	711
96%	80	171.8	-233	-125	-95	-64	-48	-28	100	101	102	102	102	102	102	102	102	720
97%	82	175.9	-228	-118	-93	-54	-45	-26	100	101	102	102	102	102	102	102	102	726
98%	84	180.0	-223	-105	-75	-49	-29	-12	101	101	102	102	102	102	102	102	102	796
99%	86	198.1	-207	-89	-40	-28	-14	1	101	102	102	102	102	102	102	102	102	1007
Max	90	226.8	-145	-65	-29	-2	15	30	101	102	102	102	102	102	102	102	102	1227

Panel C6: 3 Month Short ATM Put Margin Excess Returns

	Mean	**StdDev**	**Min**	**1%**	**2%**	**3%**	**4%**	**5%**	**25%**	**50%**	**75%**	**95%**	**96%**	**97%**	**98%**	**99%**	**Max**	**n**
Mean	3.1	28	-135	-82	-70	-62	-56	-51	-11	11	22	34	35	37	39	43	59	442
StdDev	17	8	57	31	30	29	29	29	26	19	12	7	7	7	8	9	18	158
Min	-90	11	-429	-223	-207	-182	-171	-166	-126	-91	-63	0	10	18	22	27	31	154
1%	-56	14	-315	-152	-140	-134	-130	-126	-88	-57	-30	17	21	24	26	29	36	163
2%	-48	14	-280	-146	-134	-127	-124	-120	-78	-45	-18	23	23	25	27	30	38	185
3%	-38	14	-267	-141	-128	-116	-113	-109	-68	-38	-7	23	25	26	28	31	38	195
4%	-34	15	-253	-133	-126	-114	-109	-103	-62	-33	-2	24	25	27	29	31	38	218
5%	-31	16	-245	-133	-123	-113	-107	-101	-58	-30	-1	25	26	27	29	32	39	232
25%	-3	21	-157	-100	-86	-77	-72	-68	-24	7	22	29	30	31	33	36	46	340
50%	7	29	-123	-82	-68	-61	-55	-51	-7	19	25	33	35	36	38	41	54	417
75%	15	34	-98	-60	-47	-40	-34	-30	10	21	27	38	39	41	44	48	66	508
95%	22	41	-70	-36	-26	-21	-14	-10	19	25	32	46	48	50	54	59	96	711
96%	23	42	-65	-36	-25	-20	-13	-9	20	26	33	46	49	51	54	60	98	720
97%	23	43	-60	-33	-24	-19	-12	-7	21	27	33	48	50	52	56	62	100	726
98%	24	45	-50	-30	-23	-17	-9	-4	21	27	35	50	51	53	57	66	109	796
99%	27	46	-44	-27	-15	-9	-4	0	23	28	36	53	55	57	60	73	115	1007
Max	29	52	-38	-20	-10	-0	4	10	24	30	37	61	64	67	69	75	122	1227

Panel C7: 6 Month Short ATM Put Price Excess Returns

	Mean	**StdDev**	**Min**	**1%**	**2%**	**3%**	**4%**	**5%**	**25%**	**50%**	**75%**	**95%**	**96%**	**97%**	**98%**	**99%**	**Max**	**n**
Mean	12.1	101.2	-554	-302	-247	-217	-197	-180	-38	47	89	101	101	102	102	102	102	529
StdDev	64	34	284	140	124	119	115	112	94	74	42	6	5	2	1	1	1	187
Min	-279	30.1	-1904	-746	-665	-634	-605	-582	-413	-278	-157	47	56	80	100	100	100	164
1%	-197	33.8	-1543	-681	-593	-525	-491	-470	-300	-196	-92	70	90	97	100	100	100	176
2%	-178	37.9	-1300	-654	-561	-508	-485	-463	-274	-172	-75	89	100	100	100	100	100	212
3%	-163	43.1	-1184	-617	-548	-499	-477	-461	-263	-158	-52	100	100	100	100	100	100	234
4%	-150	46.3	-1081	-591	-516	-464	-442	-423	-257	-139	-31	100	100	100	100	100	100	256
5%	-140	48.2	-1034	-565	-486	-450	-426	-410	-243	-132	-27	100	100	100	100	100	100	293
25%	-4	79.5	-707	-358	-301	-259	-236	-224	-76	22	101	101	101	101	101	101	101	416
50%	25	99.9	-491	-285	-232	-200	-183	-167	-31	76	102	102	102	102	102	102	102	478
75%	54	118.9	-356	-214	-169	-148	-129	-114	25	101	103	103	103	103	103	103	103	617
95%	83	166.1	-220	-105	-72	-50	-34	-20	101	103	103	103	103	103	103	103	103	854
96%	84	170.8	-218	-99	-63	-48	-28	-16	101	103	103	103	103	103	103	103	103	859
97%	85	174.7	-203	-90	-59	-40	-19	-7	101	103	103	103	103	103	103	103	103	903
98%	87	182.3	-183	-66	-44	-19	-10	-2	101	103	103	103	103	103	103	103	103	1003
99%	90	191.6	-158	-50	-26	-10	11	23	101	103	103	103	103	103	103	103	103	1212
Max	91	196.9	-140	-32	-9	8	17	25	103	103	104	104	104	104	104	104	104	1356

Panel C8: 6 Month Short ATM Put Margin Excess Returns

	Mean	**StdDev**	**Min**	**1%**	**2%**	**3%**	**4%**	**5%**	**25%**	**50%**	**75%**	**95%**	**96%**	**97%**	**98%**	**99%**	**Max**	**n**
Mean	3.8	33	-140	-91	-77	-70	-64	-59	-14	12	26	44	46	48	52	59	91	529
StdDev	21	9	54	31	31	31	32	32	30	22	15	12	12	14	15	18	48	187
Min	-83	15	-329	-180	-171	-168	-161	-154	-120	-90	-52	17	20	25	30	35	41	164
1%	-63	16	-314	-163	-148	-144	-139	-136	-100	-67	-35	21	26	29	33	37	45	176
2%	-60	17	-274	-158	-142	-134	-129	-126	-93	-65	-28	26	28	32	34	37	46	212
3%	-49	17	-267	-151	-137	-131	-126	-123	-83	-50	-18	28	28	32	34	37	48	234
4%	-45	18	-256	-148	-135	-129	-125	-117	-80	-47	-9	29	30	32	35	37	49	256
5%	-44	19	-244	-144	-132	-125	-118	-115	-79	-43	-7	29	31	32	35	38	50	293
25%	-3	27	-164	-107	-96	-88	-83	-78	-27	8	25	36	37	39	41	46	65	416
50%	7	32	-127	-92	-76	-68	-63	-57	-11	21	28	40	42	44	48	54	80	478
75%	16	41	-105	-71	-57	-50	-44	-38	8	24	33	51	54	57	61	69	105	617
95%	30	47	-76	-42	-28	-20	-11	-7	23	30	40	64	66	71	76	87	160	854
96%	30	49	-71	-41	-26	-18	-11	-5	24	32	40	67	74	78	83	91	167	859
97%	31	49	-70	-36	-25	-14	-7	-4	24	34	46	72	75	82	87	105	197	903
98%	32	50	-68	-31	-16	-9	-4	-1	25	36	48	76	80	85	92	111	214	1003
99%	39	50	-47	-22	-10	-4	4	9	30	38	49	81	86	92	103	128	281	1212
Max	43	52	-35	-20	-3	3	8	13	32	41	50	83	88	101	109	137	410	1356

Panel D1: 1 Month Short OTM Put Price Excess Returns

	Mean	**StdDev**	**Min**	**1%**	**2%**	**3%**	**4%**	**5%**	**25%**	**50%**	**75%**	**95%**	**96%**	**97%**	**98%**	**99%**	**Max**	**n**
Mean	17.1	232	-2512	-888	-612	-464	-364	-297	36	87	98	100	100	100	100	100	100	504
StdDev	113	161	2208	576	504	470	438	416	179	79	25	0	0	0	0	0	0	204
Min	-759	26	-20143	-3227	-2424	-2294	-2064	-1942	-1180	-675	-231	100	100	100	100	100	100	155
1%	-518	35	-11085	-2833	-2267	-2112	-1888	-1758	-797	-352	90	100	100	100	100	100	100	164
2%	-304	39	-8353	-2387	-2003	-1693	-1573	-1508	-502	-86	100	100	100	100	100	100	100	183
3%	-244	47	-6621	-2144	-1688	-1475	-1394	-1333	-462	-43	100	100	100	100	100	100	100	188
4%	-209	59	-5830	-2036	-1606	-1343	-1190	-1044	-370	100	100	100	100	100	100	100	100	194
5%	-162	65	-5558	-1868	-1492	-1283	-1111	-1019	-314	100	100	100	100	100	100	100	100	216
25%	9	128	-3090	-1193	-872	-691	-558	-486	100	100	100	100	100	100	100	100	100	351
50%	51	192	-1924	-829	-519	-400	-288	-220	100	100	100	100	100	100	100	100	100	484
75%	79	302	-1366	-484	-255	-125	-29	48	100	100	100	100	100	100	100	100	100	658
95%	91	524	-692	-113	25	100	100	100	100	100	100	100	100	100	100	100	100	841
96%	94	527	-598	-73	67	100	100	100	100	100	100	100	100	100	100	100	100	870
97%	95	562	-525	-46	86	100	100	100	100	100	100	100	100	100	100	100	100	883
98%	96	642	-436	-33	94	100	100	100	100	101	101	101	101	101	101	101	101	893
99%	96	711	-347	-15	100	100	100	100	101	101	101	101	101	101	101	101	101	932
Max	98	1339	-100	100	100	100	100	100	101	101	101	101	101	101	101	101	101	1135

Panel D2: 1 Month Short OTM Put Margin Excess Returns

	Mean	**StdDev**	**Min**	**1%**	**2%**	**3%**	**4%**	**5%**	**25%**	**50%**	**75%**	**95%**	**96%**	**97%**	**98%**	**99%**	**Max**	**n**
Mean	1.6	20	-175	-71	-49	-38	-30	-25	1	6	9	12	12	13	13	15	82	504
StdDev	9	20	132	42	37	35	34	32	15	7	3	1	2	2	2	2	413	204
Min	-64	3	-1115	-199	-180	-165	-157	-151	-102	-63	-22	9	10	10	10	11	13	155
1%	-39	4	-686	-176	-156	-142	-133	-125	-67	-31	5	10	10	10	10	12	14	164
2%	-25	5	-540	-166	-142	-132	-122	-114	-49	-9	7	10	10	10	11	12	14	183
3%	-21	5	-487	-158	-133	-114	-105	-100	-36	-3	7	10	10	10	11	12	14	188
4%	-16	5	-396	-151	-119	-105	-99	-94	-32	5	7	10	10	10	11	12	15	194
5%	-12	6	-359	-146	-112	-100	-88	-82	-23	5	7	10	10	11	11	12	15	216
25%	0	11	-210	-96	-72	-61	-50	-44	5	7	8	11	11	12	12	13	17	351
50%	4	16	-149	-68	-44	-33	-25	-19	6	7	9	12	12	13	13	14	21	484
75%	7	25	-98	-38	-21	-11	-3	3	6	8	10	13	13	14	14	16	30	658
95%	8	43	-50	-10	2	5	5	5	7	9	11	14	15	15	16	19	118	841
96%	8	46	-48	-10	3	5	5	5	7	9	11	15	15	15	16	20	139	870
97%	9	49	-41	-6	4	5	5	5	8	9	11	15	15	16	17	20	170	883
98%	9	63	-37	-4	4	5	5	5	8	10	12	15	16	17	18	21	196	893
99%	12	91	-33	-2	5	5	6	6	8	10	12	16	17	18	19	23	1947	932
Max	16	191	-9	4	5	6	6	7	10	11	13	18	18	19	21	31	4644	1135

Panel D3: 2 Month Short OTM Put Price Excess Returns

	Mean	**StdDev**	**Min**	**1%**	**2%**	**3%**	**4%**	**5%**	**25%**	**50%**	**75%**	**95%**	**96%**	**97%**	**98%**	**99%**	**Max**	**n**
Mean	14.4	217.1	-2519	-813	-580	-456	-376	-313	27	84	96	101	101	101	101	101	101	847
StdDev	120	175	2386	523	459	425	399	380	185	99	42	0	0	0	0	0	0	249
Min	-848	24.7	-27390	-2993	-2551	-2330	-2179	-2036	-1208	-781	-385	100	100	100	100	100	100	161
1%	-529	30.8	-8221	-2479	-2200	-2066	-1904	-1784	-824	-421	2	100	100	100	100	100	100	176
2%	-354	44.2	-6199	-2158	-1850	-1584	-1405	-1285	-587	-251	100	100	100	100	100	100	100	184
3%	-191	44.4	-5389	-1888	-1715	-1481	-1279	-1160	-331	39	100	100	100	100	100	100	100	192
4%	-178	46.5	-5206	-1854	-1434	-1279	-1199	-1097	-299	100	100	100	100	100	100	100	100	201
5%	-147	52.9	-4844	-1772	-1368	-1169	-1059	-959	-275	100	100	100	100	100	100	100	100	220
25%	-11	124.9	-3142	-1090	-795	-670	-574	-516	53	100	100	100	100	100	100	100	100	736
50%	54	180.3	-2097	-743	-503	-373	-299	-233	100	101	101	101	101	101	101	101	101	842
75%	76	284.3	-1320	-465	-303	-176	-103	-47	101	101	101	101	101	101	101	101	101	984
95%	94	438.0	-701	-115	55	100	100	100	101	101	101	101	101	101	101	101	101	1238
96%	94	448.9	-622	-89	73	100	100	100	101	101	101	101	101	101	101	101	101	1250
97%	95	506.8	-502	-25	93	100	100	101	101	101	101	101	101	101	101	101	101	1314
98%	96	582.2	-437	29	100	100	100	101	101	101	101	101	101	101	101	101	101	1338
99%	97	646.7	-401	45	100	100	101	101	101	101	101	101	101	101	101	101	101	1363
Max	98	1896.6	-335	100	101	101	101	101	101	101	101	101	101	101	101	101	101	1436

Panel D4: 2 Month Short OTM Put Margin Excess Returns

	Mean	**StdDev**	**Min**	**1%**	**2%**	**3%**	**4%**	**5%**	**25%**	**50%**	**75%**	**95%**	**96%**	**97%**	**98%**	**99%**	**Max**	**n**
Mean	1.5	20	-196	-74	-55	-44	-37	-31	0	7	10	14	15	15	16	18	38	847
StdDev	12	12	144	40	38	36	35	34	18	10	5	2	3	3	3	4	34	249
Min	-89	3	-1398	-228	-205	-197	-192	-185	-128	-92	-50	10	10	11	12	12	16	161
1%	-45	4	-725	-174	-164	-154	-145	-135	-77	-42	-1	11	11	12	12	13	16	176
2%	-34	5	-530	-160	-136	-127	-118	-113	-60	-25	7	11	11	12	13	14	17	184
3%	-16	6	-465	-152	-126	-114	-104	-99	-34	3	8	11	12	12	13	14	17	192
4%	-14	6	-431	-144	-122	-109	-102	-96	-28	5	8	12	12	12	13	14	17	201
5%	-14	6	-404	-139	-115	-106	-101	-93	-26	6	8	12	12	12	13	14	18	220
25%	-1	12	-233	-101	-79	-64	-58	-50	5	8	10	13	13	13	14	15	22	736
50%	5	17	-172	-72	-51	-40	-32	-25	6	8	10	14	14	15	15	17	28	842
75%	7	26	-115	-46	-30	-18	-11	-5	7	9	12	15	16	17	17	19	38	984
95%	10	37	-71	-14	4	5	5	6	9	11	14	19	20	20	22	24	100	1238
96%	10	39	-63	-11	4	5	6	6	9	11	14	19	20	21	22	25	101	1250
97%	10	44	-57	-3	5	5	6	7	9	11	14	20	21	22	23	26	101	1314
98%	11	50	-56	3	5	6	6	7	9	12	14	21	21	23	24	27	134	1338
99%	12	56	-49	4	6	6	7	7	10	12	15	22	23	25	27	29	199	1363
Max	14	98	-32	5	6	7	7	7	12	14	17	25	25	27	30	35	277	1436

Panel D5: 3 Month Short OTM Put Price Excess Returns

	Mean	**StdDev**	**Min**	**1%**	**2%**	**3%**	**4%**	**5%**	**25%**	**50%**	**75%**	**95%**	**96%**	**97%**	**98%**	**99%**	**Max**	**n**
Mean	14.4	195.0	-1661	-733	-545	-441	-365	-311	21	82	97	101	101	101	101	101	101	391
StdDev	119	129	1299	518	463	430	407	387	190	92	39	0	0	0	0	0	0	145
Min	-893	23.3	-10760	-3246	-2876	-2710	-2603	-2457	-1241	-792	-397	100	100	100	100	100	100	125
1%	-420	29.3	-6298	-2189	-1927	-1714	-1544	-1482	-689	-313	9	100	100	100	100	100	100	131
2%	-386	34.2	-5611	-1997	-1587	-1458	-1370	-1312	-661	-250	72	100	100	100	100	100	100	143
3%	-301	40.5	-4976	-1840	-1543	-1342	-1263	-1188	-559	-125	100	100	100	100	100	100	100	154
4%	-229	43.3	-4092	-1756	-1511	-1269	-1144	-1027	-424	-57	100	100	100	100	100	100	100	164
5%	-191	49.8	-3459	-1645	-1397	-1242	-1084	-1014	-375	-7	100	100	100	100	100	100	100	199
25%	6	103.8	-1991	-946	-780	-635	-556	-482	46	100	100	100	100	100	100	100	100	298
50%	50	165.2	-1332	-651	-463	-369	-297	-251	100	101	101	101	101	101	101	101	101	367
75%	80	241.3	-888	-384	-217	-130	-59	-16	101	101	101	101	101	101	101	101	101	442
95%	94	450.9	-475	-91	41	100	100	100	101	102	102	102	102	102	102	102	102	636
96%	95	468.6	-396	-59	72	100	100	100	101	102	102	102	102	102	102	102	102	651
97%	96	497.8	-324	-29	98	100	100	101	101	102	102	102	102	102	102	102	102	659
98%	97	520.7	-239	-3	100	100	101	101	102	102	102	102	102	102	102	102	102	702
99%	97	587.7	-183	30	100	101	101	101	102	102	102	102	102	102	102	102	102	926
Max	97	806.1	-129	92	101	101	101	101	102	102	102	102	102	102	102	102	102	1074

Panel D6: 3 Month Short OTM Put Margin Excess Returns

	Mean	**StdDev**	**Min**	**1%**	**2%**	**3%**	**4%**	**5%**	**25%**	**50%**	**75%**	**95%**	**96%**	**97%**	**98%**	**99%**	**Max**	**n**
Mean	1.7	20	-146	-74	-58	-47	-39	-34	-0	8	11	16	17	17	18	21	32	391
StdDev	12	11	82	44	42	39	38	37	20	10	5	3	3	3	4	5	20	145
Min	-91	4	-645	-273	-249	-224	-210	-203	-137	-90	-46	12	12	12	13	14	16	125
1%	-46	4	-407	-178	-165	-149	-143	-139	-84	-40	1	12	12	12	13	15	17	131
2%	-37	5	-339	-163	-150	-136	-132	-126	-67	-26	7	12	12	13	13	15	17	143
3%	-28	5	-315	-157	-139	-123	-117	-111	-55	-12	8	12	12	13	13	15	18	154
4%	-23	6	-310	-153	-135	-117	-112	-103	-48	-6	9	12	13	13	14	15	18	164
5%	-19	6	-297	-147	-133	-117	-107	-98	-40	-1	9	12	13	13	14	15	19	199
25%	0	11	-176	-99	-80	-69	-61	-57	5	8	11	14	14	15	15	17	22	298
50%	6	19	-132	-75	-55	-46	-36	-30	7	9	11	15	16	17	18	19	28	367
75%	8	26	-96	-42	-26	-17	-7	-3	8	10	13	18	18	19	21	23	34	442
95%	11	40	-50	-11	4	6	6	7	10	12	16	22	23	24	26	30	55	636
96%	11	42	-46	-5	5	6	7	7	10	13	16	23	24	25	27	30	62	651
97%	12	44	-37	-3	5	6	7	7	10	13	16	23	24	25	28	33	66	659
98%	13	48	-22	0	6	7	7	8	11	13	16	23	24	26	30	36	84	702
99%	13	51	-21	3	6	7	8	8	12	14	17	25	26	28	31	38	109	926
Max	14	67	-14	6	7	8	9	9	12	16	19	27	28	30	32	40	208	1074

Panel D7: 6 Month Short OTM Put Price Excess Returns

	Mean	**StdDev**	**Min**	**1%**	**2%**	**3%**	**4%**	**5%**	**25%**	**50%**	**75%**	**95%**	**96%**	**97%**	**98%**	**99%**	**Max**	**n**
Mean	9.4	182.0	-1472	-695	-523	-432	-370	-320	4	77	97	102	102	102	102	102	102	469
StdDev	115	111	931	457	398	369	352	340	191	98	34	1	1	1	1	1	1	179
Min	-651	8.6	-4790	-2103	-1921	-1802	-1720	-1616	-954	-606	-248	100	100	100	100	100	100	133
1%	-429	22.1	-4558	-2035	-1699	-1458	-1351	-1274	-703	-377	-35	100	100	100	100	100	100	137
2%	-348	27.8	-4126	-1859	-1516	-1384	-1282	-1219	-604	-291	-9	100	100	100	100	100	100	152
3%	-337	33.7	-3861	-1758	-1475	-1303	-1195	-1137	-598	-230	100	100	100	100	100	100	100	189
4%	-314	36.4	-3439	-1678	-1435	-1253	-1131	-1079	-560	-188	100	100	100	100	100	100	100	236
5%	-262	43.6	-3290	-1618	-1356	-1205	-1115	-1061	-486	-150	100	100	100	100	100	100	100	248
25%	-3	107.1	-1866	-892	-671	-572	-505	-454	-22	101	101	101	101	101	101	101	101	364
50%	46	166.9	-1250	-632	-472	-387	-333	-259	101	102	102	102	102	102	102	102	102	415
75%	76	224.5	-843	-424	-263	-180	-128	-83	102	103	103	103	103	103	103	103	103	564
95%	95	414.5	-375	-73	9	92	100	101	103	103	103	103	103	103	103	103	103	790
96%	95	427.4	-354	-57	32	98	101	101	103	103	103	103	103	103	103	103	103	807
97%	97	471.3	-297	-34	55	100	101	101	103	103	103	103	103	103	103	103	103	823
98%	97	482.8	-271	32	88	101	101	101	103	103	103	103	103	103	103	103	103	928
99%	99	497.6	-218	67	101	101	101	101	103	103	103	103	103	103	103	103	103	1134
Max	100	545.1	-41	86	101	101	101	103	103	104	104	104	104	104	104	104	104	1273

Panel D8: 6 Month Short OTM Put Margin Excess Returns

	Mean	**StdDev**	**Min**	**1%**	**2%**	**3%**	**4%**	**5%**	**25%**	**50%**	**75%**	**95%**	**96%**	**97%**	**98%**	**99%**	**Max**	**n**
Mean	1.6	25	-150	-85	-68	-58	-50	-44	-3	8	14	22	23	24	26	30	66	469
StdDev	15	16	71	43	42	42	41	41	25	14	6	6	6	7	8	9	265	179
Min	-82	5	-404	-207	-197	-192	-182	-176	-129	-86	-33	14	14	15	16	19	21	133
1%	-58	6	-394	-188	-171	-158	-153	-149	-98	-54	-5	14	15	16	17	19	23	137
2%	-50	7	-338	-178	-155	-145	-140	-136	-89	-49	-1	15	15	16	17	19	25	152
3%	-39	8	-310	-176	-154	-144	-138	-134	-75	-31	9	15	15	16	18	20	26	189
4%	-37	8	-304	-170	-150	-142	-130	-126	-71	-27	9	15	16	16	18	20	26	236
5%	-35	8	-295	-164	-146	-137	-128	-120	-70	-19	10	15	16	17	18	20	27	248
25%	-1	15	-187	-108	-94	-85	-76	-69	-3	10	13	18	18	19	21	23	32	364
50%	6	22	-132	-87	-66	-54	-46	-38	8	11	14	20	21	22	24	26	39	415
75%	9	32	-105	-57	-42	-28	-19	-12	9	13	16	25	26	27	30	33	55	564
95%	16	50	-63	-17	1	7	8	9	13	16	20	34	36	39	42	49	92	790
96%	17	50	-61	-14	4	8	9	9	13	16	21	35	36	40	43	50	98	807
97%	19	51	-58	-8	7	8	9	10	14	17	22	37	38	41	43	51	111	823
98%	20	54	-52	3	7	9	10	11	15	19	24	38	39	41	44	57	113	928
99%	21	59	-28	8	9	10	11	11	16	20	25	39	42	47	55	67	125	1134
Max	22	159	-14	10	11	12	12	12	17	21	28	45	49	52	59	73	3513	1273

Panel E1: 1 Month Short ATM Straddle Price Excess Returns

	Mean	**StdDev**	**Min**	**1%**	**2%**	**3%**	**4%**	**5%**	**25%**	**50%**	**75%**	**95%**	**96%**	**97%**	**98%**	**99%**	**Max**	**n**
Mean	3.6	78	-522	-241	-195	-170	-153	-138	-35	19	61	93	95	97	98	99	100	744
StdDev	22	13	297	60	50	47	43	41	30	24	16	6	5	4	3	2	0	201
Min	-141	51	-1978	-466	-397	-365	-330	-317	-209	-136	-69	37	43	51	67	73	98	260
1%	-93	53	-1813	-425	-360	-333	-297	-280	-145	-87	-17	65	73	82	87	95	99	310
2%	-55	55	-1738	-406	-330	-296	-271	-256	-115	-50	16	82	86	90	93	96	100	329
3%	-49	59	-1374	-390	-310	-266	-251	-233	-107	-36	23	85	88	91	94	97	100	343
4%	-42	60	-1202	-354	-296	-256	-238	-218	-97	-24	32	87	90	93	95	98	100	348
5%	-33	61	-1086	-345	-281	-245	-222	-204	-88	-12	41	89	92	94	96	98	100	367
25%	-4	68	-571	-270	-221	-195	-174	-157	-46	15	58	93	95	96	98	99	100	603
50%	8	76	-456	-231	-187	-165	-144	-131	-29	24	64	95	96	97	99	100	100	731
75%	16	83	-355	-198	-161	-140	-126	-114	-16	33	69	95	97	98	99	100	100	874
95%	27	105	-251	-164	-125	-103	-88	-81	-2	42	73	97	98	99	100	100	100	1058
96%	29	107	-248	-161	-116	-100	-86	-75	-1	42	74	97	98	99	100	100	100	1068
97%	30	108	-243	-145	-115	-97	-81	-72	0	44	74	97	98	99	100	100	100	1089
98%	33	114	-231	-137	-112	-93	-79	-70	4	45	75	97	98	100	100	100	101	1103
99%	34	121	-221	-133	-104	-89	-77	-66	9	48	77	97	98	100	100	100	101	1113
Max	41	128	-195	-121	-97	-80	-70	-59	15	53	80	98	98	100	100	101	101	1396

Panel E2: 1 Month Short ATM Straddle Margin Excess Returns

	Mean	**StdDev**	**Min**	**1%**	**2%**	**3%**	**4%**	**5%**	**25%**	**50%**	**75%**	**95%**	**96%**	**97%**	**98%**	**99%**	**Max**	**n**
Mean	1.7	36	-237	-111	-90	-78	-70	-63	-16	9	28	43	44	45	46	48	52	744
StdDev	10	6	135	27	23	22	20	19	14	11	8	3	3	2	2	2	3	201
Min	-66	24	-918	-224	-196	-177	-156	-145	-98	-65	-32	17	21	26	31	35	46	260
1%	-42	25	-841	-196	-162	-146	-135	-125	-68	-40	-8	30	33	37	41	43	47	310
2%	-25	25	-721	-188	-150	-136	-124	-114	-54	-24	7	37	39	41	43	44	47	329
3%	-22	27	-668	-175	-145	-124	-113	-107	-50	-17	10	38	40	41	43	44	48	343
4%	-19	28	-615	-163	-133	-119	-110	-101	-43	-11	14	39	41	42	43	45	49	348
5%	-14	28	-515	-156	-129	-112	-100	-97	-39	-5	18	40	41	42	44	45	49	367
25%	-2	31	-257	-125	-102	-88	-78	-72	-21	7	26	42	43	44	45	47	50	603
50%	4	35	-206	-107	-86	-75	-65	-60	-13	11	29	43	44	45	46	48	52	731
75%	8	38	-166	-93	-75	-64	-57	-52	-7	14	31	44	45	46	47	49	54	874
95%	13	47	-121	-75	-58	-49	-41	-35	-1	19	34	45	46	47	49	51	57	1058
96%	13	48	-118	-75	-55	-46	-39	-34	-0	19	34	45	46	47	49	51	58	1068
97%	14	51	-110	-69	-53	-44	-37	-33	0	20	35	46	46	48	49	51	59	1089
98%	15	54	-104	-63	-51	-42	-36	-33	2	21	35	46	47	48	49	51	59	1103
99%	16	56	-100	-61	-49	-41	-35	-30	4	22	35	46	47	48	49	51	60	1113
Max	19	60	-95	-57	-46	-40	-34	-27	7	25	38	47	48	49	50	52	61	1396

Panel E3: 2 Month Short ATM Straddle Price Excess Returns

	Mean	**StdDev**	**Min**	**1%**	**2%**	**3%**	**4%**	**5%**	**25%**	**50%**	**75%**	**95%**	**96%**	**97%**	**98%**	**99%**	**Max**	**n**
Mean	3.9	76.3	-543	-234	-189	-165	-148	-135	-34	19	60	93	95	96	98	100	101	1051
StdDev	24	16	306	74	59	53	49	46	31	25	18	8	7	6	4	2	0	273
Min	-156	45.6	-2387	-699	-466	-426	-383	-358	-221	-157	-90	14	24	31	59	75	99	240
1%	-91	49.2	-1607	-556	-454	-365	-343	-300	-152	-90	-21	59	67	74	83	92	100	275
2%	-63	55.1	-1469	-395	-352	-326	-294	-276	-117	-58	2	78	83	86	91	96	100	290
3%	-39	55.8	-1457	-355	-317	-284	-265	-252	-93	-16	39	88	91	93	95	98	100	301
4%	-35	56.9	-1393	-338	-293	-267	-242	-227	-81	-13	43	90	92	94	96	98	100	314
5%	-31	56.9	-1205	-334	-285	-258	-230	-205	-77	-11	44	90	92	94	96	98	100	321
25%	-3	67.2	-593	-258	-209	-184	-164	-150	-44	13	57	92	94	96	98	99	100	939
50%	7	75.2	-448	-223	-182	-159	-140	-128	-32	24	64	94	96	97	99	100	101	1068
75%	17	81.1	-358	-190	-157	-134	-121	-110	-16	31	69	95	97	98	99	100	101	1212
95%	28	102.5	-271	-146	-114	-96	-84	-75	-1	41	73	97	97	99	100	101	101	1439
96%	29	103.6	-270	-145	-111	-93	-83	-71	0	43	74	97	97	99	100	101	101	1447
97%	34	105.2	-267	-144	-106	-90	-78	-69	9	47	75	97	98	99	100	101	101	1501
98%	36	124.7	-255	-140	-103	-85	-72	-63	11	48	76	97	98	99	100	101	101	1532
99%	40	143.8	-253	-113	-82	-68	-58	-48	15	50	77	97	98	99	101	101	101	1555
Max	44	157.3	-218	-98	-77	-56	-48	-43	22	55	79	98	101	101	101	101	101	1701

Panel E4: 2 Month Short ATM Straddle Margin Excess Returns

	Mean	**StdDev**	**Min**	**1%**	**2%**	**3%**	**4%**	**5%**	**25%**	**50%**	**75%**	**95%**	**96%**	**97%**	**98%**	**99%**	**Max**	**n**
Mean	1.9	36	-252	-110	-90	-78	-70	-63	-16	9	28	44	45	46	48	50	56	1051
StdDev	11	7	144	33	28	25	23	22	15	12	9	4	3	3	2	2	3	273
Min	-76	21	-1188	-298	-221	-202	-183	-164	-109	-73	-41	6	10	16	29	34	48	240
1%	-43	24	-740	-258	-207	-173	-153	-146	-71	-42	-10	28	32	34	37	42	50	275
2%	-30	26	-689	-194	-171	-156	-139	-130	-54	-27	1	36	38	40	43	47	50	290
3%	-18	27	-637	-172	-146	-138	-127	-116	-44	-8	18	41	42	44	45	47	51	301
4%	-16	27	-612	-162	-138	-125	-114	-106	-38	-6	20	42	43	44	46	47	51	314
5%	-14	27	-587	-155	-136	-121	-106	-98	-36	-5	21	42	43	44	46	48	52	321
25%	-2	32	-270	-123	-100	-87	-79	-72	-21	6	27	44	45	46	47	49	54	939
50%	3	35	-210	-106	-86	-75	-67	-61	-15	11	30	45	46	47	48	50	56	1068
75%	8	39	-169	-92	-73	-64	-57	-51	-7	15	32	45	46	47	49	51	58	1212
95%	13	49	-131	-70	-54	-45	-40	-35	-0	19	34	47	48	49	50	53	60	1439
96%	14	49	-129	-69	-52	-44	-39	-34	0	20	35	47	48	49	50	53	61	1447
97%	16	50	-128	-68	-51	-42	-38	-33	4	22	35	47	48	49	50	53	61	1501
98%	17	59	-126	-63	-48	-41	-34	-29	5	23	36	47	48	49	51	53	61	1532
99%	19	67	-121	-53	-41	-33	-28	-23	7	24	36	47	48	49	51	54	62	1555
Max	20	77	-108	-45	-35	-26	-22	-19	9	26	38	47	49	50	52	55	63	1701

Panel E5: 3 Month Short ATM Straddle Price Excess Returns

	Mean	**StdDev**	**Min**	**1%**	**2%**	**3%**	**4%**	**5%**	**25%**	**50%**	**75%**	**95%**	**96%**	**97%**	**98%**	**99%**	**Max**	**n**
Mean	3.5	76.6	-437	-234	-192	-166	-149	-134	-35	18	60	93	95	96	98	100	101	434
StdDev	25	19	241	101	83	70	63	55	32	25	19	7	6	4	3	2	1	155
Min	-156	47.7	-1557	-1035	-813	-655	-542	-439	-233	-153	-84	32	40	59	72	81	98	152
1%	-79	49.5	-1327	-555	-498	-422	-389	-369	-139	-77	-20	59	67	77	82	92	99	161
2%	-72	51.7	-1198	-483	-400	-339	-323	-256	-124	-58	-1	79	83	86	92	96	100	184
3%	-61	53.4	-1079	-473	-378	-300	-273	-241	-112	-41	19	85	87	91	94	96	100	194
4%	-51	54.3	-1016	-399	-312	-268	-249	-228	-103	-31	28	87	90	92	94	98	100	218
5%	-41	55.5	-937	-363	-302	-261	-244	-225	-96	-28	31	87	90	92	94	98	100	229
25%	-3	64.4	-497	-267	-222	-192	-174	-158	-46	12	59	92	94	96	97	99	100	337
50%	9	73.6	-370	-214	-175	-155	-138	-127	-30	24	64	94	95	97	99	100	101	413
75%	18	83.5	-289	-182	-147	-123	-111	-97	-14	30	68	95	97	98	99	100	101	504
95%	32	103.3	-204	-134	-108	-91	-80	-69	5	44	74	97	98	99	101	101	102	698
96%	32	113.9	-196	-132	-100	-86	-78	-67	6	45	76	97	99	99	101	101	102	700
97%	33	118.0	-182	-130	-98	-84	-72	-64	7	46	76	98	99	99	101	101	102	713
98%	35	120.9	-172	-127	-93	-76	-69	-63	8	48	76	98	99	100	101	101	102	776
99%	36	145.8	-166	-110	-83	-73	-66	-62	11	49	77	98	99	100	101	101	102	981
Max	38	209.1	-145	-104	-79	-64	-54	-47	17	51	78	99	100	101	101	101	102	1214

Panel E6: 3 Month Short ATM Straddle Margin Excess Returns

	Mean	**StdDev**	**Min**	**1%**	**2%**	**3%**	**4%**	**5%**	**25%**	**50%**	**75%**	**95%**	**96%**	**97%**	**98%**	**99%**	**Max**	**n**
Mean	1.6	36	-199	-111	-91	-79	-71	-64	-16	8	28	44	45	47	48	50	55	434
StdDev	12	9	104	44	38	32	28	26	15	12	9	3	3	3	2	2	3	155
Min	-76	21	-740	-441	-355	-266	-225	-198	-113	-72	-39	15	18	31	34	40	49	152
1%	-38	24	-661	-252	-238	-197	-184	-179	-66	-36	-9	28	30	34	38	43	50	161
2%	-33	24	-512	-233	-192	-159	-136	-121	-60	-28	-0	35	36	39	42	45	50	184
3%	-29	25	-423	-213	-174	-145	-125	-116	-53	-19	9	40	42	43	44	47	51	194
4%	-25	25	-411	-180	-155	-133	-121	-110	-48	-14	13	41	42	44	45	47	51	218
5%	-20	26	-393	-169	-147	-126	-116	-109	-47	-13	15	41	42	44	45	47	51	229
25%	-1	30	-236	-128	-104	-92	-82	-74	-22	6	27	44	45	46	48	49	53	337
50%	4	35	-172	-98	-84	-74	-66	-60	-14	11	30	45	46	47	49	50	55	413
75%	8	40	-133	-88	-69	-58	-51	-46	-6	14	32	46	47	48	50	52	57	504
95%	15	49	-99	-64	-50	-42	-37	-33	2	20	35	47	48	49	51	53	60	698
96%	15	51	-97	-63	-48	-40	-36	-31	3	20	35	47	48	49	51	53	60	700
97%	16	52	-94	-62	-47	-39	-33	-31	3	21	35	47	48	50	51	54	60	713
98%	17	58	-88	-53	-43	-38	-32	-29	4	22	36	48	48	50	51	54	61	776
99%	17	65	-79	-50	-41	-36	-31	-26	5	23	36	48	49	50	52	55	62	981
Max	18	93	-62	-48	-37	-33	-25	-22	8	24	36	48	50	51	52	56	64	1214

Panel E7: 6 Month Short ATM Straddle Price Excess Returns

	Mean	**StdDev**	**Min**	**1%**	**2%**	**3%**	**4%**	**5%**	**25%**	**50%**	**75%**	**95%**	**96%**	**97%**	**98%**	**99%**	**Max**	**n**
Mean	1.1	79.8	-492	-263	-203	-174	-154	-139	-37	16	58	93	95	96	98	100	102	517
StdDev	26	24	262	144	94	77	68	62	33	27	19	7	6	5	3	2	1	182
Min	-126	49.5	-1741	-1386	-886	-716	-586	-498	-192	-131	-56	54	58	71	74	85	98	159
1%	-82	51.0	-1664	-936	-590	-445	-385	-352	-139	-83	-21	62	69	76	83	92	100	167
2%	-76	52.2	-1316	-675	-395	-331	-308	-288	-124	-72	-13	66	73	78	87	94	100	205
3%	-68	53.1	-1129	-499	-378	-318	-297	-279	-117	-55	1	71	77	80	88	95	100	225
4%	-61	55.1	-976	-484	-345	-312	-260	-239	-109	-50	13	80	86	89	93	96	100	250
5%	-54	55.3	-966	-450	-322	-285	-242	-224	-107	-42	18	84	88	91	94	97	100	288
25%	-7	66.4	-542	-293	-234	-206	-185	-169	-48	9	56	92	94	96	98	100	101	406
50%	8	75.0	-431	-237	-189	-160	-141	-127	-30	22	63	94	96	97	99	101	102	468
75%	16	88.5	-333	-188	-146	-127	-114	-99	-18	31	68	96	97	98	100	101	103	594
95%	34	115.9	-235	-139	-106	-91	-79	-68	9	45	75	98	99	100	101	103	103	838
96%	35	124.8	-227	-134	-105	-89	-76	-67	10	49	75	98	99	100	101	103	103	848
97%	36	126.5	-212	-123	-102	-87	-75	-64	13	49	75	98	99	100	102	103	103	872
98%	37	142.4	-200	-122	-95	-76	-64	-60	15	51	76	99	100	101	102	103	103	963
99%	40	177.0	-190	-117	-85	-71	-57	-49	16	52	77	99	100	101	102	103	103	1185
Max	43	244.2	-176	-98	-82	-67	-46	-35	19	54	79	99	100	101	103	103	104	1326

Panel E8: 6 Month Short ATM Straddle Margin Excess Returns

	Mean	**StdDev**	**Min**	**1%**	**2%**	**3%**	**4%**	**5%**	**25%**	**50%**	**75%**	**95%**	**96%**	**97%**	**98%**	**99%**	**Max**	**n**
Mean	0.4	36	-221	-118	-94	-81	-71	-64	-16	7	26	43	45	46	48	51	57	517
StdDev	12	10	104	51	40	33	29	27	15	12	9	4	4	3	3	3	3	182
Min	-60	19	-686	-455	-347	-282	-219	-191	-92	-61	-23	23	27	31	32	36	46	159
1%	-38	21	-551	-286	-223	-180	-166	-156	-65	-35	-9	25	28	32	37	42	47	167
2%	-33	22	-509	-252	-174	-153	-138	-122	-57	-31	-5	29	31	34	39	43	51	205
3%	-31	23	-496	-228	-163	-140	-125	-120	-53	-25	0	32	33	36	40	45	52	225
4%	-27	24	-449	-205	-163	-135	-121	-113	-51	-20	6	38	39	40	43	46	53	250
5%	-25	25	-424	-191	-158	-129	-115	-106	-48	-19	8	38	39	41	43	46	53	288
25%	-3	30	-264	-136	-111	-98	-87	-79	-21	4	24	42	44	45	47	50	55	406
50%	4	35	-201	-115	-90	-74	-65	-59	-12	9	28	44	46	47	49	51	57	468
75%	7	41	-148	-86	-69	-59	-52	-47	-7	14	30	46	47	48	50	52	59	594
95%	14	51	-98	-60	-48	-40	-34	-29	4	19	33	47	48	50	52	54	62	838
96%	15	51	-96	-59	-46	-38	-32	-28	4	19	34	48	48	50	52	54	63	848
97%	16	53	-91	-56	-45	-36	-31	-26	5	19	34	48	49	50	52	55	63	872
98%	16	60	-86	-56	-41	-33	-27	-23	5	21	34	48	49	50	52	55	63	963
99%	17	65	-84	-50	-38	-29	-24	-21	7	21	35	48	50	50	53	55	69	1185
Max	19	93	-79	-40	-28	-22	-19	-15	7	22	35	49	50	51	53	56	70	1326

Table 1B.3: Distribution of Index Option Returns

The table below presents the time-series distribution of short $k \in \{1, 2, 3, 6\}$ month (Panels A, B, C, and D) ATM and OTM call and put, and ATM straddle price and margin-based excess returns for S&P 500 (S&P) and Nasdaq 100 (Nasdaq) index options. Each month, on the second trading day following the monthly expiration, the ATM (OTM) call and put for each index are defined to be the k month options with delta closest to 0.5 and -0.5 (0.2 and -0.2) respectively. The straddle is comprised of the ATM call and the put with the same strike. The table presents the mean and selected percentiles of the time-series distribution of price and margin-based excess returns. The column labeled **Reduction%** presents the percentage reduction in average cross-sectional mean excess return achieved by using the margin return as compared to the price return. The sample covers holding periods ending from February, March, April and July 1996 through October 2010 for the 1, 2, 3, and 6 month samples respectively. All returns are in percent.

Panel A: 1 Month Short Option Positions

Position	ATM/OTM	Index	Return	Mean	Reduction%	Min	1%	2%	3%	4%	5%	25%	50%	75%	95%	96%	97%	98%	99%	Max
Short Call	**ATM**	**S&P**	*Price*	1.32		-367	-310	-292	-265	-260	-257	-80	61	100	100	100	100	100	100	101
			Margin	0.28	78.7	-83	-70	-64	-61	-59	-55	-18	13	22	24	24	24	25	25	27
		Nasdaq	*Price*	-12.88		-615	-401	-360	-350	-329	-302	-105	76	100	100	100	100	100	101	101
			Margin	-2.78	78.5	-125	-81	-74	-72	-69	-66	-23	16	21	23	23	23	24	25	28
	OTM	**S&P**	*Price*	12.84		-1050	-873	-637	-618	-570	-522	100	100	100	100	100	100	101	101	101
			Margin	1.08	91.6	-75	-59	-52	-47	-43	-40	6	7	8	9	9	9	9	10	10
		Nasdaq	*Price*	-14.19		-1813	-999	-809	-733	-705	-647	100	100	100	100	100	100	101	101	101
			Margin	-1.11	92.1	-134	-75	-66	-62	-60	-53	6	7	8	10	10	10	11	11	22
Short Put	**ATM**	**S&P**	*Price*	18.83		-639	-565	-463	-347	-284	-282	-21	100	100	100	100	100	100	101	101
			Margin	3.20	83.0	-106	-94	-80	-64	-50	-47	-3	15	17	19	19	19	19	20	21
		Nasdaq	*Price*	20.93		-630	-528	-345	-281	-274	-266	-9	100	100	100	100	100	100	101	101
			Margin	3.73	82.2	-108	-92	-62	-54	-51	-49	-1	16	18	20	21	21	22	23	24
	OTM	**S&P**	*Price*	44.02		-1244	-1121	-900	-566	-361	-314	100	100	100	100	100	100	101	101	101
			Margin	3.40	92.3	-109	-91	-73	-51	-29	-26	7	8	8	10	10	10	10	10	11
		Nasdaq	*Price*	36.70		-1488	-1157	-589	-478	-422	-405	100	100	100	100	100	100	101	101	101
			Margin	3.42	90.7	-111	-89	-50	-37	-35	-32	7	8	8	9	9	10	10	11	100
Short Straddle	**ATM**	**S&P**	*Price*	10.33		-274	-235	-193	-148	-120	-98	-30	18	67	93	96	98	98	99	99
			Margin	4.03	61.0	-107	-92	-77	-58	-47	-40	-11	7	26	37	37	38	39	39	41
		Nasdaq	*Price*	4.64		-290	-244	-188	-133	-115	-111	-37	16	61	92	95	97	98	99	99
			Margin	1.88	59.5	-110	-102	-80	-59	-49	-47	-14	7	25	38	39	40	41	41	43

Panel B: 2 Month Short Option Positions

Position	Delta	Index	Return	Mean	Reduction%	Min	1%	2%	3%	4%	5%	25%	50%	75%	95%	96%	97%	98%	99%	Max
Short Call	ATM	S&P	*Price*	6.16		-437	-292	-265	-239	-237	-234	-74	65	101	101	101	101	101	101	101
			Margin	1.34	78.2	-99	-63	-59	-50	-48	-48	-17	14	21	23	23	23	24	25	26
		Nasdaq	*Price*	-16.40		-663	-468	-420	-363	-331	-322	-116	71	101	101	101	101	101	101	101
			Margin	-3.28	80.0	-128	-93	-82	-73	-70	-63	-25	14	20	23	23	23	24	24	25
	OTM	S&P	*Price*	17.33		-1270	-860	-621	-511	-477	-441	100	100	101	101	101	101	101	101	101
			Margin	1.40	91.9	-98	-52	-45	-34	-30	-29	6	7	7	8	9	9	10	11	16
		Nasdaq	*Price*	-33.15		-2204	-1369	-925	-810	-702	-656	20	100	101	101	101	101	101	101	101
			Margin	-2.24	93.2	-139	-90	-76	-67	-60	-49	2	7	8	12	12	13	14	15	22
Short Put	ATM	S&P	*Price*	24.07		-703	-607	-410	-335	-285	-248	-3	100	101	101	101	101	101	101	101
			Margin	4.62	80.8	-124	-110	-74	-60	-51	-45	-1	17	19	21	21	21	22	22	22
		Nasdaq	*Price*	25.97		-681	-474	-338	-282	-274	-228	8	100	101	101	101	101	101	101	101
			Margin	4.96	80.9	-129	-97	-71	-61	-53	-50	2	18	20	23	23	24	24	25	27
	OTM	S&P	*Price*	44.36		-1653	-1398	-793	-426	-290	-225	100	101	101	101	101	101	101	101	101
			Margin	4.37	90.1	-135	-115	-63	-40	-25	-20	8	9	10	11	11	11	12	12	12
		Nasdaq	*Price*	40.22		-1687	-1019	-689	-501	-454	-306	100	100	101	101	101	101	101	101	101
			Margin	3.77	90.6	-140	-96	-61	-44	-35	-30	8	9	10	11	12	12	12	14	15
Short Straddle	ATM	S&P	*Price*	15.90		-286	-258	-174	-145	-103	-97	-17	28	69	95	96	99	99	100	100
			Margin	6.69	57.9	-129	-113	-72	-63	-42	-40	-7	12	29	39	40	41	42	43	43
		Nasdaq	*Price*	6.22		-312	-255	-175	-171	-142	-120	-32	23	66	91	92	96	99	99	100
			Margin	2.60	58.2	-135	-118	-87	-74	-62	-56	-14	10	29	41	41	43	44	45	47

Panel C: 3 Month Short Option Positions

Position	Delta	Index	Return	Mean	Reduction%	Min	1%	2%	3%	4%	5%	25%	50%	75%	95%	96%	97%	98%	99%	Max
Short Call	**ATM**	**S&P**	*Price*	5.21		-421	-316	-287	-274	-241	-219	-61	44	101	102	102	102	102	102	102
			Margin	1.19	77.2	-89	-60	-57	-53	-50	-47	-12	9	20	22	22	22	23	24	27
		Nasdaq	*Price*	-33.72		-2469	-560	-439	-394	-315	-292	-111	39	101	101	102	102	102	102	102
			Margin	-4.76	85.9	-177	-103	-81	-67	-62	-60	-21	9	18	21	22	22	22	23	24
	OTM	**S&P**	*Price*	28.38		-965	-660	-628	-563	-497	-416	100	101	101	102	102	102	102	102	102
			Margin	1.89	93.3	-85	-48	-45	-39	-38	-36	5	7	7	9	11	12	13	15	18
		Nasdaq	*Price*	-23.51		-2469	-1167	-850	-697	-692	-614	15	100	101	102	102	102	102	102	102
			Margin	-2.68	88.6	-177	-104	-75	-63	-52	-47	2	7	7	12	13	13	15	16	22
Short Put	**ATM**	**S&P**	*Price*	27.07		-763	-549	-375	-324	-274	-225	6	100	101	101	101	101	101	102	102
			Margin	5.13	81.0	-154	-102	-73	-61	-51	-44	1	18	20	22	22	22	22	23	24
		Nasdaq	*Price*	25.23		-738	-437	-381	-321	-308	-255	-1	100	101	101	101	101	101	102	102
			Margin	5.17	79.5	-145	-82	-74	-68	-62	-59	-0	19	21	25	25	27	28	28	30
	OTM	**S&P**	*Price*	48.96		-1890	-1070	-681	-519	-292	-170	100	101	101	102	102	102	102	102	102
			Margin	5.00	89.8	-177	-103	-60	-44	-29	-15	9	10	10	12	12	13	13	14	14
		Nasdaq	*Price*	34.80		-1851	-929	-684	-575	-512	-387	100	101	101	101	101	102	102	102	102
			Margin	3.54	89.8	-163	-74	-62	-54	-51	-40	8	9	10	12	13	13	13	15	19
Short Straddle	**ATM**	**S&P**	*Price*	17.07		-368	-232	-159	-136	-99	-88	-8	33	66	89	91	93	94	96	99
			Margin	7.48	56.2	-166	-102	-70	-63	-43	-40	-3	15	27	40	41	41	43	44	47
		Nasdaq	*Price*	4.94		-331	-213	-172	-151	-146	-129	-31	19	59	92	93	96	97	99	101
			Margin	1.97	60.1	-155	-101	-74	-72	-69	-65	-13	9	26	41	43	44	46	47	49

Panel D: 6 Month Short Option Positions

Position	Delta	Index	Return	Mean	Reduction%	Min	1%	2%	3%	4%	5%	25%	50%	75%	95%	96%	97%	98%	99%	Max
Short Call	**ATM**	**S&P**	*Price*	-5.37		-304	-297	-285	-256	-235	-222	-70	29	101	103	103	103	103	103	103
			Margin	-0.82	84.8	-57	-56	-54	-48	-44	-42	-13	5	19	21	21	21	22	22	22
		Nasdaq	*Price*	-44.31		-606	-494	-405	-399	-394	-390	-149	4	101	103	103	103	103	103	103
			Margin	-7.90	82.2	-117	-90	-69	-66	-64	-64	-25	1	16	19	19	20	20	21	21
	OTM	**S&P**	*Price*	19.58		-726	-658	-586	-502	-426	-356	100	101	103	103	103	103	103	103	103
			Margin	1.48	92.4	-37	-35	-33	-32	-30	-25	5	6	7	8	8	8	8	9	9
		Nasdaq	*Price*	-27.77		-791	-699	-624	-612	-605	-604	-139	101	102	103	103	103	103	103	103
			Margin	-5.37	80.7	-117	-87	-63	-61	-60	-60	-13	6	7	13	14	15	16	17	18
Short Put	**ATM**	**S&P**	*Price*	26.63		-413	-411	-396	-347	-321	-320	-19	101	103	103	103	103	103	103	103
			Margin	5.62	78.9	-92	-92	-90	-83	-77	-72	-4	20	22	26	26	27	28	29	30
		Nasdaq	*Price*	26.86		-561	-454	-368	-348	-310	-255	21	101	103	103	103	103	103	103	103
			Margin	7.06	73.7	-99	-92	-85	-84	-75	-59	6	21	25	30	30	30	30	31	31
	OTM	**S&P**	*Price*	35.52		-909	-836	-751	-630	-567	-566	101	102	103	103	103	103	103	103	103
			Margin	3.91	89.0	-87	-87	-85	-75	-66	-57	10	11	12	14	14	14	14	14	14
		Nasdaq	*Price*	27.44		-823	-759	-707	-691	-575	-354	101	102	103	103	103	103	103	103	103
			Margin	2.92	89.4	-99	-87	-78	-76	-65	-43	10	11	12	14	15	16	18	20	22
Short Straddle	**ATM**	**S&P**	*Price*	11.66		-184	-182	-177	-158	-146	-143	-25	24	61	94	94	95	96	97	97
			Margin	5.37	53.9	-90	-89	-87	-79	-72	-66	-12	11	27	43	44	45	46	47	47
		Nasdaq	*Price*	-1.16		-281	-213	-157	-147	-135	-123	-37	14	53	91	92	93	95	95	96
			Margin	-0.34	70.8	-119	-98	-80	-72	-66	-61	-18	7	24	45	45	45	46	47	47

Chapter 2

Does Risk-Neutral Skewness Predict the Cross-Section of Equity Option Portfolio Returns?

Arditti (1967), Kraus and Litzenberger (1976), and Kane (1982) extend the mean-variance portfolio theory of Markowitz (1952) to incorporate the effect of skewness on valuation. They present a three-moment asset pricing model in which investors hold concave preferences and like positive skewness. Their results indicate that assets that decrease a portfolio's skewness (i.e., that make the portfolio returns more left-skewed) are less desirable and should command higher expected returns. Similarly, assets that increase a portfolio's skewness should generate lower expected returns. In this framework, systematic skewness explains the cross-sectional variation in stocks returns, whereas idiosyncratic skewness is unlikely to affect expected returns because investors hold the market portfolio in which idiosyncratic skewness is diversified away.[1]

Barberis and Huang (2008) demonstrate that in a model where investors have utility functions based on the cumulative prospect theory (CPT) of Tversky and Kahneman (1992), idiosyncratic skewness may be priced along with systematic skewness. Under CPT, investors overweight the tails of a probability distribution, thus capturing investors' demand for lottery-like assets with a small chance of a large gain and for insurance protecting against a small chance of a large loss. Given their preference for upside potential and dislike of large losses, CPT investors are willing to accept lower expected returns for assets with higher

[1] Arditti (1971), Friend and Westerfield (1980), Sears and Wei (1985), Barone-Adesi (1985), and Lim (1989) provide empirical and analytical tests of total and systematic skewness. Harvey and Siddique (2000) present an asset pricing model with conditional co-skewness and find that stocks with lower co-skewness outperform stocks with higher co-skewness by about 30 basis points per month. Chabi-Yo (2008, 2009) shows that use of higher order moments (skewness and kurtosis) in asset pricing models can improve performance.

idiosyncratic skewness. Mitton and Vorkink (2007) develop a model of agents with heterogeneous skewness preferences and find an equilibrium in which idiosyncratic skewness is priced.[2]

A large number of studies document that investors hold less than perfectly diversified portfolios (e.g., Blume and Friend (1975), Odean (1999), Barber and Odean (2000), Polkovnichenko (2005), and Goetzmann and Kumar (2008)), a phenomenon in contradiction with widely held beliefs regarding optimal portfolio construction.[3] The three-moment asset pricing models indicate that the contradiction may be the result of the inadequacy of the traditional mean-variance framework. In particular, if positive skewness (systematic or idiosyncratic) is a desirable characteristic of return distributions, then the fact that the simple act of diversification destroys portfolio skew (or eliminates idiosyncratic skewness) is a likely explanation of observed behavior. More specifically, investors who take into account the third-moment of the return distribution would be willing to hold a limited number of assets in their portfolios, the exact number being a function of each individual's skewness/variance preferences. Those who are most concerned with skew (variance) will hold a relatively small (large) number of assets in their portfolios.[4]

Earlier studies test the significance of the *physical* measure of skewness in predicting the cross-sectional variation in stock returns. The literature, however, has not yet reached an agreement on the existence of a negative relation between skewness and expected returns

[2]Kumar (2009) shows that certain groups of individual investors appear to exhibit a preference for lottery-type stocks, which he defines as low-priced stocks with high idiosyncratic volatility and high idiosyncratic skewness. Bali, Cakici, and Whitelaw (2011) document a statistically and economically significant relation between lagged extreme positive returns (proxying for demand for lottery-like stocks) and the cross-section of future stock returns.

[3]Blume and Friend (1975) find that the average number of securities held in the portfolio of a typical investor is about 3.41. Barber and Odean (2000) report that the mean household's portfolio contains only 4.3 stocks and the median household invests in only 2.61 stocks. Both studies indicate that most individuals hold a very small number of stocks in their portfolios.

[4]Simkowitz and Beedles (1978) and Conine and Tamarkin (1981) show that investors who take into account the third-moment of the return distribution may optimally choose to remain underdiversified. Mitton and Vorkink (2007) and Goetzmann and Kumar (2008) indicate that similar to retail investors, less diversified institutions may trade expected returns for skewness.

on individual stocks. Due to the fact that the skewness of the distribution of future returns is not observable, different approaches used by previous studies to estimate the physical measure of skewness are largely responsible for the conflicting empirical evidence. It is well known that computing high moments of the distribution of future returns is a difficult task, as knowledge of the exact physical return distribution is unattainable. To estimate higher order moments, one can either make assumptions regarding the distribution of future returns (e.g. using the assumption that returns are log-normally distributed), in which case the assumed distribution is likely to be incorrect, or one can use purely empirical techniques, which require a very long sample and stationarity of the distribution to produce reasonable estimates.

To mitigate the issues of measurement error in skewness, I use a distribution-free risk-neutral measure of skewness developed by Bakshi and Madan (2000) and Bakshi, Kapadia, and Madan (2003) (BKM) that can be obtained from prices of actively traded options and does not rely on any particular assumptions about the return distribution. Suppose an investor wants to estimate the skewness of the distribution of the one-month ahead returns of a financial security. Under the physical measure, an estimate can only be obtained from historical data (e.g., daily returns over the past one month or one year) and the investor has to use this historical measure to proxy for future skewness. However, this physical (or historical) measure does not reflect the market's view of the skewness of future returns.[5] Using options' implied measures of skewness solves this problem by making the skewness of the distribution of future returns observable, as option prices incorporate the market's perception of this distribution.

This paper tests for positive skewness preference in the cross-section of asset returns by investigating the relation between implied skewness, derived from option prices, and expected

[5] In an unreported analysis, I find that physical skewness, measured as the the skewness of daily returns over the past one year, fails to predict future equity and equity/option portfolio returns.

future equity/option portfolio returns. Stock option prices are determined by the market's view of the risk-neutral distribution of the stock price at option expiration. The most basic option pricing model, introduced by Black and Scholes (1973), assumes that the risk-neutral distribution of the future stock price is log-normal. Under the Black-Scholes model, all that is needed to price an option is the volatility of the underlying stock. Alternatively, given the option price, one can infer the volatility parameter (implied volatility) of the lognormal distribution that the market believes describes the risk-neutral distribution of the future stock price. The main drawback of the Black-Scholes model is that it does not fit actual market data very well. Several authors have documented higher implied volatilities for options with strikes that are far away from the at-the-money (ATM) strike, a phenomenon known as the volatility smile or smirk (e.g. Rubinstein (1994)). Different implied volatilities at different strikes are an indication that the market views the log-normal assumption underlying the Black-Scholes model as incorrect. Therefore, higher order moments of the market-implied risk-neutral distribution cannot be determined by the log-normal distribution.

I examine the predictive power of options' implied skewness in the cross-sectional pricing of stocks and options. I form *skewness assets*, comprised of two option positions and a stock position in quantities such that the assets have no exposure to changes in the price of the underlying stock (delta neutrality) and no exposure to changes in the implied volatility of the stock (vega neutrality), isolating the effect of risk-neutral skewness. The value of the assets will increase (decrease) if the implied skewness of the risk-neutral distribution of the underlying security increases (decreases). Equivalently, the assets will realize a positive (negative) abonormal return when held to expiration if the implied skewness is too low (high). Thus, a long position in the skewness asset for a stock constitutes a long skewness position for that stock. The purpose of the skewness assets is to isolate the effect of skewness in asset returns. The skewness assets' returns are very sensitive to large moves in the underlying stock (tails of the distribution of returns, i.e. skewness) and insensitive to small stock movements. The assets therefore isolate and magnify the effect of skewness in the cross-section of equity/option portfolio returns.

I analyze the cross-sectional relation between the returns of the skewness assets and implied risk-neutral skewness, estimated from option prices using the BKM model-free methodology. The results indicate a strong, negative relation between implied risk-neutral skewness and skewness asset returns, implying a preference for positively skewed assets (investors accept a lower expected return on assets with positive skewness). I show that the cross-sectional return pattern is due to the market's evaluation of the left side of the risk-neutral distribution. Specifically, I find that the negative relation between implied risk-neutral skewness and skewness asset returns exists when the skewness assets are created using OTM and ATM puts (put prices are affected only by left side of risk-neutral distribution), but the relation disappears when trading OTM and ATM calls (call prices are affected only by right side of risk-neutral distribution). I find very little evidence that the observed return pattern is due to compensation for exposure to previously established priced risk factors.

This research extends that of previous researchers who have analyzed volatility in the cross-section of options. Most related to this paper is the work of Goyal and Saretto (2009), who form volatility assets (straddles and delta-hedged calls) and find a positive relation between volatility returns and the difference between historical realized volatility and implied volatility (HV-IV). Cao and Han (2009) find that delta-hedged option returns are negative for most stocks, and decrease with total and idiosyncratic volatility. Conrad, Dittmar, and Ghysels (2009) and Xing, Zhang, and Zhao (2010) investigate the power of implied risk-neutral skewness to predict future stock returns. I employ methodologies similar to Goyal and Saretto (2009) to examine the cross-sectional pricing of options with respect to the third moment (skewness) of the implied risk-neutral distribution. To my knowledge, this is the first paper using option returns to investigate the pricing of implied-skewness in the cross-section of stocks and options.

The remainder of this paper is organized as follows. Section 1 describes the creation of the skewness assets. Section 2 describes the main variables and presents the data. Section 3 demonstrates the strong negative relation between implied risk-neutral skewness and skewness asset returns. In section 4, I check the robustness of the main result to the inclusion of several different control variables. Section 5 investigates a potential risk-based explanation of my findings. Section 6 concludes.

1 Skewness Assets

Skewness, at its core, measures the asymmetry of a probability density. Non-zero skewness of the risk-neutral density of future stock returns may result due to relatively high risk-neutral probabilities of a large up-move in the stock (positive skewness) or high risk-neutral probabilities of a down-move in a stock (negative skewness). To analyze the pricing of implied risk-neutral skewness in the market for stock options, I create three types of skewness assets for each stock/expiration combination. Each different type of skewness asset is intended to test the stock-option market's pricing of a specific portion of the risk-neutral stock return density. The skewness assets are designed to increase in value if risk-neutral skewness increases, and thus represent long skewness positions. When held until expiration, the skewness assets will realize high (low) payoffs when high (low) stock returns are realized, but are largely insensitive to small stock moves. To isolate the effects of skewness, it is necessary to remove exposure to changes in other moments of the risk-neutral distribution. To this end, the skewness assets are constructed so that the value of the asset will not change due to an increase in the mean (delta neutral) or volatility (vega neutral) of the risk-neutral distribution of the underlying stock's returns. The skewness assets are created on the second trading day following each monthly option expiration, and are held to expiration.[6]

To construct the skewness assets, I begin by finding the ATM put and call contracts. I define the ATM put (call) contract to be the contract with a delta closest to -0.5 (0.5).[7] I use delta to identify the ATM contracts instead of finding the strike that is closest to the spot (or forward) price for two reasons. First, because many of the stocks in the data set pay dividends, the spot price may not be close to the mean of the distribution of the stock price at expiration. Second, the deltas calculated by OptionMetrics come from the Cox et al. (1979) (CRR) binomial tree model, which handles not only dividends, but also the possibility of early exercise.

I define the OTM put (call) contract to be the contract with a delta closest to -0.1 (0.1).[8,9] I require that the strike of the OTM put (call) be lower (higher) than the strike of the ATM put (call). If data for any of the 4 required options are not available for a given stock/expiration combination, that observation is omitted from the analyses. I define K to be the strike price of an option, Δ to be the delta of an option, υ to represent the vega of an option, and IV to represent the implied volatility of an option. All deltas, vegas, and implied volatilities come from the OptionMetrics database. I use subscripts of the form $OptionType, Moneyness$ to indicate which option I am referring to. For example, $\Delta_{P,OTM}$ refers to the delta of the OTM put contract.

[6] I avoid using the expiration date because of potential microstructure noise in option prices arising due to the expiration. I use the first trading date following expiration to calculate the signal. To allow a one day lag between signal generation and portfolio inception, I enter into the portfolios on the second trading day following the monthly option expiration. This methodology follows that of Goyal and Saretto (2009).

[7] It is worth noting that the ATM put and ATM call may not have the same strike.

[8] As will be discussed later in the paper, my main findings remain intact when the OTM put (call) contract is defined with a delta closest to -0.2 (0.2).

[9] I target a specific delta, instead of a specific price/strike ratio, for the OTM option so that the OTM options have strike prices at approximately the same location in the cumulative distribution function of the future stock returns. I use a simple example to exemplify this. Imagine two stocks, both priced at $50, one with a 50% volatility and the other with a 10% volatility. Assuming normally distributed returns, options with strike prices of 25 (45) for the 50% volatility (10% volatility) stock both have strikes that are one standard deviation below the current stock price, and thus the strikes are placed at the same point in the cumulative distribution function of their respective stocks, and thus would have the same delta. The goal in targeting a specific delta therefore is to construct the skewness assets similarly across all stocks.

1.1 PUTCALL Asset

The first skewness asset, which I call the PUTCALL asset, is designed to change value if there is a change in the skewness of the risk-neutral return density coming from a change in either the left or right tail of the risk-neutral density. The PUTCALL asset consists of a position of $Pos^{PC}_{C,OTM} = 1$ contract of the OTM call, a position of $Pos^{PC}_{P,OTM} = \frac{-v_{C,OTM}}{v_{P,OTM}}$ contracts (a short position) in the OTM put, and a stock position of $Pos^{PC}_{S} = -\left(Pos^{PC}_{C,OTM}\Delta_{C,OTM} + Pos^{PC}_{P,OTM}\Delta_{P,OTM}\right)$ shares of the underlying stock.[10] The position in the OTM put is designed to completely remove any exposure of the PUTCALL asset to changes in implied volatility of the underlying security (vega neutral), as the sum of the vega exposures of the options times the position sizes is zero. Thus, if the implied volatility of the OTM put and OTM call in the asset both increase by the same amount, the value of the asset will not change. The position in the stock is designed to remove any exposure to changes in the price of the underlying stock (delta neutral), and thus is set to the negative of the sum of the option delta exposures times the position sizes.

To see that a long position in the PUTCALL asset is in fact a long skewness position, imagine a shift in the risk neutral density of future stock returns such that the probabilities in the right tail of the density increase, but those in the left tail remain unchanged. Such a change corresponds to an increase in the skewness of the risk-neutral density. These changes will also cause the OTM call to increase in value, and will have no affect on the value of the OTM put. Thus, all else equal, the value of the PUTCALL asset will increase with an increase in the skewness of the risk-neutral density. Now imagine an increase in the left tail probabilities, with the right tail probabilities remaining the same. This change corresponds to a decrease in the skewness of the density, and will thus increase the value of the OTM put. The short position in the OTM put results in a decrease in the value of the PUTCALL

[10]The superscript PC represents the PUTCALL asset, and the subscript C,OTM represents the OTM call contract. Other superscripts and subscripts have analogous meanings.

asset. Thus, the PUTCALL asset does in fact represent a long skewness position, and the value of the PUTCALL asset will change based on changes in the left or right tail of the risk-neutral density of the underlying stock.

One may argue that the PUTCALL assets are only truly skewness assets at the time of construction because the hedges only hold instantaneously. However, the assets are designed to not only represent skewness position in a continuous time framework, but also in the context of a one-period model (time 0 is when the portfolios are formed, time 1 is option expiraiton). When held until expiration the PUTCALL asset will realize high (low) *payoffs* when extremely high (low) stock returns are realized. *Returns* of the skewness assets, however, are determined not only by the return of the underlying stock, but by the prices of the options comprising the assets. For example, two stocks with equivalent stock returns may have different PUTCALL asset returns because for one stock the OTM call was relatively expensive, while for the other it was cheap. What can be said about returns is that the returns of the PUTCALL assets will be, on average, positive, if high (low) stock returns are realized with a higher (lower) probability than would be indicated by the risk-neutral distribution used to price the options. The reverse is true for negative PUTCALL asset returns.[11]

When applied to the cross-section of PUTCALL asset returns, a negative relation between risk-neutral implied skewness and future skewness asset returns (the main finding of this paper) will occur if the difference between the realized probabilities (physical distribution) and the implied probabilities (risk-neutral distribution) of very high stock returns (physical probability - risk-neutral probability) is higher for low implied skewness stocks than for high implied skewness stocks, or if the physical - implied probabilities of large negative

[11]It is also worth mentioning that the methodology of creating volatility assets (straddles, delta-hedged calls/puts) and holding for a prolonged period of time is well established in the literature. The methodology used in this paper is exactly the same as that of Goyal and Saretto (2009). Coval and Shumway (2001) analyze the weekly returns of call and put options.

stock returns is lower for low implied skewness stocks than for high implied skewness stocks. Therefore, the negative cross-sectional relation between risk-neutral skewness and skewness asset returns is evidence of the market's pricing of skewness risk. Assets with low implied skewness (large probabilities of large losses) realize, on average, higher excess returns than assets with high implied skewness (relatively large probabilities of large gains, or equivalently relatively small probabilities of large losses).

1.2 PUT Asset

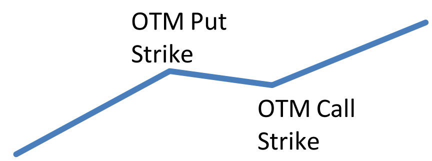
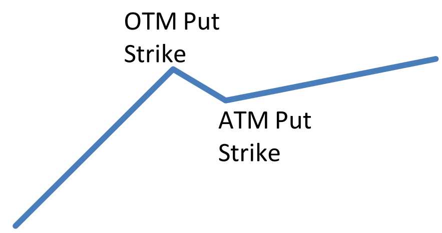
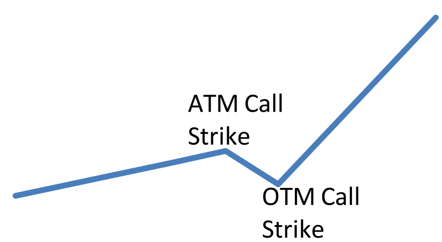
The PUT asset consists of a position of $Pos^{P}_{P,OTM} = -1$ contract of the OTM put, a position of $Pos^{P}_{P,ATM} = \frac{\upsilon_{P,OTM}}{\upsilon_{P,ATM}}$ contracts of the ATM put, and a stock position of $Pos^{P}_{S} = -\left(Pos^{P}_{P,OTM}\Delta_{P,OTM} + Pos^{P}_{P,ATM}\Delta_{P,ATM}\right)$ shares. As with the PUTCALL asset, the PUT asset is, by construction, long skewness, and the position sizes are designed to remove delta and vega exposure. The main difference between the PUT asset and the PUTCALL asset is that the value of the PUT asset changes only with a change of the probabilities of the left half of the risk-neutral density. Holding the total probability of the risk-neutral density to the left of the ATM put strike constant, a decrease (increase) in the risk-neutral probability of a large down-move in the stock and corresponding increase (decrease) of a small down move in the stock would correspond to a positive (negative) change in the skewness of the risk-neutral density, and also an increase (decrease) in the value of the PUT asset, as the value of the OTM put contract will decrease (increase) more than the value of the ATM put contract. Any changes to the risk-neutral density for prices higher than the strike of the ATM put have no effect on the value of the PUT asset. The PUT asset therefore represents a long skewness position, and its value will change only due to changes in the left side of the risk-neutral distribution. Held until expiration, a negative cross-sectional relation between risk-neutral skewness and future PUT asset returns will be realized if the physical-implied probabilities of large negative stock returns is lower for low implied skewness stocks than for high implied skewness stocks. The PUT asset is insensitive to large positive underlying stock returns.

1.3 CALL Asset

The final skewness asset, which I name the CALL asset, consists of a position of $Pos^C_{C,OTM} = 1$ contract of the OTM call, a position of $Pos^C_{C,ATM} = \frac{-\upsilon_{C,OTM}}{\upsilon_{C,ATM}}$ contracts of the ATM call, and a stock position of $Pos^C_S = -\left(Pos^C_{C,OTM}\Delta_{C,OTM} + Pos^C_{C,ATM}\Delta_{C,ATM}\right)$ shares. As with the other assets, the CALL asset is delta and vega neutral, and is by construction long skewness. To see this, one must simply invert the arguments made for the PUT asset. If the probabilities of large up moves in the stock increase, with a corresponding decrease in the probabilities of a small up move, then the skewness of the risk-neutral distribution increases, as does the value of the CALL asset, as the OTM call increases in value more than the ATM call. Thus, the CALL asset represents a long skewness position, and its value is determined only by the right side of the risk-neutral density. A negative cross-sectional relation between risk-neutral skewness and future CALL asset returns is realized if the physical-implied probabilities of large positive stock returns is higher for low implied skewness stocks than for high implied skewness stocks. The CALL asset is insensitive to large negative underlying stock returns.

Figure 2.1 provides a summary of the skewness assets, along with diagrams depicting the shape of the payoff functions for each asset. Notice that the PUTCALL asset has a low payoff when the stock price at expiration is low, and a high payoff when the stock price at expiration is high. Thus, if the stock realizes a large up-move (down-move) with higher probability than the market had initially assessed, then the asset will, on average, realize a positive (negative) abnormal return. The PUT asset has a similar payoff function, but its payoff is not as sensitive to large up-moves, only to large down-moves. The payoff for the CALL asset is the same as the PUT asset payoff rotated 180 degrees about the ATM strike. Thus, the CALL asset payoff is most sensitive to large up-moves in the stock price.

Figure 2.1: Summary of Skewness Assets

	Positions	Detects Pricing Of:	Payoff Function
PUTCALL Asset	Long 1 OTM Call Short OTM Puts (hedges vega) Short Stock (hedges delta)	Either the extreme left tail, extreme right tail, or both tails of the risk-neutral distribution.	
PUT Asset	Short 1 OTM Put Long ATM Puts (hedges vega) Long Stock (hedges delta)	The left side of the risk-neutral distribution.	
CALL Asset	Long 1 OTM Call Short ATM Calls (hedges vega) Long Stock (hedges delta)	The right side of the risk-neutral distribution.	

With all assets, a large up-move (down-move) in the stock price corresponds to a high (low) payoff. If the risk-neutral probabilities of such moves, as priced by the options market, were the same as the physical probabilities, then the assets should realize, on average, zero abnormal returns. Any pattern in the returns of the skewness asset must therefore be viewed as difference between the risk-neutral and physical distribution, and thus as compensation for risk.

2 Data and Variables

Data used in this paper come from IvyDB's OptionMetrics database. OptionMetrics provides options price data and Greeks for the period from January 1, 1996 through October 31, 2010. I include in my dataset all options for securities listed as common stocks in the OptionMetrics database. I use option data only from the first and second days following the monthly option expirations. The data from the first day after expiration are used to calculate the implied risk-neutral skewness, which is used as the signal. The data from the second day after expiration are used to determine the prices for the skewness assets. I use stock data, also from OptionMetrics, from those same dates as well as the expiration date of the options being considered.[12] The stock price at expiration is used to calculate the payoff of the skewness asset. I remove options with a missing bid price or offer price, a bid price less than or equal to zero, an offer price less than or equal to the bid price, a spread (offer price - bid price) less than the minimum spread ($0.05 for options with prices less than $3.00, $0.10 for options with prices greater than or equal to $3.00). I take the price of an option to be the average of the bid and offer prices. The analyses presented in this paper are done on monthly data. I also remove options where the special settlement flag in the OptionMetrics database is set, and options where there are multiple entries for a call or put options with the same underlyer/strike/expiration combination on the same date. Finally, I remove options that violate basic arbitrage conditions.[13] When creating the skewness assets, options with missing or bad Greeks or implied volatilities are removed, as the Greeks (delta and vega) are necessary to create the skewness assets. There are 178 months of data used in the analysis, leading to 177 monthly return periods, as the first month's data is needed for

[12] I use the term expiration date to refer to the last trading day before the expiration of the option. The options considered in this paper expire on the Saturday following the third Friday of each month. Thus, the last trading day for an option is usually the Friday before its expiration, or the third Friday of the month.

[13] For calls, I require that the bid price be less than the spot price and the offer price at least as large as the spot price minus the strike. For puts, I require that the bid price be less than the strike and that offer price be at least as large as the strike price minus the spot price.

signal generation and asset creation.

The OptionMetrics data is augmented with stock price and return data for 1995 from the Center for Research in Security Prices (CRSP). OptionMetrics and CRSP stocks are matched using CUSIP numbers. Several of the robustness analyses use 1 year previous returns as control variables. Using CRSP allows me to include option data from 1996 in these analyses. For a stock/expiration combination to gain entry into the sample, I require that stock return data be available (from OptionMetrics or from CRSP) for each trading day beginning 1 year before the signal generation date and ending on the option expiration date.

The two main variables to be used in this paper are the option implied skewness of the risk-neutral distribution of future stock returns ($RNSkew$) and the returns of the skewness assets. $RNSkew$ is calculated using a discretized version of the methodology of BKM. The returns of the skewness assets are calculated following Goyal and Saretto (2009), who calculate the asset return as the profits from the asset divided by the absolute value of the asset price. The remainder of this section describes these variables.

2.1 *RNSkew*

Each month, I use the methodology of BKM to calculate the option implied skewness of the risk-neutral density for each stock/expiration combination on the first trading day after the monthly expiration. BKM demonstrate that, assuming a continuum of option strikes are available, the risk-neutral skewness of the distribution of the rate of return realized on the underlying stock from the time of calculation until the expiration of the options is

$$RNSkew = \frac{e^{rt}\left(W - 3\mu V\right) + 2\mu^3}{\left(e^{rt}V - \mu^2\right)^{\frac{3}{2}}} \tag{1}$$

where $\mu = e^{rt} - 1 - \frac{e^{rt}}{2}V - \frac{e^{rt}}{6}W - \frac{e^{rt}}{24}X$, and V, W, and X are given by equations (7), (8), and (9) in BKM. Here, r is the risk free rate on a deposit to be withdrawn at expiration, and t is the time, in years, until expiration.[14] The calculations of V, W, and X are based on weighted integrals of the prices of OTM calls and puts, where the integrals are taken over all OTM strike prices. In the real world however, a continuum of strikes is not available, thus V, W, and X must be calculated using whatever data is available from the option market. Equation (31) of BKM provides a discrete strike formula for calculating W, and discrete versions of V and X can be created analogously, as described in BKM. In calculating $RNSkew$, I modify these discrete formulae slightly. First, instead of using the current spot price in the calculations, I use the spot price minus the present value of all dividends with ex-dates on or before the expiration date ($PVDivs$).[15] Second, the discrete formulae in BKM assume that option prices are available with strikes that are equally spaced above and below the current spot price. I modify the formulae slightly to allow the use of all available options data. Thus, I define V, W, and X as

$$V = \sum_{i=1}^{n^C} \frac{2\left(1 - ln\left[\frac{K_i^C}{Spot^*}\right]\right)}{\left(K_i^C\right)^2} Call\left(K_i^C\right)\Delta K_i^C + \sum_{i=1}^{n^P} \frac{2\left(1 + ln\left[\frac{Spot^*}{K_i^P}\right]\right)}{\left(K_i^P\right)^2} Put\left(K_i^P\right)\Delta K_i^P \qquad (2)$$

$$W = \sum_{i=1}^{n^C} \frac{6ln\left[\frac{K_i^C}{Spot^*}\right] - 3ln\left[\frac{K_i^C}{Spot^*}\right]^2}{\left(K_i^C\right)^2} Call\left(K_i^C\right)\Delta K_i^C - \sum_{i=1}^{n^P} \frac{6ln\left[\frac{Spot^*}{K_i^P}\right] + 3ln\left[\frac{Spot^*}{K_i^P}\right]^2}{\left(K_i^P\right)^2} Put\left(K_i^P\right)\Delta K_i^P \qquad (3)$$

[14]Calculation of the applicable risk-free rate is described in Appendix 2A.

[15]Calculation of the present value of dividends is described in Appendix 2A.

$$X=\sum_{i=1}^{n^C}\frac{12ln\left[\frac{K_i^C}{Spot^*}\right]^2-4ln\left[\frac{K_i^C}{Spot^*}\right]^3}{\left(K_i^C\right)^2}Call\left(K_i^C\right)\Delta K_i^C-\sum_{i=1}^{n^P}\frac{12ln\left[\frac{Spot^*}{K_i^P}\right]^2+4ln\left[\frac{Spot^*}{K_i^P}\right]^3}{\left(K_i^P\right)^2}Put\left(K_i^P\right)\Delta K_i^P \tag{4}$$

where i indexes the OTM call and put options with available price data. In the calculations, I set $Spot^* = Spot - PVDivs$. $Spot$ is the closing price of the stock, K_i^P (K_i^C) is the strike of the i^{th} OTM put (call) option when the strikes are ordered in decreasing (increasing) order, $Put\left(K_i^P\right)$ ($Call\left(K_i^C\right)$) is the price of the put (call) option with strike K_i^P (K_i^C), and n^P (n^C) is the number of OTM puts (calls) for which valid prices are available. Finally, I set $\Delta K_i^P = K_{i-1}^P - K_i^P$ for $2 \leq i \leq n^P$, $\Delta K_1^P = Spot^* - K_1^P$, $\Delta K_i^C = K_i^C - K_{i-1}^C$ for $2 \leq i \leq n^C$, and $\Delta K_1^C = K_1^C - Spot^*$. Allowing the ΔK to vary for each option relaxes the assumption in the BKM formulae that prices are available for options with fixed intervals between strikes.

Each month, on the first trading day after the monthly expiration, I calculate $RNSkew$ for each stock/expiration combination. In each calculation, I require that a minimum of 2 OTM puts and 2 OTM calls have valid prices. If not enough data is available, the observation is discarded.

2.2 Skewness Asset Returns

Skewness asset returns are calculated following Goyal and Saretto (2009). The return for a skewness asset is calculated as the total profits resulting from holding the asset until expiration divided by the absolute value of the initial price of the asset. I use the absolute value of the skewness asset price because the price of the skewness assets is not guaranteed to be positive. The profits realized from holding a skewness asset are simply the difference between the payoff of the asset at option expiration and the total price paid for all positions comprising the asset. The payoff includes any dividends received or paid out on the stock position inside the asset. Dividends accrue interest at the risk-free rate from the pay-date of the dividend until option expiration. All ensuing analyses use the excess return, not the simple return, of the skewness assets. Thus, I define the excess return for a skewness asset as

$$Ret = \frac{Payoff - Price}{|Price|} - \left(e^{rt} - 1\right) \tag{5}$$

where $Price$ is the sum of the position sizes times the market prices for the securities comprising the asset, calculated at the time of asset creation, and $Payoff$ is the sum of the payoffs, at expiration, of all positions comprising the asset.

2.3 Summary Statistics

To create the sample, I begin with all securities listed as common stocks in the OptionMetrics database. I remove from the sample all stock/expiration observations with less than 2 OTM puts or 2 OTM calls to calculate $RNSkew$, and observations where there was not enough data on the asset creation date to create and calculate returns for all 3 assets. The main sample uses only 1 month options to calculate $RNSkew$ and create the skewness assets.[16] This sample consists of 57,535 stock/month observations over the 177 monthly expirations from February 1996 through October 2010.

Summary statistics for asset characteristics and excess returns, along with $RNSkew$ and market capitalization of the sample are presented in Table 2.1. Market capitalization is calculated on the first day after the monthly expiration (the same day as the calculation of $RNSkew$). All values are taken to be the time-series average of monthly values taken in the

[16] As will be discussed later in the paper, my main findings remain intact when I repeat my analyses using 2-month options.

cross-section of stocks.

Table 2.1 illustrates that, on average, each of the skewness assets has a negative average excess return. The average monthly minimum return is -87.05% for the PUTCALL asset and around -100% for the PUT and CALL assets, and the maximums range from an average of 57.51% for the PUT asset to 138.24% for the CALL asset. Only a very small portion of the sample exhibits absolute returns in excess of 100%. It is worth noting that because the assets contain short option positions, they are not limited liability assets, and thus they may realize losses in excess of 100%.[17] The positions sizes of the securities comprising the assets and the deltas of the options in the assets exhibit significant variation. Even though an absolute delta of 0.1 (0.5) was targeted for OTM (ATM) options in the creation of the asset, this was not always attainable due to the limitations of using actual market data. The average absolute delta for the OTM options is slightly higher than targeted, potentially indicating a lack of valid prices for far OTM options. The average delta for the ATM options is very close to the target, but significant variation exists. Additionally, there is significant variation in the stock position in each of the assets.

$RNSkew$ varies from an average monthly minimum of -5.29 to an average monthly maximum of 1.60, with a mean of -1.19 and a median of -1.09. Slightly fewer than 5% of the stocks, on average, exhibit positive $RNSkew$. Finally, and perhaps most importantly, Table 1 indicates that the sample consists mostly of large capitalization stocks. The mean (median) market capitalization for the stocks in the sample is more than \$12.1 (\$3.4) billion. There are however, some small stocks included in the sample.

[17] One may be concerned that due to the construction of the assets and the fact that they are not limited liability, margin requirements may have a large effect on the returns of these assets. I will demonstrate that using a margin-requirement based return calculation produces qualitatively similar results to the price based return calculation.

Table 2.1: Summary Statistics for Skewness Assets, Implied Skewness, and Size
This table shows the mean, minimum, maximum, and 5th, 25th, 50th, 75th, and 95th percentiles of the excess returns of the skewness assets along with the size of the positions and deltas of the options comprising the skewness assets. Also shown are statistics for the implied skewness (*RNSkew*) and market capitalization of the stocks in the sample. All values are calculated as the time-series average of the monthly cross-sectional percentiles or mean. Returns are shown in percent. The sample consists of skewness assets formed using options expiring from February 1996 through October 2010. The skewness assets are formed on the second trading day following the expiration date that comes 1 month before the expiration of the options and held until expiration. *RNSkew* and market capitalization are calculated for each stock on the day before skewness asset formation.

PUTCALL Asset	**Mean**	**Min**	**5%**	**25%**	**50%**	**75%**	**95%**	**Max**
Excess Return	-0.76	-87.05	-18.83	-6.75	-0.52	5.64	16.19	78.15
OTM Put Position	-1.22	-3.98	-2.24	-1.50	-1.11	-0.83	-0.55	-0.33
Stock Position	-0.25	-0.61	-0.46	-0.31	-0.23	-0.17	-0.12	-0.08
OTM Call Delta	0.13	0.04	0.06	0.08	0.11	0.16	0.27	0.38
OTM Put Delta	-0.11	-0.34	-0.21	-0.13	-0.10	-0.08	-0.05	-0.03
PUT Asset	**Mean**	**Min**	**5%**	**25%**	**50%**	**75%**	**95%**	**Max**
Excess Return	-0.02	-103.65	-17.44	-7.15	-1.03	6.73	22.42	57.51
ATM Put Position	0.47	0.17	0.27	0.37	0.45	0.55	0.74	0.96
Stock Position	0.13	0.03	0.06	0.09	0.12	0.15	0.22	0.42
OTM Put Delta	-0.11	-0.34	-0.21	-0.13	-0.10	-0.08	-0.05	-0.03
ATM Put Delta	-0.50	-0.77	-0.65	-0.57	-0.50	-0.43	-0.35	-0.23
CALL Asset	**Mean**	**Min**	**5%**	**25%**	**50%**	**75%**	**95%**	**Max**
Excess Return	-0.83	-102.95	-32.86	-9.35	1.38	9.11	22.05	138.24
ATM Call Position	-0.52	-0.98	-0.84	-0.63	-0.50	-0.40	-0.29	-0.20
Stock Position	0.13	0.03	0.06	0.09	0.12	0.16	0.24	0.47
OTM Call Delta	0.13	0.04	0.06	0.08	0.11	0.16	0.27	0.38
ATM Call Delta	0.50	0.24	0.35	0.43	0.50	0.57	0.66	0.79
All Assets	**Mean**	**Min**	**5%**	**25%**	**50%**	**75%**	**95%**	**Max**
RNSkew	-1.19	-5.29	-2.71	-1.63	-1.09	-0.64	-0.00	1.60
MktCap $mm	12151	157	426	1241	3489	10502	52320	273878

3 Portfolio Analysis

I begin my analysis of the skewness asset returns by forming monthly portfolios of the skewness assets based on deciles of *RNSkew*. Each month, on the day after the monthly option expiration, *RNSkew* for each stock is calculated using 1-month options. On the second day after the monthly expiration, portfolios of skewness assets are formed on deciles of *RNSkew* skewness. The portfolios are held until the next monthly expiration, at which time the option positions in the skewness assets expire. For example, the July 1996 expiration falls on the 20^{th} day of the month (all expirations are Saturdays), and the August 1996 expiration falls on the 17^{th} day of August. Thus, on Monday July 22nd (the first trading day after the July expiration), I calculate $RNSkew$. Then, on Tuesday, July 23rd, we create the skewness assets using options that expire on August 17^{th}. The skewness assets are sorted into portfolios based on deciles of $RNSkew$ as calculated on the previous day. The portfolios are held, unchanged, until the options expire on August 17^{th} (actually August 16^{th} as this is the last trading day before expiration). By using a risk-neutral options' implied measure of skewness to investigate the cross-sectional predictability of stock/option portfolio returns, I am able to accurately measure the market's view of the skewness of the distribution of *future* returns.

Table 2.2 shows the equal-weighted average raw returns, along with CAPM (CAPM), Fama-French 3-factor (FF3 Alpha) and Fama-French-Carhart 4-factor (FFC4 Alpha) alphas from the regression of the decile portfolio returns on a constant, the excess market return (MKT), a size factor (SMB), a book-to-market factor (HML), and a momentum factor (UMD), following Fama and French (1993) and Carhart (1997).[18,19] The 10-1 column represents the raw and risk-adjusted returns for the portfolio that is long skewness assets for decile 10 of $RNSkew$ and short skewness assets for decile 1. The 10-1 t-stat column is the t-statistic testing the null hypothesis that the average 10-1 return, CAPM alpha, FF3 alpha, and FFC4 alpha is equal to zero. The t-statistics are adjusted using Newey and West (1987) with lag of 6 months.

[18] The MKT (market) factor is the excess return on the stock market portfolio proxied by the value-weighted CRSP index. The SMB (small minus big) factor is the difference between the returns on the portfolio of small size stocks and the returns on the portfolio of large size stocks. The HML (high minus low) factor is the difference between the returns on the portfolio of high book-to-market stocks and the returns on the portfolio of low book-to-market stocks. The UMD (winner minus loser) factor is the difference between the returns on the portfolio of stocks with higher past 2-month to 12-month cumulative returns (winners) and the returns on the portfolio of stocks with lower past 2-month to 12-month cumulative returns (losers).

[19] As the holding period for the skewness assets does not conform to the standard calendar month holding period, I calculate the monthly returns for each of the Fama-French-Carhart factors during the holding period for the skewness assets using the daily Fama-French-Carhart factor return data.

Table 2.2: Relation between Risk-Neutral Skewness and Future Returns
This table shows the average monthly returns for portfolios of skewness assets formed on deciles of $RNSkew$. $RNSkew$ is calculated for each stock on the first trading day after each monthly expiration using the options that expire in the next month. The skewness assets are formed on the second day after each monthly expiration using options that expire in the next month, and sorted into portfolios on that same day. The skewness assets are held until expiration. The table shows raw excess returns (Excess Return), along with CAPM (CAPM Alpha), Fama-French 3-factor (FF3 Alpha), and Fama-French-Carhart 4-factor alphas (FFC4 Alpha). The 10-1 column represents the difference between the returns for decile 10 and decile 1. The 10-1 t-stat column is the t-statistic testing the null hypothesis that the average 10-1 excess return, CAPM alpha, FF3 alpha, or FFC4 alpha is equal to zero. The t-statistics are adjusted using Newey and West (1987) with lag of 6 months. The sample covers the period January 1996 through October 2010.

PUTCALL Asset	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**10-1**	**10-1 t-stat**
Excess Return	-0.13	-0.28	-0.30	-0.81	-0.57	-0.58	-1.05	-0.97	-1.34	-1.59	-1.46	-4.74
CAPM Alpha	-0.02	-0.18	-0.25	-0.72	-0.54	-0.57	-1.03	-0.96	-1.34	-1.56	-1.54	-5.31
FF3 Alpha	-0.05	-0.20	-0.27	-0.77	-0.57	-0.63	-1.12	-1.04	-1.43	-1.60	-1.55	-5.22
FFC4 Alpha	-0.04	-0.24	-0.31	-0.80	-0.66	-0.61	-1.14	-1.09	-1.47	-1.69	-1.65	-5.52
PUT Asset	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**10-1**	**10-1 t-stat**
Excess Return	0.88	0.41	0.42	-0.22	0.00	-0.04	-0.45	-0.32	-0.70	-0.22	-1.09	-2.67
CAPM Alpha	1.00	0.50	0.49	-0.13	0.04	-0.04	-0.42	-0.32	-0.74	-0.21	-1.21	-2.95
FF3 Alpha	1.02	0.50	0.52	-0.13	0.05	-0.05	-0.48	-0.37	-0.79	-0.23	-1.25	-3.09
FFC4 Alpha	1.03	0.47	0.46	-0.12	-0.05	-0.04	-0.49	-0.41	-0.86	-0.30	-1.34	-3.38
CALL Asset	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**10-1**	**10-1 t-stat**
Excess Return	-1.31	-0.68	-0.51	-0.91	-0.55	-0.39	-0.78	-0.42	-0.86	-1.83	-0.52	-1.03
CAPM Alpha	-1.23	-0.63	-0.50	-0.80	-0.54	-0.34	-0.74	-0.41	-0.78	-1.76	-0.53	-1.13
FF3 Alpha	-1.35	-0.70	-0.57	-0.94	-0.59	-0.44	-0.86	-0.50	-0.91	-1.81	-0.46	-0.94
FFC4 Alpha	-1.30	-0.77	-0.60	-1.00	-0.69	-0.39	-0.88	-0.64	-0.92	-1.98	-0.67	-1.40

The PUTCALL and PUT assets demonstrate a strong negative relation between $RNSkew$ and future skewness returns. For these assets, the excess returns, CAPM, FF3 and FFC4 alphas of the decile 10 minus decile 1 portfolio are very significantly negative. This negative relation is not present, however, in the CALL asset returns, as the 10-1 returns and alphas are insignificantly different from zero.

The results in Table 2.2 provide preliminary evidence for the two main results of this paper. First, there is a statistically significant negative relation between implied risk-neutral skewness and future skewness returns. This is evident in the returns for the PUTCALL asset, for which the returns are determined by the probabilities in both tails of the risk-neutral distribution. Second, the negative relation is driven primarily by the market's pricing of the left side of the risk-neutral distribution. I arrive at this second conclusion because the negative relation holds for the PUTCALL asset (prices both tails of the risk-neutral distribution), and the PUT asset (prices the left side of the risk-neutral distribution), but not the call asset (prices the right side of the risk-neutral distribution). Thus, assets having exposure to the left side of the risk-neutral distribution exhibit the negative relation, but for those assets with exposure to only the right side of the risk-neutral distribution, the relation does not hold.

While Table 2.2 provides evidence supporting the hypothesis of a negative relation between $RNSkew$ and skewness returns driven by the market's pricing of the left side of the risk-neutral distribution, the returns have not been directly attributed the difference in performance of the options. Xing et al. (2010), Bali and Hovakimian (2009), Ang et al. (2010), and Cremers and Weinbaum (2010) demonstrate a positive relation between metrics similar in nature to implied risk-neutral skewness and future stock returns. Contradictory evidence is presented on the relation between BKM implied skewness and future stock returns. Conrad et al. (2009) find a negative relation between BKM implied skewness and future stock returns, while Rehman and Vilkov (2010) find a position relation. Given the evidence that implied skewness has predictive power over stock returns, it is possible that negative relation between $RNSkew$ and skewness returns is driven simply by the stock portion of the asset. To determine the source of the asset returns, I break down the returns on the 10-1 portfolios into the different components comprising each asset. To determine which securities are driving the asset returns, I decompose each of the decile 10 minus decile 1 asset returns into the option component and the stock component. The portion of the return attributed to each component is simply the profits or losses from that component divided by the price of the asset. The sum of the component returns therefore will equal the asset return. Additionally, the option component of the return can be broken down into the long and short option positions for each asset. The FFC4 factor alphas for the return breakdowns are presented in Table 2.3.

Table 2.3: Portfolio Returns Breakdown

This table breaks the Fama-French-Carhart 4-factor alpha (FFC4 Alpha) for the monthly returns of the decile 10 minus decile 1 of *RNSkew* portfolios into components corresponding to the profits generated by the options and the profits generated by the stock. In addition, the profits generated by the option positions are decomposed into profits from the long option position and profits from the short option position. Newey and West (1987) t-statistics with lag of 6 months are given in parentheses. The standard deviations of the monthly raw excess returns are shown in square brackets. For the PUTCALL asset, the long option is the OTM call and the short option is the OTM put. For the PUT asset, the long option in the ATM put and the short option is the OTM put. For the CALL asset, the long option is the OTM call, and the short option is the ATM call.

	10-1 FFC4 Alpha	**10-1 Option Portion FFC4 Alpha**	**10-1 Stock Portion FFC4 Alpha**	**10-1 Long Option FFC4 Alpha**	**10-1 Short Option FFC4 Alpha**
PUTCALL	-1.65	-1.11	-0.54	-0.39	-0.71
Asset	(-5.52)	(-3.01)	(-1.71)	(-1.81)	(-2.57)
	[4.06]	[6.23]	[4.91]	[4.17]	[4.19]
PUT	-1.34	-1.78	0.45	-1.19	-0.59
Asset	(-3.38)	(-3.50)	(1.73)	(-1.38)	(-0.78)
	[4.94]	[6.18]	[3.94]	[12.05]	[10.95]
CALL	-0.67	-1.43	0.76	-1.21	-0.23
Asset	(-1.40)	(-1.91)	(1.71)	(-1.97)	(-0.22)
	[6.90]	[10.08]	[6.69]	[16.61]	[11.86]

Table 2.3 demonstrates that it is in fact the option portion of the assets that dominate the returns. The option portion of the asset for each 10-1 return is negative, and larger in magnitude than the stock portion of the asset. By itself, the FFC4 alpha for the option portion of the asset is significantly negative at the 1% level for the PUT and PUTCALL asset, and at the 10% level for the CALL asset. The PUTCALL (PUT and CALL) assets have short (long) positions in stock, and exhibit a negative (positive) relation between the returns on the stock portion of the asset and *RNSkew*. These results are consistent with the positive relation between implied skewness and future stock returns documented by other authors (see above). It should be noted however that the FFC4 alphas for the different components are not indicative of the returns that would be realized on a portfolio that included only the securities comprising the specific components, as the denominator in all component return calculations is the price of the entire asset, not the price of only the specific component of the asset.

The main result from Table 2.3 is that the option portion of the asset does play the largest role in the asset return. Perhaps the most interesting result however comes from looking at the standard deviation of the different components of the return (shown in square brackets). The standard deviation of the monthly 10-1 raw returns for the PUTCALL asset is 4.06%. Notice that the standard deviations of the option and stock portions are 6.23% and 4.91%, respectively. The fact that the standard deviation of the return on the entire asset is much lower than the option portion alone indicates that the stock portion is indeed providing a hedge, as intended in the asset design. This is true for the PUT and CALL assets as well. Thus, in addition to demonstrating that the option positions drive the asset return, Table 2.3 also provides strong evidence that the hedges inherent in the asset design are working as desired.

As mentioned previously, another concern with the returns from Table 2.2 is that the return calculation is based on the initial price of the skewness assets. The skewness assets, however, are not limited liability assets, thus losses may (and in fact in some cases do) exceed 100% of the initial price of the asset. Murray (2011) develops a margin requirement based return calculation for assets comprised of options with the same underlier and expiration, and a position in the underlying stock. Using his methodology, the denominator of the return calculation is the margin requirement, taken to be the worst case loss on the asset for expiration strike prices between three standard deviations below and two standard deviations above the current spot price. To certify that the main results presented in Table 2.2 are not driven by the return calculation, I calculate returns for $RNSkew$ based decile portfolios of skewness assets using the margin-based return. One characteristic of the margin-requirement based return is that, because the worst case loss, and thus the denominator of the return calculation, is different when the asset is held long than when it is held short, the return for a long skewness asset position is not the negative of the return for a short skewness asset position. When analyzing returns of short skewness asset positions, we expect the cross-sectional relation between *RNSkew* and future short skewness asset returns to be positive instead of negative. The results for both the long (Panel A) and short (Panel B) margin-based skewness asset returns are presented in Table 2.4.

Table 2.4 provides evidence consistent with the previous conclusions. Panel A demonstrates that when using the margin-based return calculation, the negative relation between *RNSkew* and skewness asset returns persists for the PUTCALL and PUT assets, and the relation remains insignificant for the CALL asset. When analyzing the margin-based returns of short skewness assets, as expected, the relation between *RNSkew* and short skewness asset returns is positive and significant for the PUTCALL and PUT assets, but insignificant for the CALL asset.

The results from Tables 2.2, 2.3, and 2.4 provide evidence for the main results of this paper. First, there is a strong negative cross-sectional relation between *RNSkew* and skewness asset returns. Second, the relation is driven by the market's pricing of the left side of the risk-neutral distribution. The next section is devoted to ensuring that the results presented so far are truly due to skewness, not other factors that may affect the skewness asset returns.

4 Robustness

To certify that the results presented in the previous section are truly due to a cross-sectional relation between implied risk-neutral skewness and skewness returns, I now perform several analyses that control for the effects of other potential determinants of skewness asset returns. The main methodology employed in this section is Fama and MacBeth (1973) (FM) regressions. First, I check whether the results are driven by option or stock liquidity. Stock options are notoriously illiquid. It is possible that the apparent relation between *RNSkew* and skewness asset returns is driven primarily by assets comprised of illiquid options or small stocks. In addition to controlling for liquidity using FM regressions, I restrict my sample to

Table 2.4: Margin Requirement Based Portfolio Returns

This table shows the average monthly margin-based returns for long (Panel A) and short (Panel B) portfolios of skewness assets formed on deciles of *RNSkew*. The long and short margin-based returns are calculated using the methodoloyg of Murray (2011). *RNSkew* is calculated for each stock on the first trading day after each monthly expiration using the options that expire in the next month. The skewness assets are formed on the second day after each monthly expiration using options that expire in the next month, and sorted into portfolios on that same day. The skewness assets are held until expiration. The table shows raw excess margin-based returns (Excess Return), along with CAPM (CAPM Alpha), Fama-French 3-factor (FF3 Alpha), and Fama-French-Carhart 4-factor alphas (FFC4 Alpha) of the margin-based returns. The 10-1 column represents the difference between the returns for decile 10 and decile 1. The 10-1 t-stat column is the t-statistic testing the null hypothesis that the average 10-1 excess return, CAPM alpha, FF3 alpha, or FFC4 alpha is equal to zero. The t-statistics are adjusted using Newey and West (1987) with lag of 6 months. The sample covers the period January 1996 through October 2010.

Panel A. Long Skewness Asset Portfolios

PUTCALL Asset	1	2	3	4	5	6	7	8	9	10	10-1	10-1 t-stat
Excess Return	2.95	1.28	0.96	0.05	-0.01	0.23	-1.25	-0.37	-1.70	-2.64	-5.60	-4.86
CAPM Alpha	3.56	1.61	1.15	0.28	0.13	0.29	-1.13	-0.32	-1.63	-2.54	-6.10	-5.78
FF3 Alpha	3.52	1.56	1.12	0.17	0.10	0.16	-1.38	-0.40	-1.82	-2.65	-6.17	-5.82
FFC4 Alpha	3.62	1.53	1.06	0.12	-0.12	0.23	-1.43	-0.52	-1.88	-2.84	-6.46	-6.21

PUT Asset	1	2	3	4	5	6	7	8	9	10	10-1	10-1 t-stat
Excess Return	8.85	2.47	2.57	0.56	1.25	1.25	-0.24	0.16	-0.70	-0.25	-9.10	-3.76
CAPM Alpha	9.72	2.93	2.79	0.82	1.52	1.31	-0.12	0.25	-0.70	-0.22	-9.94	-4.07
FF3 Alpha	9.92	2.93	2.88	0.73	1.65	1.29	-0.31	0.19	-0.75	-0.29	-10.21	-4.04
FFC4 Alpha	10.32	2.88	2.74	0.77	1.43	1.33	-0.36	0.15	-0.86	-0.49	-10.82	-4.31

CALL Asset	1	2	3	4	5	6	7	8	9	10	10-1	10-1 t-stat
Excess Return	-1.85	-0.83	-0.54	-0.26	-0.54	-1.04	-1.68	-0.89	-1.82	-2.48	-0.63	-0.62
CAPM Alpha	-1.74	-0.76	-0.45	-0.14	-0.52	-0.97	-1.61	-0.86	-1.70	-2.38	-0.64	-0.65
FF3 Alpha	-1.96	-0.87	-0.56	-0.29	-0.60	-1.25	-1.88	-0.97	-1.87	-2.44	-0.47	-0.50
FFC4 Alpha	-1.88	-0.86	-0.60	-0.28	-0.76	-1.13	-1.94	-1.12	-1.87	-2.52	-0.65	-0.67

Panel B. Short Skewness Asset Portfolios

PUTCALL Asset	1	2	3	4	5	6	7	8	9	10	10-1	10-1 t-stat
Excess Return	-0.77	-0.51	-0.13	1.10	0.77	1.32	3.52	1.75	3.85	7.65	8.42	5.54
CAPM Alpha	-1.22	-0.86	-0.36	0.81	0.64	1.23	3.34	1.64	3.80	7.36	8.58	5.69
FF3 Alpha	-1.11	-0.76	-0.29	0.98	0.72	1.44	3.72	1.92	4.15	7.54	8.65	5.62
FFC4 Alpha	-1.22	-0.80	-0.22	1.05	0.98	1.30	3.67	2.00	4.18	7.66	8.88	6.03

PUT Asset	1	2	3	4	5	6	7	8	9	10	10-1	10-1 t-stat
Excess Return	-2.65	-1.36	-0.66	0.47	0.66	0.41	1.64	1.08	2.18	1.43	4.08	3.40
CAPM Alpha	-2.99	-1.65	-0.84	0.27	0.57	0.41	1.52	1.08	2.33	1.44	4.42	3.79
FF3 Alpha	-3.01	-1.71	-0.93	0.35	0.57	0.42	1.73	1.22	2.50	1.57	4.58	3.97
FFC4 Alpha	-3.05	-1.70	-0.82	0.33	0.82	0.38	1.70	1.28	2.69	1.85	4.90	4.40

CALL Asset	1	2	3	4	5	6	7	8	9	10	10-1	10-1 t-stat
Excess Return	8.80	5.57	3.00	4.32	3.99	4.07	16.45	3.67	7.42	11.09	2.29	1.09
CAPM Alpha	8.48	5.33	2.86	3.96	3.83	3.90	16.01	3.55	6.91	10.68	2.21	1.06
FF3 Alpha	8.73	5.61	3.07	4.21	3.99	4.19	16.20	3.83	7.38	10.77	2.04	1.00
FFC4 Alpha	8.54	5.60	3.11	4.32	4.16	4.05	16.09	4.00	6.97	10.83	2.29	1.10

those assets comprised of options with positive open interest and perform the decile portfolio analysis on the restricted sample. Next, it is possible that the asset returns are due to cross-sectional variation in asset construction across deciles of $RNSkew$. Table 2.1 indicated that there was significant variation in the deltas and position sizes of the options comprising the assets. Thus, it is necessary to ensure that the predictability of skewness asset returns is not due to differences in asset construction. I also demonstrate that the results persist when using assets constructed with a target absolute OTM delta of 0.2, as well as using 2-month options. To control for transaction costs, I first restrict the sample to the largest 500 stocks by market capitalization, and then apply the additional restriction that the option spread must be less than \$0.15. Applying these two restraints dramatically decreases the sample size. Despite the much reduced sample, the main results persist. Finally, I control for potential relations between other moments of the risk-neutral distribution and skewness asset returns. Specifically, I verify that the results are not due to the first, second, or fourth moment of the distribution of stock returns.

4.1 Controls for Option Liquidity

Option liquidity is a serious concern with any analysis of stock-option returns as several stock-options have very large bid-ask spreads or very low trading volume. I check the robustness of the main result to the inclusion of several different measures of option liquidity. First, I use the open interest of the options used to create the assets ($OpenInt$). Second, I use three different measures of option spreads. I define the dollar spread ($Spread\$$) to be the difference between the offer price and the bid price for the option. The volatility spread ($SpreadVol$) is calculated as the dollar spread divided by the option vega. This represents the difference in the option implied volatility at the offer price and the bid price. Finally, as both the $Spread\$$ and $SpreadVol$ would be expected to be larger for options with higher implied volatilities (or equivalently higher priced options), I scale $SpreadVol$ by the implied volatility of the option to find the percentage of implied volatility encompassed by the spread ($Spread\%Vol$). As options on smaller stocks tend to be less liquid, I include the log of market capitalization ($lnMktCap$) of the stock, calculated on the day after the most recent option expiration, as my final liquidity control. Dennis and Mayhew (2002) find a cross-sectional relation between implied skewness and firm size, raising the possibility that a size effect is driving the results. Table 2.5 presents decile means for each of the liquidity variables (Panel A), along with the results of FM regressions (Panel B) that control for the liquidity variables.

The decile portfolio means in Panel A indicate significant differences in option liquidity and stock size across the deciles of $RNSkew$. Option open interest is significantly lower, spreads are significantly higher, and average market capitalization significantly lower, for decile 10 than decile 1 of $RNSkew$. The FM regressions in Panel B confirm the main results of the paper. The negative relation between $RNSkew$ and skewness asset returns persists after controlling for liquidity for the PUTCALL and PUT assets, and the relation remains insignificant for the CALL asset.

As an additional check that the results are not driven by options with low liquidity, i.e. those with very low open interest, I recalculate the decile portfolio returns on the restricted sample of stock/expiration combinations where all options (OTM and ATM call and put) have positive open interest. This reduces my sample to 47,899 (from 57,535) stock/expiration data points. The results of this analysis are presented in Table 2.5, Panel C. Despite the reduction in the sample size, the portfolio results on the restricted sample are qualitatively similar to those of the full sample, and confirm all previous conclusions.

Table 2.5: Controls for Liquidity

The tables below show the effects of controlling for option liquidity in analyzing the ability of implied skewness (*RNSkew*) to predict skewness asset returns. Controls for liquidity include option open interest (OpenInt), dollar, volatility, and percentage of volatility spreads (Spread$, SpreadVol, Spread%Vol), and the size of the underlying stock (MktCap $mm, lnMktCap $mm). Panel A shows the monthly average for each variable across the deciles of *RNSkew*. Panel B shows the results of FM regressions controlling for each of the variables. All dependent variables are winsorized at the 1% level. The t-statistics are Newey and West (1987) adjusted using lag of 6 months. Panel C shows the decile portfolio raw excess returns (Excess Return) and CAPM (CAPM Alpha), Fama-French 3-factor (FF3 Alpha) and Fama-French-Carhart 4-factor (FFC4 Alpha) alphas of the skewness assets when restricting the sample to options with positive open interest.

Panel A. Decile Portfolio Means for Variables Proxying for Option Liquidity

	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**10-1**	**10-1 t-stat**
MktCap $mm	20239	17509	14480	12252	11171	10183	9637	9459	8491	7973	-12266	-11.10
logMktCap $mm	8.618	8.538	8.383	8.276	8.200	8.111	8.076	8.019	7.918	7.850	-0.768	-12.90
OTM Put												
OpenInt	2026	1596	1425	1148	1015	933	877	846	796	947	-1079	-10.46
Spread$	0.151	0.151	0.158	0.162	0.162	0.165	0.171	0.176	0.185	0.194	0.043	10.26
SpreadVol	9.485	9.283	9.499	9.705	9.836	9.873	10.068	10.235	10.335	10.452	0.967	4.04
Spread%Vol	15.726	15.116	15.437	15.515	15.754	15.867	16.299	16.404	16.754	17.130	1.404	4.86
OTM Call												
OpenInt	2173	1730	1485	1369	1233	1110	1101	1128	1115	1412	-760	-6.38
Spread$	0.147	0.150	0.156	0.158	0.158	0.162	0.165	0.168	0.176	0.180	0.034	8.37
SpreadVol	7.381	7.449	7.568	7.790	8.045	8.379	8.702	9.191	9.783	10.826	3.445	16.23
Spread%Vol	16.749	15.825	15.663	15.497	15.698	16.057	16.424	16.711	17.471	18.030	1.282	5.11
ATM Put												
OpenInt	2116	1757	1497	1402	1252	1203	1071	1134	1059	1214	-903	-8.30
Spread$	0.227	0.235	0.247	0.249	0.250	0.256	0.265	0.266	0.272	0.281	0.054	6.06
SpreadVol	5.709	5.762	5.931	6.154	6.243	6.388	6.647	6.832	7.236	7.719	2.010	10.45
Spread%Vol	12.235	11.596	11.528	11.538	11.486	11.614	11.963	11.964	12.620	13.269	1.034	4.67
ATM Call												
OpenInt	3352	2857	2469	2117	1986	1851	1742	1624	1614	1917	-1434	-8.89
Spread$	0.199	0.208	0.218	0.222	0.221	0.225	0.232	0.237	0.242	0.252	0.054	7.66
SpreadVol	4.990	5.069	5.259	5.401	5.517	5.625	5.807	6.077	6.380	6.965	1.975	12.86
Spread%Vol	11.129	10.655	10.593	10.485	10.613	10.566	10.879	11.070	11.642	12.367	1.238	5.86

Panel B. FM Regressions of Skewness Asset Returns on *RNSkew* and Liquidity Controls

	PUTCALL Asset			PUT Asset			CALL Asset		
	Price	Excess	Return	Price	Excess	Return	Price	Excess	Return
RNSkew	-0.524	-0.538	-0.551	-0.448	-0.413	-0.448	-0.039	0.034	-0.045
	(-4.93)	(-5.11)	(-5.28)	(-3.61)	(-3.25)	(-3.48)	(-0.26)	(0.22)	(-0.31)
Long Option	0.002	0.006	0.006	0.010	0.011	0.014	-0.003	0.001	-0.001
OpenInt (1000s)	(0.80)	(1.77)	(1.87)	(1.89)	(1.95)	(2.40)	(-0.36)	(0.17)	(-0.14)
Short Option	0.011	0.012	0.009	0.007	0.009	0.008	-0.000	0.002	-0.004
OpenInt (1000s)	(1.68)	(2.14)	(1.44)	(1.46)	(1.85)	(1.55)	(-0.06)	(0.31)	(-0.69)
Long Option	-2.171			-1.774			-5.556		
Spread$	(-1.89)			(-1.81)			(-3.09)		
Short Option	0.019			1.914			3.068		
Spread$	(0.02)			(1.41)			(3.64)		
Long Option		-0.028			-0.038			-0.145	
SpreadVol		(-1.25)			(-1.29)			(-4.40)	
Short Option		-0.006			0.054			-0.016	
SpreadVol		(-0.29)			(3.35)			(-0.36)	
Long Option			0.009			0.032			-0.039
Spread%Vol			(0.76)			(2.08)			(-2.07)
Short Option			-0.034			-0.003			-0.038
Spread%Vol			(-3.16)			(-0.27)			(-1.62)
logMktCap	-0.234	-0.310	-0.278	-0.126	-0.068	-0.147	0.016	-0.301	-0.002
$mm	(-3.76)	(-3.91)	(-4.44)	(-1.73)	(-0.73)	(-1.88)	(0.16)	(-2.19)	(-0.02)
Intercept	0.827	1.353	1.177	0.456	-0.418	0.084	-0.819	2.955	0.238
	(1.18)	(1.46)	(1.58)	(0.60)	(-0.44)	(0.11)	(-0.71)	(1.95)	(0.18)

Panel C. Decile Portfolio Returns for Sample Restricted to Open Interest > 0

PUTCALL Asset	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**10-1**	**10-1 t-stat**
Excess Return	-0.06	-0.18	-0.31	-0.77	-0.66	-0.94	-1.02	-0.84	-1.30	-1.38	-1.32	-4.08
CAPM Alpha	0.03	-0.10	-0.24	-0.71	-0.62	-0.92	-1.02	-0.85	-1.30	-1.34	-1.38	-4.32
FF3 Alpha	-0.00	-0.11	-0.27	-0.72	-0.67	-0.99	-1.10	-0.94	-1.40	-1.39	-1.39	-4.26
FFC4 Alpha	0.00	-0.14	-0.33	-0.74	-0.74	-0.98	-1.15	-1.02	-1.47	-1.45	-1.45	-4.45

PUT Asset	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**10-1**	**10-1 t-stat**
Excess Return	0.85	0.48	0.45	-0.10	0.11	-0.28	-0.47	-0.24	-0.64	-0.09	-0.94	-2.08
CAPM Alpha	0.95	0.57	0.54	-0.00	0.15	-0.27	-0.46	-0.25	-0.68	-0.07	-1.02	-2.21
FF3 Alpha	0.95	0.58	0.57	0.01	0.15	-0.32	-0.51	-0.34	-0.75	-0.11	-1.06	-2.33
FFC4 Alpha	0.97	0.55	0.50	0.02	0.11	-0.35	-0.53	-0.40	-0.84	-0.19	-1.16	-2.53

CALL Asset	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**10-1**	**10-1 t-stat**
Excess Return	-1.03	-0.70	-0.62	-0.84	-0.77	-1.03	-0.29	-0.26	-0.74	-1.47	-0.44	-0.88
CAPM Alpha	-0.98	-0.68	-0.59	-0.79	-0.74	-0.99	-0.28	-0.27	-0.69	-1.40	-0.42	-0.90
FF3 Alpha	-1.09	-0.75	-0.70	-0.85	-0.79	-1.07	-0.37	-0.34	-0.81	-1.44	-0.35	-0.72
FFC4 Alpha	-1.05	-0.78	-0.76	-0.90	-0.95	-0.99	-0.42	-0.45	-0.90	-1.51	-0.46	-0.95

4.2 Controls for Skewness Asset Construction

Table 2.1 demonstrated that there is significant variation in the deltas of the options used to construct the skewness assets, as well as in the position sizes of the securities comprising the assets. The next set of control variables I employ relate to the potential for there to be cross-sectional differences in the construction of the skewness assets. To control for differences in asset construction, I use the deltas ($Delta$) and vegas ($Vega$) of the options used to create the skewness asset. Additionally, as different deltas and vegas can result in cross-sectional differences in the size of the option positions and stock positions in the assets, I control for the size of the position in the second option in each asset ($OptionPosition$) as well as the size of the stock position ($StockPosition$) in each asset. Panel A of Table 2.6 shows the decile means for each of the control variables, and Panel B presents the results of FM regressions that control for variation in asset construction.

The decile averages presented in Panel A of Table 2.6 indicate that there is strong cross-sectional variation in the construction of the skewness assets across deciles of $RNSkew$ for almost all of the variables. The FM regression results in Panel B demonstrate that after controlling for cross-sectional variation in asset construction, the negative relation between $RNSkew$ and skewness asset returns persists for the PUTCALL and PUT assets, and remains insignificant for the CALL asset. Thus, despite the strong variation in asset construction across deciles of $RNSkew$, the negative relation between $RNSkew$ and skewness asset returns is not driven by differences in the construction of the skewness assets.

Table 2.6: Controls for Asset Construction

The tables below show the effects of controlling for skewness asset construction in analyzing the ability of implied skewness ($RNSkew$) to predict skewness asset returns. Controls for asset construction include the deltas and vegas of the options comprising the assets, as well as the size of the option and stock positions. Panel A shows the monthly average for each variable across the deciles of $RNSkew$. Panel B shows the results of FM regressions controlling for each of the variables. All dependent variables are winsorized at the 1% level. The t-statistics are adjusted using Newey and West (1987) with lag of 6 months. Panels C and D show the decile portfolio raw excess returns (Excess Return), and CAPM (CAPM Alpha), Fama-French 3-factor (FF3 Alpha) and Fama-French-Carhart 4-factor (FFC4 Alphas) alphas of the skewness asset portfolios when constructing the assets using a target absolute delta of 0.2 instead of 0.1 for OTM options (Panel C), and using 2 month options (Panel D).

Panel A. Decile Portfolio Means for Asset Construction Variables

	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**10-1**	**10-1 t-stat**
PUTCALL Asset												
OTM Put Position	-1.330	-1.336	-1.329	-1.304	-1.275	-1.237	-1.195	-1.141	-1.078	-0.980	0.350	19.23
Stock Position	-0.245	-0.252	-0.256	-0.257	-0.255	-0.250	-0.249	-0.245	-0.248	-0.244	0.001	0.34
OTM Put Delta	-0.097	-0.097	-0.099	-0.102	-0.104	-0.106	-0.111	-0.115	-0.127	-0.145	-0.049	-19.86
OTM Call Delta	0.131	0.136	0.138	0.138	0.136	0.132	0.130	0.127	0.127	0.121	-0.011	-4.92
OTM Put Vega	2.142	2.204	2.291	2.294	2.275	2.303	2.378	2.395	2.486	2.542	0.399	5.60
OTM Call Vega	2.658	2.775	2.844	2.809	2.731	2.680	2.639	2.552	2.491	2.270	-0.388	-5.16
PUT Asset												
ATM Put Position	0.432	0.433	0.439	0.447	0.452	0.459	0.472	0.484	0.517	0.561	0.130	22.37
Stock Position	0.123	0.122	0.122	0.125	0.124	0.124	0.126	0.126	0.131	0.132	0.008	5.68
OTM Put Delta	-0.097	-0.097	-0.099	-0.102	-0.104	-0.106	-0.111	-0.115	-0.127	-0.145	-0.049	-19.86
ATM Put Delta	-0.509	-0.506	-0.506	-0.507	-0.502	-0.502	-0.500	-0.499	-0.498	-0.492	0.018	7.24
OTM Put Vega	2.142	2.204	2.291	2.294	2.275	2.303	2.378	2.395	2.486	2.542	0.399	5.60
ATM Put Vega	5.093	5.222	5.345	5.283	5.154	5.162	5.200	5.120	4.950	4.651	-0.442	-3.06
CALL Asset												
ATM Call Position	-0.524	-0.533	-0.537	-0.537	-0.535	-0.525	-0.523	-0.514	-0.514	-0.499	0.025	4.59
Stock Position	0.134	0.134	0.132	0.131	0.133	0.132	0.133	0.133	0.134	0.135	0.001	0.59
OTM Call Delta	0.131	0.136	0.138	0.138	0.136	0.132	0.130	0.127	0.127	0.121	-0.011	-4.92
ATM Call Delta	0.498	0.499	0.499	0.498	0.500	0.501	0.502	0.503	0.506	0.512	0.014	5.33
OTM Call Vega	2.658	2.775	2.844	2.809	2.731	2.680	2.639	2.552	2.491	2.270	-0.388	-5.16
ATM Call Vega	5.093	5.219	5.341	5.281	5.158	5.160	5.194	5.122	4.951	4.647	-0.446	-3.10

Panel B. Fama-MacBeth Regressions of Skewness Asset Returns on *RNSkew* and Asset Construction Controls

	PUTCALL Asset Price Excess Return	PUT Asset Price Excess Return	CALL Asset Price Excess Return
RNSkew	-0.662	-0.567	-0.046
	(-5.39)	(-3.83)	(-0.32)
Long Option Delta	-8.846	-1.615	23.501
	(-0.70)	(-0.47)	(2.01)
Short Option Delta	3.973	-15.293	-4.332
	(1.25)	(-0.86)	(-1.03)
Long Option Vega	-0.143	-0.256	0.036
	(-1.70)	(-2.59)	(0.15)
Short Option Vega	0.162	0.417	0.199
	(1.66)	(1.94)	(1.40)
Option Position	0.489	-5.609	10.457
	(1.33)	(-0.75)	(1.63)
Stock Position	-9.476	-3.173	17.100
	(-1.18)	(-0.45)	(2.13)
Intercept	-1.691	0.198	0.419
	(-2.64)	(0.08)	(0.14)

Panel C. Portfolio Returns Using Target Absolute OTM Delta of 0.2

PUTCALL Asset	1	2	3	4	5	6	7	8	9	10	10-1	10-1 t-stat
Excess Return	-0.46	-0.46	-0.50	-0.68	-0.54	-0.43	-0.78	-0.81	-0.91	-1.23	-0.77	-3.27
CAPM Alpha	-0.40	-0.42	-0.47	-0.62	-0.51	-0.42	-0.77	-0.79	-0.90	-1.19	-0.79	-3.48
FF3 Alpha	-0.44	-0.44	-0.50	-0.67	-0.53	-0.48	-0.83	-0.84	-0.95	-1.22	-0.79	-3.34
FFC4 Alpha	-0.41	-0.46	-0.54	-0.69	-0.57	-0.46	-0.87	-0.87	-0.99	-1.29	-0.88	-3.88

PUT Asset	1	2	3	4	5	6	7	8	9	10	10-1	10-1 t-stat
Excess Return	0.46	0.07	0.14	-0.31	-0.09	-0.07	-0.32	-0.26	-0.56	-0.20	-0.66	-2.00
CAPM Alpha	0.53	0.13	0.18	-0.25	-0.06	-0.07	-0.30	-0.24	-0.58	-0.17	-0.70	-2.06
FF3 Alpha	0.52	0.11	0.19	-0.27	-0.05	-0.09	-0.34	-0.29	-0.62	-0.19	-0.71	-2.11
FFC4 Alpha	0.55	0.09	0.11	-0.27	-0.12	-0.09	-0.36	-0.32	-0.69	-0.25	-0.81	-2.43

CALL Asset	1	2	3	4	5	6	7	8	9	10	10-1	10-1 t-stat
Excess Return	-1.13	-0.56	-0.52	-0.69	-0.40	-0.02	-0.68	-0.54	-0.50	-1.41	-0.27	-0.53
CAPM Alpha	-1.06	-0.53	-0.51	-0.59	-0.39	0.04	-0.65	-0.52	-0.45	-1.35	-0.29	-0.62
FF3 Alpha	-1.17	-0.58	-0.55	-0.72	-0.42	-0.09	-0.78	-0.59	-0.55	-1.40	-0.23	-0.47
FFC4 Alpha	-1.13	-0.64	-0.62	-0.79	-0.49	-0.04	-0.81	-0.71	-0.60	-1.57	-0.44	-0.94

Panel D. Portfolio Returns Using 2 Month Options

<u>**PUTCALL Asset**</u>	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**10-1**	**10-1 t-stat**
Excess Return	-0.83	-1.19	-1.40	-1.61	-1.60	-2.10	-1.89	-2.59	-2.05	-2.60	-1.77	-4.81
CAPM Alpha	-0.96	-1.24	-1.47	-1.73	-1.68	-2.23	-1.97	-2.69	-2.11	-2.66	-1.70	-4.47
FF3 Alpha	-1.08	-1.30	-1.61	-1.80	-1.79	-2.30	-1.96	-2.74	-2.16	-2.72	-1.65	-4.45
FFC4 Alpha	-1.02	-1.34	-1.61	-1.74	-1.79	-2.36	-1.89	-2.71	-2.14	-2.61	-1.60	-4.18
<u>**PUT Asset**</u>	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**10-1**	**10-1 t-stat**
Excess Return	0.31	0.05	-0.57	-0.57	-0.38	-1.13	-0.74	-1.45	-1.15	-1.37	-1.68	-4.47
CAPM Alpha	0.15	-0.04	-0.67	-0.71	-0.53	-1.28	-0.90	-1.66	-1.25	-1.52	-1.67	-4.02
FF3 Alpha	0.05	-0.16	-0.87	-0.78	-0.65	-1.41	-0.94	-1.68	-1.34	-1.55	-1.60	-4.08
FFC4 Alpha	0.09	-0.21	-0.89	-0.73	-0.74	-1.49	-0.89	-1.77	-1.33	-1.50	-1.59	-3.76
<u>**CALL Asset**</u>	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**10-1**	**10-1 t-stat**
Excess Return	0.13	-0.13	-0.29	-0.42	-0.43	-0.34	-0.66	-1.18	-0.39	-0.80	-0.93	-1.25
CAPM Alpha	0.02	-0.13	-0.27	-0.49	-0.39	-0.37	-0.65	-1.07	-0.42	-0.73	-0.75	-1.01
FF3 Alpha	-0.06	-0.08	-0.25	-0.49	-0.45	-0.28	-0.53	-1.15	-0.30	-0.80	-0.74	-0.97
FFC4 Alpha	-0.08	-0.12	-0.33	-0.46	-0.37	-0.33	-0.48	-0.94	-0.39	-0.54	-0.46	-0.65

While Panels A and B present evidence that the negative relation between $RNSkew$ and skewness asset returns is not generated by cross-sectional variation in asset construction, it is still possible that the relation is a manifestation of having chosen very far OTM options (target absolute delta of 0.1) for the OTM option positions. Panel C of Table 2.6 presents the decile returns for skewness assets created using a target absolute delta of 0.2. The return patterns observed in the previous analyses remain. The 10-1 returns are significantly negative for the PUTCALL and PUT asset, and insignificantly different from zero for the CALL asset.

One might also question the choice of 1 month options. Indeed, no justification was given for this choice. Thus, in Panel D of Table 2.6, I present the decile portfolio analysis using 2-month options for both calculation of $RNSkew$ and creation of the skewness assets. The 2-month sample has a total of 83,303 stock/expiration combinations over 176 monthly return periods. The main results of the paper persist in the 2-month sample, thus there is no evidence that the results arise to do pricing of the front month options only.

4.3 The Effect of Transaction Costs

In this subsection, I scrutinize more diligently the effects of transaction costs on the return pattern observed in the previous analyses. I accomplish this by reducing the sample to include only those observations where transaction costs on the options are expected to be low. The results demonstrate that the cross-sectional return pattern persists in these drastically restricted samples.

I begin by including in my sample only stock/expiration observations where the stock is one of the largest 500 stocks, by market capitalization, on the signal creation date (the first trading day after the monthly expiration). Options on the stocks included in this sample are expected to have small transaction costs. This sample includes 25,824 stock/expiration observations (compared to 57,535 for the full sample). The decile portfolio analysis for this restricted sample, presented in Table 2.7, Panel A, shows that for this sample, 10-1 portfolio return for the PUTCALL and PUT assets are smaller in magnitude when compared to the full sample, but remain statistically significant at the 5% level. The 10-1 portfolio return for the CALL asset remains insignificant.

I continue the transaction cost analysis by further reducing my sample to include only those stock/month observations where all 4 options in the skewness assets (OTM put, OTM call, ATM put, ATM call) have bid-offer spreads of $0.15 or less. This is quite a stringent restriction, and there are very few observations before 2001 that meet these criteria, thus I begin this analysis with portfolios created in July 2001, with options expiring in August 2001. This sample contains only 5,377 stock/expiration observations, down from 37,120 for the corresponding period in the full sample. Panel B of Table 2.7 demonstrates that the main results of this paper hold for this much restricted sample. Notice that despite the reduced t-statistics for the PUTCALL and PUT asset portfolios, the magnitude of the returns has actually increased. Thus, the decreased t-statistic is due to increased volatility caused by the lack of diversification in the reduced sample. The 10-1 CALL asset returns remain insignificant.

Table 2.7: Transaction Costs

The tables below show the effects of controlling for transaction costs in analyzing the ability of implied skewness (*RNSkew*) to predict skewness asset returns. Panel A presents the skewness asset decile portfolios returns for the sample restricted to stocks in the top 500 stocks by market capitalization. Panel B presents the portfolio returns for the further restricted sample requiring both that the stock be one of the top 500 stocks by market capitalization, and that all four options (OTM put, OTM call, ATM put, ATM call) have quoted bid-offer spreads of less than $0.15. Due to the small number of options that meet the spread criterion prior to 2001, this sample begins with portfolios created in July 2001 and thus expiring in August 2001 (instead of January 1996, expiring February 1996). The table shows raw excess returns (Excess Return), along with CAPM (CAPM Alpha), Fama-French 3-factor (FF3 Alpha), and Fama-French-Carhart 4-factor alphas (FFC4 Alpha). The 10-1 column represents the difference between the returns for decile 10 and decile 1. The 10-1 t-stat column is the t-statistic testing the null hypothesis that the average 10-1 excess return, CAPM alpha, FF3 alpha, or FFC4 alpha is equal to zero. The t-statistics are adjusted using Newey and West (1987) with lag of 6 months.

Panel A. Decile Portfolio for Largest 500 Stocks

PUTCALL Asset	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**10-1**	**10-1 t-stat**
Excess Return	-0.32	-0.08	-0.93	-0.84	-0.58	-1.41	-1.48	-1.66	-1.25	-1.54	-1.22	-3.24
CAPM Alpha	-0.22	0.02	-0.84	-0.74	-0.53	-1.42	-1.49	-1.66	-1.25	-1.50	-1.28	-3.09
FF3 Alpha	-0.24	-0.01	-0.77	-0.80	-0.54	-1.46	-1.59	-1.72	-1.32	-1.58	-1.34	-3.32
FFC4 Alpha	-0.21	-0.03	-0.81	-0.83	-0.59	-1.56	-1.59	-1.78	-1.37	-1.65	-1.45	-3.54

PUT Asset	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**10-1**	**10-1 t-stat**
Excess Return	0.72	0.89	-0.18	-0.37	0.20	-0.42	-0.49	-0.80	-0.42	-0.25	-0.97	-2.01
CAPM Alpha	0.83	1.02	-0.09	-0.26	0.28	-0.45	-0.51	-0.79	-0.45	-0.23	-1.06	-2.04
FF3 Alpha	0.87	1.02	-0.01	-0.28	0.29	-0.47	-0.58	-0.83	-0.49	-0.26	-1.13	-2.18
FFC4 Alpha	0.88	0.97	0.02	-0.31	0.26	-0.59	-0.64	-0.90	-0.58	-0.38	-1.25	-2.43

CALL Asset	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**10-1**	**10-1 t-stat**
Excess Return	-0.62	-0.60	-0.76	-0.37	-0.53	-1.43	-1.19	-0.69	-0.80	-0.91	-0.29	-0.59
CAPM Alpha	-0.57	-0.59	-0.74	-0.26	-0.52	-1.34	-1.19	-0.71	-0.79	-0.86	-0.29	-0.59
FF3 Alpha	-0.70	-0.65	-0.71	-0.36	-0.54	-1.42	-1.29	-0.71	-0.83	-0.97	-0.27	-0.55
FFC4 Alpha	-0.62	-0.66	-0.78	-0.35	-0.65	-1.48	-1.23	-0.75	-0.84	-1.03	-0.41	-0.89

Panel B. Decile Portfolios for Largest 500 Stocks with Option Spreads < \$0.15

PUTCALL Asset	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**10-1**	**10-1 t-stat**
Excess Return	0.61	0.64	-1.31	-0.24	-0.84	-0.57	-1.88	-1.24	-0.82	-1.68	-2.29	-2.95
CAPM Alpha	0.72	0.72	-1.30	-0.17	-0.89	-0.46	-2.10	-1.20	-0.83	-1.65	-2.37	-3.29
FF3 Alpha	0.67	0.59	-1.33	-0.31	-1.06	-0.56	-2.21	-1.19	-0.91	-1.65	-2.33	-3.45
FFC4 Alpha	0.68	0.60	-1.27	-0.28	-1.08	-0.59	-2.24	-1.20	-0.92	-1.65	-2.33	-3.45

PUT Asset	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**10-1**	**10-1 t-stat**
Excess Return	1.54	1.24	-0.78	1.38	-1.15	0.50	-1.06	-0.40	-0.04	-0.22	-1.76	-2.06
CAPM Alpha	1.72	1.36	-0.78	1.54	-1.16	0.67	-1.33	-0.36	-0.05	-0.20	-1.92	-2.35
FF3 Alpha	1.68	1.36	-0.87	1.48	-1.16	0.56	-1.50	-0.38	-0.08	-0.08	-1.76	-2.17
FFC4 Alpha	1.66	1.35	-0.78	1.49	-1.20	0.53	-1.54	-0.40	-0.13	-0.05	-1.71	-2.17

CALL Asset	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**10-1**	**10-1 t-stat**
Excess Return	-0.05	-0.13	-1.05	-0.88	0.22	-0.63	-1.02	-1.33	-0.88	-2.16	-2.11	-1.47
CAPM Alpha	-0.04	-0.12	-1.13	-0.90	0.15	-0.56	-1.01	-1.31	-0.94	-2.14	-2.10	-1.48
FF3 Alpha	-0.20	-0.23	-1.05	-1.04	-0.17	-0.66	-1.04	-1.25	-1.14	-2.23	-2.03	-1.48
FFC4 Alpha	-0.15	-0.20	-1.03	-1.00	-0.14	-0.68	-1.08	-1.27	-1.09	-2.27	-2.12	-1.57

In summary, after reducing the sample to those observations where transaction costs are expected to be smallest, the negative cross-sectional pattern between $RNSkew$ and skewness asset returns persists for the PUTCALL and PUT assets, and remains insignificant for the CALL asset.

4.4 Controls for Mean, Volatility, and Kurtosis of Stock Returns

Option prices are determined by all moments of the distribution of stock returns. To ensure that the results presented in Table 2.2 are not driven by other moments of the distribution of future stock returns, I perform FM regressions of the skewness asset returns on $RNSkew$ and several controls for the mean, volatility, and kurtosis of the distribution of future stock returns. I control for the mean of the distribution of stock returns using the log return of the underlying stock during the 1 month ($Ret1M$) and 1 year ($Ret1Yr$) periods ending on the signal calculation date. Additionally, to make sure the returns on the skewness assets are not driven simply by the returns on the stock position that is part of the asset, I include the return of the stock during the period for which the asset is held ($RetHldPer$). I control for the second moment of the distribution by including the 1 year ($RV1Yr$) and 1 month ($RV1M$) realized volatility of the log stock returns, along with the realized volatility during the asset holding period ($RVHldPer$).[20] Finally, I control for the implied volatility and kurtosis by including the BKM implied volatility ($BKMIV$) and BKM implied kurtosis ($BKMKurt$) as control variables.[21] As additional controls for volatility, I use the implied volatilities of the options comprising the skewness assets. The decile portfolio averages for each of the control variables, along with the results of the FM regressions are presented in Panels A and B of Table 2.8, respectively.

The decile portfolio averages for $RNSkew$ are, by construction, increasing from -2.96 to 0.11 across the deciles of $RNSkew$. All of the different volatility measures, both implied and realized, have significantly higher means in decile 10 of $RNSkew$ than in decile 1. Previous 1 month returns are significantly lower in decile 10 than in decile 1, but the difference in previous 1 year returns is insignificant. There is no statistically significant difference in the holding period returns.

The FM regressions in Panel B indicate that, despite the strong relations between $RNSkew$ and many of the control variables, the negative relation between $RNSkew$ and the PUTCALL and PUT skewness asset returns is not driven by other moments of the stock return distribution. The coefficients on $RNSkew$ in the regressions with the PUTCALL and PUT asset returns as the dependent variables (with one exception) are significantly negative.

[20] All realized volatilities are calculated using daily data and annualized for consistency and easy comparison to implied volatilities.

[21] The BKM methodology calculates the implied variance of the risk-neutral distribution of log-returns from the time of calculation to option expiration. I annualize this variance, and take the square root of the annualized version to be the BKM implied volatility.

Table 2.8: Controls for Other Moments of the Distribution of Stock Returns
The tables below show the effects of controlling for other moments of the distribution of stock returns in analyzing the ability of implied skewness (RNSkew - third moment) to predict skewness asset returns. Controls for the mean (first moment) include the previous 1 year and 1 month return of the underlying stock (Ret1Yr and Ret1M), along with the return during the period during which the skewness asset was held (RetHldPer). Controls for the volatility (second moment) include the implied volatility calculated using the methodology of BKM (BKM IV), the implied volatilities of the options comprising the skewness assets (OTM Put IV, OTM Call IV, ATM Put IV, ATM Call IV), the previous 1 year and 1 month realized volatility (RV1Yr and RV1M), along with the realized volatility during the period during which the skewness asset was held (RVHldPer). I control for kurtosis using the implied kurtosis calculated with the methodology of BKM (BKM Kurt). Panel A shows the monthly average for each variable across the deciles of *RNSkew*. Panel B shows the results of FM regressions controlling for each of the variables. All dependent variables are winsorized at the 1% level. The t-statistics are Newey and West (1987) adjusted using lag of 6 months.

Panel A. Portfolio Means for 1^{st}, 2^{nd}, and 4^{th} Moments Variables

	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**10-1**	**10-1 t-stat**
RNSkew	-2.96	-1.99	-1.63	-1.39	-1.18	-1.00	-0.82	-0.63	-0.40	0.11	3.07	91.70
BKM IV	41.71	42.52	43.26	44.29	44.65	44.92	44.60	45.14	44.69	44.39	2.67	3.94
BKM Kurt	19.17	12.19	10.15	8.93	8.24	7.70	7.36	7.08	7.02	8.07	-11.10	-27.89
OTM Put IV	59.38	60.63	61.09	61.91	61.91	61.88	61.28	61.82	61.64	61.76	2.37	2.85
OTM Call IV	44.05	46.89	48.43	50.36	51.39	52.31	52.93	54.53	55.67	59.55	15.49	18.90
ATM Put IV	45.99	49.04	50.71	52.35	53.25	54.15	54.27	55.50	55.95	57.31	11.32	13.84
ATM Call IV	44.47	47.66	49.36	51.18	52.06	52.93	53.43	54.54	55.09	56.78	12.31	15.39
Ret1Yr	39.74	46.72	49.07	48.94	56.57	54.07	52.87	54.15	48.56	43.82	4.08	1.22
Ret1M	4.97	4.73	4.33	3.62	2.83	2.29	1.38	0.17	-1.48	-4.40	-9.37	-16.66
RetHldPer	0.45	0.68	0.83	0.71	0.51	1.21	0.62	0.92	0.63	1.07	0.62	1.60
RV1Yr	47.78	50.74	51.50	53.36	54.56	54.76	55.05	56.26	56.00	56.29	8.51	10.89
RV1M	45.40	48.26	49.46	51.48	52.44	53.20	53.75	54.86	54.67	56.11	10.70	10.95
RVHldPer	43.71	47.02	48.69	50.38	50.85	51.75	51.81	52.47	53.66	54.41	10.70	10.32

Panel B. FM Regressions of Skewness Asset Returns on *RNSkew* and Other Moments Controls

	PUTCALL Asset			PUT Asset			CALL Asset		
	Price Excess Return			Price Excess Return			Price Excess Return		
RNSkew	-0.685	-1.020	-0.578	-0.330	-0.599	-0.196	-0.215	-0.387	-0.423
	(-5.81)	(-5.88)	(-5.03)	(-2.19)	(-3.66)	(-1.38)	(-1.26)	(-1.85)	(-2.39)
BKM IV	0.054			0.056			0.036		
	(2.68)			(2.52)			(1.30)		
Long Option IV		0.009			0.010			-0.027	
		(0.51)			(0.46)			(-1.19)	
Short Option IV			0.068			0.077			0.089
			(3.98)			(3.94)			(3.17)
BKM Kurt	-0.099	-0.151	-0.090	0.019	-0.021	0.033	-0.138	-0.171	-0.130
	(-4.75)	(-5.38)	(-5.10)	(0.72)	(-0.87)	(1.43)	(-4.42)	(-4.52)	(-4.31)
Ret1Yr	0.000	0.000	0.001	0.001	0.001	0.001	-0.001	-0.001	-0.000
	(0.21)	(0.06)	(0.48)	(0.48)	(0.54)	(0.74)	(-0.28)	(-0.35)	(-0.13)
Ret1M	-0.004	-0.010	-0.001	-0.017	-0.022	-0.013	0.012	0.006	0.017
	(-0.45)	(-1.02)	(-0.08)	(-1.47)	(-1.84)	(-1.16)	(0.99)	(0.50)	(1.48)
RetHldPer	-0.134	-0.131	-0.135	-0.074	-0.071	-0.074	-0.178	-0.175	-0.180
	(-3.92)	(-3.82)	(-3.93)	(-2.61)	(-2.50)	(-2.63)	(-3.65)	(-3.61)	(-3.68)
RV1Yr	0.024	0.039	0.007	0.016	0.032	-0.004	0.009	0.035	-0.021
	(2.75)	(4.49)	(0.88)	(1.74)	(3.12)	(-0.49)	(0.64)	(2.57)	(-1.47)
RV1M	0.004	0.013	0.001	0.001	0.009	-0.004	0.006	0.020	-0.001
	(0.82)	(2.42)	(0.12)	(0.11)	(1.16)	(-0.59)	(0.76)	(2.56)	(-0.13)
RetHldPer	-0.059	-0.052	-0.063	-0.064	-0.057	-0.069	-0.044	-0.033	-0.053
	(-2.60)	(-2.23)	(-2.70)	(-2.59)	(-2.24)	(-2.73)	(-1.74)	(-1.29)	(-2.01)
Intercept	-0.122	0.140	-0.726	0.088	0.380	-0.561	1.684	2.064	0.540
	(-0.39)	(0.49)	(-2.62)	(0.23)	(1.12)	(-1.46)	(3.15)	(3.79)	(1.14)

Interestingly, in the PUT asset return regression using the short option IV, which in the case of the PUT asset is the OTM put option, the coefficient on $RNSkew$ becomes insignificant. This is evidence that the price of OTM puts may be the main cause of the cross-sectional differences in $RNSkew$ that are driving the previous analyses. This is not surprising given that most of the implied skewness values are negative. The same coefficient for the PUTCALL asset, however, remains strongly significant. The relation between $RNSkew$ and CALL asset returns remains insignificant in the regression using $BKMIV$ and the

OTM Call IV (*LongOptionIV*). In the regression using the ATM Call implied volatility (*ShortOptionIV*), the coefficient on *RNSkew* becomes significantly negative. This is an indication that the negative relation between *RNSkew* and skewness returns may exist across the entire distribution, but is masked by volatility effects on the right side of the return distribution. Finally, it is worth noting that the coefficient on kurtosis is significant in the PUTCALL and CALL regressions, but not in the PUT regressions. This may indicate that kurtosis is mispriced on the right side of the distribution of future stock returns. In summary, all of the previous results are supported by the analyses presented in Table 2.8, and the relation between *RNSkew* and skewness asset returns is not driven by other moments of the distribution of stock returns. In fact, in the case of the CALL asset, the relation appears to be stronger after controlling for other moments.

5 Is There a Risk-Based Explanation for Skewness Returns?

The previous sections have been devoted to demonstrating the two main results of this paper. First, there is a robust negative relation between implied risk neutral skewness (*RNSkew*) and the skewness asset returns. Second, the relation is driven by the stock-option market's pricing of the left side of the risk-neutral distribution, as the relation does not persist for the CALL asset, whose price, and thus returns, are determined only by the right side of the stock return distribution. The question that has not yet been asked is whether the predictability in skewness asset returns can be explained by cross-sectional differences in the risk of the decile portfolios. I begin the risk analysis by examining three commonly used measures of portfolio risk: the standard deviation of monthly returns, value-at-risk, and expected shortfall. In addition to these risk measures, I look at the sensitivities of the skewness asset portfolio returns to the market factor (*MKT*), Fama and French (1993) size

(SMB) and book-to-market (HML) factors, Carhart (1997) momentum (UMD) factor, and the short-term reversal factor.[22]

5.1 Standard Deviation, Value-At-Risk, and Expected ShortFall

The most commonly employed measure of portfolio risk is the standard deviation of portfolio returns. Portfolios with high risk are expected to have a high return standard deviation. In addition to the standard deviation, risk is often measured by analyzing the magnitude of the losses that occur in extreme situations, i.e. the magnitude of the losses in the extreme left side of the distribution of returns. Two risk-metrics designed to measure such losses are value-at-risk (VaR) and expected shortfall (ES). VaR is defined as the maximum loss expected on a portfolio of assets over a certain holding period at a given confidence level (probability).[23] The VaR for a portfolio is simply an estimate of a specified percentile of the probability distribution of the portfolio's returns. The specified percentile is usually computed for the lower tail of the distribution of returns. Thus, I calculate the value-at-risk for a given probability p, $VaR(p)$, to be the p^{th} percentile of the monthly returns of the skewness assets.

VaR as a risk measure is criticized for not being sub-additive. Because of this the risk of a portfolio can be larger than the sum of the stand-alone risks of its components when measured by VaR. Hence, managing risk by VaR may fail to stimulate diversification. Moreover, VaR does not take into account the severity of an incurred damage event. To alleviate these deficiencies Artzner et al. (1999) introduced the expected shortfall risk measure, which is defined as the conditional expectation of loss given that the loss is beyond the VaR level.

[22] Jegadeesh (1990) and Lehmann (1990) were the first to discover the short-term reversal effect in stock returns. The short-term reversal factor returns are calculated by Kenneth French and published in his online data library.

[23] For example, if the given period of time is one month (as it is in the portfolio returns analyzed in this paper) and the given probability is 5%, the VaR measure would be an estimate of the decline in the portfolio value that could occur with a 5% probability over the next month. In other words, if the VaR measure is accurate, losses greater than the 5% VaR measure should occur less than 5% of the time.

The ES measure is defined as $ES(p) = E[R|R \leq VaR(p)]$, where R represents the return on the portfolio. The expected shortfall considers losses beyond the VaR level. Conceptually, ES can be interpreted as the average loss in the worst $100 \times p$ percent of cases.

Panel A of Table 2.9 presents the standard deviation of monthly returns, along with the 5% VaR and 5% ES for each of the decile portfolios. As the skewness assets contain both long and short positions, and the choice to define the skewness assets in a manner such that they represent a long skewness position was arbitrary, I also calculate the 5% VaR and 5% ES for portfolios of short skewness assets.[24] Remember that when holding short skewness asset positions, the relation between $RNSkew$ and portfolio returns becomes positive. All of the risk-metrics for long skewness asset positions indicate more risk in the 10th decile portfolio (low returns) than in the 1st decile portfolio (high returns). This is the opposite of what is expected if cross-sectional differences in risk were driving the results. The 5% VaR for the short PUTCALL and PUT portfolios is lower in decile 10 than in decile 1, indicating less risk in decile, inconsistent with a positive 10-1 return. The 5% ES measures for the short PUTCALL and PUT portfolios show no pattern. In summary, the risk analysis presented in Table 2.9, Panel A gives no support for a risk-based explanation of the skewness asset returns.

[24]The standard deviation of monthly returns is the same regardless of whether long or short positions are held.

Table 2.9: Is There a Risk Based Explanation of Returns?
Panel A below shows the standard deviation (σ) of monthly returns, along with the 5% value-at-risk (VaR) and 5% expected shortfall (ES) for each of the decile portfolios. All values are calculated based on the 177 monthly returns for each decile portfolio, and are shown in percent. Panels B, C, D, and E show factor sensitivities (t-statistics in parentheses) for the CAPM, FF3, FFC4, and FFC4 + Short Term Reversal (STRev) risk factor models respectively. Returns and alphas are in percent. Newey and West (1987) t-statistics are reported in parentheses.

Panel A. Standard Deviation, Value-at-Risk, and Expected Shortfall

PUTCALL Asset	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
σ	3.19	3.59	4.13	4.00	4.23	4.39	4.27	4.64	4.17	4.05
VaR(5%)	5.48	6.67	6.12	8.14	6.63	7.32	6.36	7.60	7.13	7.29
ES(5%)	6.90	8.72	8.76	11.44	9.78	10.64	11.14	12.15	11.48	12.29
VaR(5%) Short	5.03	5.12	5.55	4.48	5.89	6.30	5.21	5.15	4.45	4.01
ES(5%) Short	5.77	7.07	9.50	6.64	8.54	9.22	6.82	7.28	5.56	6.45
PUT Asset	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
σ	3.74	4.73	3.87	4.16	4.06	3.97	4.25	4.60	4.47	4.01
VaR(5%)	3.97	5.07	4.74	6.92	5.60	4.83	5.72	5.70	5.71	5.87
ES(5%)	7.37	10.84	7.93	10.71	9.25	8.59	10.73	11.32	11.76	8.66
VaR(5%) Short	6.89	8.26	7.21	6.93	6.56	6.11	6.11	6.20	5.79	6.17
ES(5%) Short	8.88	10.93	9.09	8.74	8.44	8.52	8.49	8.30	7.36	8.50
CALL Asset	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
σ	4.87	4.88	5.82	5.75	5.82	6.01	5.22	6.16	5.54	6.80
VaR(5%)	10.19	9.36	7.27	11.81	10.32	10.79	10.68	9.56	11.81	11.90
ES(5%)	12.24	12.10	12.04	17.01	13.80	14.80	13.53	14.89	14.93	19.33
VaR(5%) Short	5.72	5.58	5.57	6.25	7.42	8.50	6.97	7.03	7.59	5.88
ES(5%) Short	8.12	9.22	13.73	8.49	12.19	14.61	9.22	13.64	9.43	12.60

Panel B. CAPM Factor Sensitivities

PUTCALL Asset	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Alpha	-0.02	-0.18	-0.25	-0.72	-0.54	-0.57	-1.03	-0.96	-1.34	-1.56
t-stat	(-0.07)	(-0.73)	(-0.82)	(-2.14)	(-1.57)	(-1.93)	(-3.25)	(-2.60)	(-4.31)	(-5.08)
MKT	-0.23	-0.19	-0.11	-0.17	-0.07	-0.02	-0.04	-0.02	-0.02	-0.07
t-stat	(-2.85)	(-2.49)	(-0.87)	(-1.37)	(-0.48)	(-0.17)	(-0.28)	(-0.09)	(-0.10)	(-0.53)
PUT Asset	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Alpha	1.00	0.50	0.49	-0.13	0.04	-0.04	-0.42	-0.32	-0.74	-0.21
t-stat	(3.29)	(1.50)	(1.84)	(-0.40)	(0.14)	(-0.15)	(-1.19)	(-0.82)	(-2.31)	(-0.73)
MKT	-0.24	-0.19	-0.14	-0.18	-0.08	-0.00	-0.06	-0.01	0.08	-0.02
t-stat	(-3.55)	(-2.43)	(-1.47)	(-1.76)	(-0.71)	(-0.02)	(-0.42)	(-0.04)	(0.58)	(-0.12)
CALL Asset	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Alpha	-1.23	-0.63	-0.50	-0.80	-0.54	-0.34	-0.74	-0.41	-0.78	-1.76
t-stat	(-3.29)	(-1.69)	(-1.14)	(-1.95)	(-1.09)	(-0.74)	(-2.39)	(-0.87)	(-1.92)	(-3.32)
MKT	-0.16	-0.09	-0.02	-0.21	-0.03	-0.11	-0.07	-0.01	-0.16	-0.15
t-stat	(-1.31)	(-0.97)	(-0.14)	(-1.37)	(-0.18)	(-0.81)	(-0.61)	(-0.07)	(-0.99)	(-0.83)

Panel C. FF3 Factor Sensitivities

PUTCALL Asset	1	2	3	4	5	6	7	8	9	10
Alpha	-0.05	-0.20	-0.27	-0.77	-0.57	-0.63	-1.12	-1.04	-1.43	-1.60
t-stat	(-0.18)	(-0.76)	(-0.87)	(-2.17)	(-1.52)	(-1.92)	(-3.49)	(-2.55)	(-4.19)	(-4.62)
MKT	-0.24	-0.21	-0.11	-0.15	-0.07	-0.01	-0.02	0.00	-0.01	-0.05
t-stat	(-3.02)	(-2.85)	(-0.97)	(-1.30)	(-0.52)	(-0.06)	(-0.14)	(0.01)	(-0.08)	(-0.38)
HML	0.04	-0.01	0.05	0.17	0.06	0.17	0.27	0.22	0.23	0.17
t-stat	(0.37)	(-0.08)	(0.37)	(1.64)	(0.42)	(1.49)	(2.11)	(1.16)	(1.62)	(1.22)
SMB	0.11	0.10	0.05	-0.03	0.07	0.02	0.04	0.03	0.13	-0.05
t-stat	(1.12)	(0.88)	(0.41)	(-0.38)	(0.86)	(0.24)	(0.41)	(0.27)	(1.40)	(-0.73)

PUT Asset	1	2	3	4	5	6	7	8	9	10
Alpha	1.02	0.50	0.52	-0.13	0.05	-0.05	-0.48	-0.37	-0.79	-0.23
t-stat	(3.27)	(1.51)	(1.86)	(-0.40)	(0.17)	(-0.20)	(-1.36)	(-0.87)	(-2.39)	(-0.78)
MKT	-0.25	-0.21	-0.13	-0.16	-0.07	0.00	-0.03	-0.00	0.08	0.00
t-stat	(-3.93)	(-2.67)	(-1.35)	(-1.49)	(-0.64)	(0.02)	(-0.21)	(-0.02)	(0.67)	(0.04)
HML	-0.06	-0.06	-0.04	0.06	-0.01	0.04	0.21	0.12	0.12	0.12
t-stat	(-0.89)	(-0.75)	(-0.41)	(0.67)	(-0.07)	(0.49)	(2.27)	(0.77)	(1.10)	(0.90)
SMB	0.01	0.10	-0.10	-0.08	-0.04	0.00	-0.06	0.06	0.06	-0.06
t-stat	(0.10)	(0.84)	(-1.05)	(-1.15)	(-0.57)	(0.04)	(-0.57)	(0.50)	(0.75)	(-0.66)

CALL Asset	1	2	3	4	5	6	7	8	9	10
Alpha	-1.35	-0.70	-0.57	-0.94	-0.59	-0.44	-0.86	-0.50	-0.91	-1.81
t-stat	(-3.29)	(-1.73)	(-1.26)	(-2.06)	(-1.12)	(-0.89)	(-2.68)	(-0.95)	(-1.95)	(-3.00)
MKT	-0.17	-0.09	-0.05	-0.19	-0.05	-0.08	-0.06	0.00	-0.14	-0.09
t-stat	(-1.64)	(-1.14)	(-0.34)	(-1.53)	(-0.39)	(-0.77)	(-0.59)	(0.02)	(-1.08)	(-0.56)
HML	0.23	0.16	0.09	0.38	0.04	0.32	0.31	0.24	0.34	0.26
t-stat	(1.25)	(1.02)	(0.40)	(2.49)	(0.20)	(2.12)	(1.82)	(1.07)	(1.82)	(1.14)
SMB	0.28	0.12	0.24	0.12	0.21	0.02	0.12	0.08	0.11	-0.20
t-stat	(1.96)	(0.68)	(1.31)	(0.83)	(1.64)	(0.21)	(1.02)	(0.47)	(0.78)	(-1.38)

Panel D. FFC4 Factor Sensitivities

PUTCALL Asset	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Alpha	-0.04	-0.24	-0.31	-0.80	-0.66	-0.61	-1.14	-1.09	-1.47	-1.69
t-stat	(-0.13)	(-0.88)	(-1.00)	(-2.14)	(-1.79)	(-1.75)	(-3.34)	(-2.60)	(-4.11)	(-4.58)
MKT	-0.25	-0.18	-0.09	-0.13	-0.02	-0.02	-0.01	0.03	0.01	0.00
t-stat	(-3.07)	(-2.25)	(-0.63)	(-1.05)	(-0.12)	(-0.17)	(-0.05)	(0.18)	(0.08)	(0.03)
HML	0.03	0.02	0.08	0.19	0.12	0.16	0.29	0.25	0.26	0.23
t-stat	(0.29)	(0.21)	(0.58)	(1.68)	(0.95)	(1.27)	(2.13)	(1.34)	(1.74)	(1.63)
SMB	0.11	0.10	0.05	-0.03	0.07	0.02	0.04	0.03	0.13	-0.05
t-stat	(1.12)	(0.92)	(0.42)	(-0.38)	(0.81)	(0.24)	(0.41)	(0.27)	(1.40)	(-0.69)
UMD	-0.02	0.07	0.06	0.04	0.14	-0.04	0.03	0.08	0.05	0.13
t-stat	(-0.49)	(1.41)	(0.63)	(0.75)	(1.92)	(-0.50)	(0.55)	(1.16)	(0.86)	(1.61)
PUT Asset	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Alpha	1.03	0.47	0.46	-0.12	-0.05	-0.04	-0.49	-0.41	-0.86	-0.30
t-stat	(3.34)	(1.41)	(1.63)	(-0.36)	(-0.16)	(-0.14)	(-1.31)	(-0.93)	(-2.53)	(-0.97)
MKT	-0.26	-0.19	-0.10	-0.17	-0.02	-0.00	-0.02	0.02	0.13	0.05
t-stat	(-3.91)	(-2.21)	(-0.84)	(-1.36)	(-0.13)	(-0.03)	(-0.15)	(0.09)	(0.94)	(0.35)
HML	-0.07	-0.03	0.00	0.05	0.06	0.03	0.22	0.15	0.17	0.16
t-stat	(-0.97)	(-0.36)	(0.02)	(0.53)	(0.60)	(0.37)	(2.03)	(0.86)	(1.43)	(1.25)
SMB	0.01	0.10	-0.10	-0.08	-0.04	0.00	-0.06	0.06	0.06	-0.06
t-stat	(0.10)	(0.87)	(-1.09)	(-1.14)	(-0.58)	(0.04)	(-0.56)	(0.49)	(0.71)	(-0.66)
UMD	-0.02	0.06	0.09	-0.01	0.15	-0.02	0.01	0.06	0.11	0.10
t-stat	(-0.56)	(0.91)	(1.64)	(-0.23)	(2.81)	(-0.24)	(0.21)	(0.92)	(1.94)	(1.75)
CALL Asset	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Alpha	-1.30	-0.77	-0.60	-1.00	-0.69	-0.39	-0.88	-0.64	-0.92	-1.98
t-stat	(-3.32)	(-1.72)	(-1.41)	(-2.05)	(-1.35)	(-0.76)	(-2.64)	(-1.19)	(-1.93)	(-3.17)
MKT	-0.20	-0.05	-0.03	-0.16	0.00	-0.11	-0.05	0.08	-0.13	0.01
t-stat	(-1.94)	(-0.56)	(-0.16)	(-1.12)	(0.03)	(-0.91)	(-0.45)	(0.52)	(-0.96)	(0.05)
HML	0.19	0.21	0.11	0.42	0.10	0.28	0.32	0.33	0.35	0.37
t-stat	(1.14)	(1.26)	(0.55)	(2.58)	(0.66)	(1.84)	(2.07)	(1.59)	(1.87)	(1.72)
SMB	0.27	0.12	0.25	0.12	0.21	0.02	0.12	0.08	0.11	-0.20
t-stat	(1.98)	(0.72)	(1.34)	(0.84)	(1.60)	(0.21)	(1.03)	(0.52)	(0.78)	(-1.32)
UMD	-0.07	0.10	0.05	0.09	0.15	-0.08	0.02	0.20	0.01	0.25
t-stat	(-0.92)	(1.16)	(0.36)	(1.00)	(1.49)	(-0.71)	(0.28)	(1.75)	(0.08)	(1.55)

Panel E. FFC4 and Short-Term Reversal (STRev) Factor Sensitivities

PUTCALL Asset	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Alpha	0.02	-0.17	-0.03	-0.68	-0.59	-0.39	-0.99	-0.93	-1.26	-1.53
t-stat	(0.06)	(-0.63)	(-0.09)	(-1.98)	(-1.60)	(-1.15)	(-2.95)	(-2.22)	(-3.74)	(-4.19)
MKT	-0.24	-0.17	-0.03	-0.11	-0.00	0.02	0.02	0.07	0.05	0.04
t-stat	(-2.87)	(-1.96)	(-0.20)	(-0.82)	(-0.03)	(0.18)	(0.14)	(0.34)	(0.37)	(0.27)
HML	0.03	0.01	0.05	0.18	0.12	0.14	0.27	0.24	0.24	0.21
t-stat	(0.25)	(0.15)	(0.37)	(1.56)	(0.90)	(1.09)	(2.01)	(1.21)	(1.56)	(1.49)
SMB	0.11	0.10	0.05	-0.03	0.07	0.02	0.04	0.03	0.13	-0.05
t-stat	(1.13)	(0.90)	(0.41)	(-0.36)	(0.80)	(0.25)	(0.41)	(0.27)	(1.39)	(-0.66)
UMD	-0.03	0.06	0.02	0.03	0.13	-0.06	0.01	0.06	0.03	0.11
t-stat	(-0.66)	(1.29)	(0.34)	(0.58)	(1.94)	(-0.86)	(0.24)	(0.94)	(0.49)	(1.46)
STRev	-0.04	-0.05	-0.20	-0.09	-0.05	-0.16	-0.11	-0.12	-0.16	-0.11
t-stat	(-0.88)	(-1.14)	(-2.21)	(-1.64)	(-0.69)	(-2.40)	(-1.79)	(-2.15)	(-2.40)	(-2.14)

PUT Asset	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Alpha	1.22	0.49	0.67	-0.01	-0.05	0.11	-0.37	-0.24	-0.64	-0.10
t-stat	(4.36)	(1.49)	(2.34)	(-0.04)	(-0.19)	(0.38)	(-1.03)	(-0.58)	(-2.01)	(-0.29)
MKT	-0.22	-0.19	-0.05	-0.14	-0.02	0.03	0.00	0.05	0.17	0.09
t-stat	(-2.85)	(-1.93)	(-0.42)	(-1.07)	(-0.12)	(0.19)	(0.01)	(0.25)	(1.13)	(0.66)
HML	-0.09	-0.04	-0.02	0.04	0.06	0.02	0.21	0.13	0.15	0.14
t-stat	(-1.06)	(-0.38)	(-0.15)	(0.42)	(0.61)	(0.22)	(1.94)	(0.74)	(1.21)	(1.06)
SMB	0.01	0.10	-0.10	-0.08	-0.04	0.00	-0.05	0.06	0.06	-0.06
t-stat	(0.12)	(0.87)	(-1.03)	(-1.12)	(-0.58)	(0.05)	(-0.56)	(0.48)	(0.70)	(-0.61)
UMD	-0.05	0.05	0.07	-0.03	0.15	-0.03	-0.00	0.04	0.09	0.08
t-stat	(-1.18)	(0.90)	(1.55)	(-0.52)	(2.82)	(-0.52)	(-0.01)	(0.65)	(1.55)	(1.22)
STRev	-0.14	-0.02	-0.16	-0.08	0.00	-0.11	-0.09	-0.12	-0.16	-0.15
t-stat	(-2.91)	(-0.28)	(-2.33)	(-1.38)	(0.02)	(-1.53)	(-1.28)	(-2.67)	(-2.73)	(-2.68)

Panel E FFC4 and Short-Term Reversal (STRev) Factor Sensitivities - Continued

CALL Asset	1	2	3	4	5	6	7	8	9	10
Alpha	-1.30	-0.72	-0.27	-0.85	-0.55	-0.12	-0.73	-0.48	-0.72	-1.79
t-stat	(-3.43)	(-1.69)	(-0.50)	(-1.96)	(-1.00)	(-0.25)	(-2.10)	(-0.86)	(-1.56)	(-2.85)
MKT	-0.20	-0.04	0.04	-0.12	0.03	-0.05	-0.02	0.11	-0.09	0.05
t-stat	(-1.92)	(-0.45)	(0.20)	(-0.93)	(0.20)	(-0.44)	(-0.16)	(0.70)	(-0.66)	(0.24)
HML	0.19	0.20	0.08	0.41	0.09	0.26	0.31	0.32	0.33	0.36
t-stat	(1.17)	(1.24)	(0.38)	(2.54)	(0.58)	(1.78)	(2.03)	(1.50)	(1.76)	(1.62)
SMB	0.27	0.12	0.25	0.12	0.21	0.02	0.12	0.08	0.11	-0.19
t-stat	(1.99)	(0.72)	(1.35)	(0.83)	(1.61)	(0.21)	(1.01)	(0.51)	(0.77)	(-1.31)
UMD	-0.07	0.10	0.01	0.07	0.13	-0.11	0.01	0.18	-0.01	0.23
t-stat	(-0.94)	(1.14)	(0.10)	(0.84)	(1.49)	(-1.07)	(0.06)	(1.75)	(-0.14)	(1.56)
STRev	-0.01	-0.04	-0.25	-0.11	-0.10	-0.20	-0.11	-0.11	-0.15	-0.14
t-stat	(-0.05)	(-0.62)	(-1.60)	(-1.30)	(-0.92)	(-2.41)	(-1.10)	(-0.94)	(-1.30)	(-1.15)

5.2 Portfolio Sensitivities to Known Factors

The results presented in Table 2.2 demonstrate that the negative relation between BKM implied skewness and skewness asset returns persists after accounting for portfolio sensitivities to the MKT, SMB, HML, and UMD factors of Fama and French (1993) and Carhart (1997). It is possible, however, that there exists a cross-sectional pattern in the factor sensitivities of the skewness asset portfolios to these risk factors. To test this, Table 2.9 Panels B, C, and D present the factor sensitivities of each of the decile portfolios to each of the factors comprising the CAPM (MKT only), Fama-French 3-factor (MKT, SMB, and HML), and Fama-French-Carhart 4-factor (MKT, SMB, HML, and UMD) models. In addition to these risk factors, Panel E presents factor sensitivities calculated using a model that includes the 4 Fama-French-Carhart factors along with the short-term reversal factor ($STRev$).

The results in Table 2.9, Panels B-E present no evidence of strong cross-sectional patterns in factor sensitivities across the decile portfolios. The coefficients on MKT, HML, and UMD are lower for the 1st decile than for the 10th decile portfolio in all models, inconsistent with the hypothesis that decile 1 has higher risk and thus commands a higher return. The SMB coefficients for the 1st decile are higher than for the 10th decile in all models, consistent with a risk-based explanation for the observed return patterns. However, these coefficients, without exception, produce t-statistics less than 2.0 in magnitude. Finally, the $STRev$ factor consistently has lower coefficients in decile 10 than in decile 1. The magnitude of the difference between the decile 10 and decile 1 coefficients (-0.07 for the PUTCALL asset, -0.01 for the PUT, and -0.13 for the CALL asset) is way too small to be taken as an explanation for the negative cross-sectional relation between $RNSkew$ and skewness asset returns. Furthermore, this difference is largest for the CALL asset, where the relation does not exist.

The results from Panels B-E of Table 2.9 provide no evidence for higher risk-factor sensitivities in the 1st decile portfolio than in the 10th decile portfolio. The coefficients on all risk-factors tend to be small in magnitude and in most cases statistically insignificant. Thus, none of the standard risk-analyses presented in Table 2.9 provide evidence of a risk-based explanation for the return patterns observed in the decile portfolios.

5.3 Aggregate Volatility, Stock and Option Market Factors

The skewness assets are comprised of both stock and option positions, thus the returns on these assets are theoretically determined not only by exposure to stock market factors, but also to option market factors. Goyal and Saretto (2009) demonstrate that a portfolio that is long ATM straddles for stocks with high values of historical realized volatility minus implied volatility ($RV - IV$), and short straddles for stocks where the opposite is true, generates positive abnormal returns. If the returns of this portfolio are due to compensation for exposure to a priced risk factor, then it is imperative that I control for such exposures. To do so, I create a proxy for this factor by taking the returns on a portfolio that is long ATM straddles for stocks in the top third of $RV - IV$ and short ATM straddles for stocks in the bottom third of $RV - IV$.[25] I call this factor $RV - IVStraddle$.

As option portfolio returns are intimately connected to the return on the underlying stocks, I control for the potential that a corresponding stock-based factor exists by calculating the returns on a portfolio that is long (short) stock for stocks in the top (bottom) third of $RV - IV$. I name this factor $RV - IVStock$ following Bali and Hovakimian (2009).

Bali and Hovakimian (2009) and Cremers and Weinbaum (2010) show that the difference between ATM call implied volatility (CIV) and ATM put implied volatility (PIV) is a strong predictor of future stock performance. I form two additional factors based on the $CIV - PIV$ signal.[26] The first is the returns on a portfolio that is long (short) stocks in the top (bottom) third of $CIV - PIV$. This factor is intended to proxy for a factor associated with the returns generated in Bali and Hovakimian (2009) and Cremers and Weinbaum (2010). I call the returns on this portfolio the $CIV - PIVStock$ factor.

As the $CIV - PIV$ signal is very similar in nature to the calculation of $RNSkew$, it is necessary that I control for the possibility that the returns generated by the skewness assets are simply a reflection of the manifestation of a $CIV - PIV$ based factor in the options market. To do so, I calculate a proxy for such a factor, which I name $CIV - PIVStraddle$, by taking the returns of a portfolio that is long (short) ATM straddles for stocks in the highest (lowest) third of $CIV - PIV$.

[25] The factor mimicking portfolio is created using the same schedule used for the skewness assets and by Goyal and Saretto (2009). The signal ($RV - IV$) is generated on the first day after each monthly expiration. The portfolios are initiated at the close of the second day following each monthly expiration using 1-month options, and are held until expiration. The ATM strike used to form each straddle is found by choosing the strike of the call option with delta closest to 0.5. I require that the delta of each of the options used to form the straddle is between 0.4 and 0.6. When data for such options are not available, the observation is discarded. RV is calculated as the annualized standard deviation of daily log returns using 12 months of daily data. I require that data be available for each trading day during the past 12 months for entry into the sample. IV is calculated using the average of the call (put) implied volatilities of the 1-month contracts with delta closest to 0.5 (-0.5). I require that the absolute values of the option deltas used to calculate IV are between 0.4 and 0.6.

[26] CIV and PIV are calculated by taking the implied volatilities of the 1-month contracts with delta closest to 0.5 and -0.5 respectively. I require that the absolute values of the option deltas used to calculate CIV and PIV are between 0.4 and 0.6.

In addition to these stock and option market factors, I control for the aggregate volatility (MN) and crash-neutral aggregate volatility ($CNMN$) factors developed by Cremers, Halling, and Weinbaum (2010). These factors are calculated as the returns of a market-neutral straddle portfolio (MN), and a crash-neutral market-neutral straddle portfolio ($CNMN$). Analyses using the MN and $CMNM$ factors end on the December 2007 expiration because data for these factors are not available for later periods.[27] There are therefore only 144 (instead of 177) monthly return periods for models using the MN or $CNMN$ factor.

In Table 2.10, I present the alphas and factor sensitivities for the returns of the decile 10 minus decile 1 portfolio of the skewness assets using several different risk models. The results demonstrate that the cross-sectional return pattern observed in the PUTCALL and PUT assets cannot be explained by any of the factor models, as the t-statistics associated with the alpha coefficient for each of these models are larger than 2.0, with one exception.[28] Interestingly, for the PUTCALL and PUT assets, models that include the $RV - IVStraddle$ factor have alphas and associated t-statistics that are substantially lower in magnitude than the other models.[29] This indicates that although this factor does not completely explain the returns generated by the skewness asset portfolios, it does explain a portion of the returns. Despite the smaller alphas however, the coefficients on the $RV - IVStraddle$ factor are consistently insignificant.

In summary, the main results of the paper hold after controlling for a wide array of stock and option market factors. Inclusion of the $RV - IVStraddle$ factor has a substantial effect on the alphas of the PUTCALL and PUT assets, indicating that exposure to this factor may be partially, but not fully responsible for the returns of the 10-1 portfolios.

[27] I thank Martijn Cremers, Michael Halling, and David Weinbaum for providing me with the daily factor returns. Factor returns corresponding to the periods during which the skewness asset portfolios are held were constructed from the daily data in the same manner as the returns for the MKT, SMB, HML, UMD, and $STRev$ factors.

[28] The only exception is model (9) for the PUT asset, which produces a t-statistic of -1.81, and thus is significant at the 10%, but not the 5% level.

[29] The only exception is the alpha in the model using all factors (model (13)).

Table 2.10: Volatility, Stock, and Option Market Factors

Panels A, B, and C below present the risk-adjusted alphas and factor sensitivities (Newey and West (1987) t-statistics in parentheses) for the returns on the decile 10 - decile 1 portfolios of PUTCALL, PUT, and CALL assets respectively, where the portfolios are formed on deciles of *RNSkew*. The RV-IV Straddle (Stock) factors are formed by taking the returns of a portfolio that is long ATM straddles (stocks) for stocks in the highest third of RV-IV, and short straddles (stocks) for stocks in the lowest third of RV-IV, where RV is the 1 year realized stock volatility, and IV is the average of the 1 month ATM call and ATM put implied volatilities. The CIV-PIV Straddle (Stock) factor returns are calculated analogously, using ATM call implied volatility (CIV) minus ATM put implied volatility (PIV) as the signal. The MN and CNMN factors are the aggregate volatility and crash-neutral aggregate volatility factors developed by Cremers, Halling, and Weinbaum (2010).

Panel A. PUTCALL Asset 10-1 Risk-Adjusted Alphas and Factor Sensitivities

	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**	**(8)**	**(9)**	**(10)**	**(11)**	**(12)**	**(13)**
Alpha	-1.54	-1.55	-1.65	-1.55	-1.53	-1.64	-1.64	-1.64	-1.42	-1.82	-1.82	-1.73	-1.90
	(-5.31)	(-5.22)	(-5.52)	(-5.04)	(-4.49)	(-5.65)	(-5.46)	(-5.42)	(-3.62)	(-5.95)	(-6.04)	(-6.29)	(-4.49)
MKT	0.159	0.197	0.256	0.277	0.252	0.243	0.251	0.255	0.246	0.240	0.229	0.310	0.280
	(1.83)	(2.55)	(3.25)	(3.33)	(3.14)	(3.06)	(3.18)	(3.07)	(2.83)	(2.67)	(2.65)	(3.42)	(2.69)
HML		-0.164	-0.162	-0.162	-0.163	-0.134	-0.157	-0.165	-0.136	-0.220	-0.239	-0.233	-0.204
		(-1.85)	(-1.78)	(-1.75)	(-1.76)	(-1.62)	(-1.74)	(-1.72)	(-1.55)	(-2.21)	(-2.33)	(-2.38)	(-2.29)
SMB		0.129	0.195	0.186	0.190	0.226	0.196	0.191	0.207	0.231	0.217	0.258	0.311
		(1.30)	(2.01)	(1.92)	(1.94)	(2.40)	(2.04)	(2.00)	(2.09)	(2.53)	(2.39)	(2.91)	(3.96)
UMD			0.151	0.139	0.152	0.148	0.149	0.153	0.144	0.243	0.240	0.261	0.272
			(1.96)	(1.78)	(1.99)	(1.95)	(1.96)	(1.98)	(1.85)	(2.91)	(2.87)	(3.25)	(3.60)
STRev				-0.075					-0.046				0.045
				(-1.26)					(-0.77)				(0.71)
RV-IV Straddle					-0.011				-0.012				0.011
					(-0.46)				(-0.57)				(0.46)
RV-IV Stock						0.139			0.122				0.154
						(1.37)			(1.17)				(1.40)
CIV-PIV Straddle							0.012		0.011				0.007
							(0.40)		(0.37)				(0.23)
CIV-PIV Stock								-0.031	-0.036				-0.029
								(-0.16)	(-0.18)				(-0.13)
MN										0.001		0.118	0.122
										(0.11)		(3.04)	(3.00)
CNMN											-0.006	-0.131	-0.135
											(-0.58)	(-3.02)	(-2.95)
n	177	177	177	177	177	177	177	177	177	144	144	144	144

Panel B. PUT Asset 10-1 Risk-Adjusted Alphas and Factor Sensitivities

	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**	**(8)**	**(9)**	**(10)**	**(11)**	**(12)**	**(13)**
Alpha	-1.207	-1.251	-1.337	-1.318	-0.973	-1.347	-1.308	-1.308	-0.837	-1.458	-1.446	-1.315	-1.443
	(-2.95)	(-3.09)	(-3.38)	(-3.37)	(-2.36)	(-3.36)	(-3.32)	(-3.17)	(-1.81)	(-3.28)	(-3.35)	(-3.53)	(-3.36)
MKT	0.225	0.255	0.305	0.309	0.294	0.315	0.280	0.299	0.268	0.260	0.251	0.368	0.343
	(1.75)	(2.31)	(2.90)	(2.86)	(3.04)	(3.07)	(2.57)	(2.78)	(2.34)	(2.59)	(2.58)	(4.32)	(3.17)
HML		-0.069	-0.068	-0.068	-0.069	-0.088	-0.044	-0.077	-0.077	-0.145	-0.174	-0.164	-0.159
		(-0.52)	(-0.53)	(-0.53)	(-0.53)	(-0.74)	(-0.37)	(-0.57)	(-0.61)	(-0.90)	(-1.03)	(-1.04)	(-1.09)
SMB		0.177	0.234	0.232	0.220	0.211	0.239	0.216	0.168	0.258	0.240	0.300	0.269
		(1.37)	(1.85)	(1.81)	(1.70)	(1.77)	(1.91)	(1.62)	(1.35)	(2.00)	(1.81)	(2.31)	(1.98)
UMD			0.129	0.127	0.134	0.131	0.120	0.137	0.135	0.217	0.213	0.243	0.233
			(1.65)	(1.49)	(1.72)	(1.69)	(1.52)	(1.70)	(1.57)	(2.09)	(2.03)	(2.43)	(2.21)
STRev				-0.014					-0.023				0.050
				(-0.20)					(-0.31)				(0.46)
RV-IV Straddle					-0.032				-0.035				0.009
					(-1.12)				(-1.14)				(0.43)
RV-IV Stock						-0.099			-0.115				-0.172
						(-0.71)			(-0.78)				(-1.12)
CIV-PIV Straddle							0.058		0.074				0.093
							(1.59)		(1.70)				(1.90)
CIV-PIV Stock								-0.122	-0.205				-0.246
								(-0.61)	(-0.86)				(-0.93)
MN										-0.007		0.171	0.193
										(-0.59)		(2.36)	(2.68)
CNMN											-0.019	-0.200	-0.223
											(-1.14)	(-2.40)	(-2.64)
n	177	177	177	177	177	177	177	177	177	144	144	144	144

Panel C. CALL Asset 10-1 Risk-Adjusted Alphas and Factor Sensitivities

	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**	**(8)**	**(9)**	**(10)**	**(11)**	**(12)**	**(13)**
Alpha	-0.527	-0.455	-0.673	-0.492	-1.176	-0.632	-0.696	-0.704	-1.135	-0.792	-0.819	-0.748	-1.489
	(-1.13)	(-0.94)	(-1.40)	(-1.03)	(-2.23)	(-1.35)	(-1.44)	(-1.55)	(-2.10)	(-1.49)	(-1.54)	(-1.46)	(-2.43)
MKT	0.011	0.085	0.212	0.249	0.227	0.174	0.232	0.218	0.255	0.247	0.217	0.280	0.290
	(0.09)	(0.70)	(1.56)	(1.66)	(1.66)	(1.49)	(1.79)	(1.53)	(2.00)	(1.43)	(1.31)	(1.56)	(1.59)
HML		-0.473	-0.471	-0.470	-0.469	-0.392	-0.490	-0.460	-0.407	-0.468	-0.479	-0.474	-0.416
		(-3.11)	(-3.01)	(-3.01)	(-3.11)	(-3.44)	(-3.20)	(-3.02)	(-3.75)	(-2.48)	(-2.58)	(-2.49)	(-3.51)
SMB		0.037	0.180	0.165	0.199	0.267	0.176	0.199	0.298	0.228	0.209	0.241	0.454
		(0.19)	(1.11)	(1.05)	(1.35)	(1.70)	(1.09)	(1.37)	(2.12)	(1.03)	(0.96)	(1.07)	(2.33)
UMD			0.325	0.304	0.318	0.318	0.332	0.317	0.297	0.468	0.459	0.476	0.510
			(2.44)	(2.39)	(2.43)	(2.52)	(2.52)	(2.38)	(2.29)	(2.98)	(2.91)	(3.04)	(3.99)
STRev				-0.132					-0.071				0.058
				(-1.05)					(-0.62)				(0.46)
RV-IV					0.044				0.044				0.048
Straddle					(0.96)				(1.10)				(0.93)
RV-IV						0.386			0.364				0.506
Stock						(2.15)			(2.17)				(2.27)
CIV-PIV							-0.047		-0.073				-0.108
Straddle							(-0.89)		(-1.58)				(-2.26)
CIV-PIV								0.132	0.229				0.343
Stock								(0.39)	(0.70)				(0.86)
MN										0.036		0.092	0.091
										(1.91)		(1.26)	(1.38)
CNMN											0.035	-0.062	-0.061
											(1.77)	(-0.83)	(-0.88)
n	177	177	177	177	177	177	177	177	177	144	144	144	144

6 Conclusion

Using stock options from 1996-2010, I find a strong and robust negative relation between implied risk-neutral skewness ($RNSkew$) and skewness asset returns. This return pattern is consistent with the existence of a negative skewness risk premium and a preference for assets with positively skewed return distributions. The returns are not explained by the market, size, book-to-market, momentum, and short-term reversal factors of Fama and French (1993), Carhart (1997), and Jegadeesh (1990). Aggregate volatility and jump factors of Cremers, Halling, and Weinbaum (2010), and other stock and option market factors of Goyal and Saretto (2009), Bali and Hovakimian (2009), and Cremers and Weinbaum (2010) also fail to explain the portfolio returns. The significant return spreads are also robust to the inclusion of controls that proxy for other moments of the return distribution, option liquidity, differences in asset construction, and transaction costs. The results are driven by the option market's pricing of risk-neutral probabilities in the left side of the risk-neutral distribution. Analyses of portfolio risk and factor sensitivities fail to detect increased risk for the highest-return decile portfolio compared to the lowest-return decile portfolio. Traditional risk metrics, therefore, fail to attribute the pattern in skewness asset returns to cross-sectional differences in portfolio risk.

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Appendix 2A Calculation of Risk Free Rate and Present Value of Dividends

The present value of dividends (*PVDivs*) on date t_0 for an option expiring on date t_1 is calculated to be the sum of the present values of all dividends paid on the underlying stock with ex-dates between date t_0 (exclusive) and t_1 (inclusive). Specifically, let $Div_{e,\tau}$ be a dividend paid on the underlying stock with ex-date e and pay-date τ, where $t_0 \leq e \leq t_1$, and let r_t be the risk-free rate of return on a deposit made on date t_0 to be withdrawn on date τ, and t_τ be the time, in years, between dates t_0 and τ, then I have

$$PVDivs = \sum_{t_0 \leq \tau \leq t_1} e^{-r_\tau t_\tau} Div_{e,\tau} \tag{6}$$

OptionMetrics provides zero-rate data for each date t_0 and a series of maturities. r_τ, for any specific value of t_0 and τ, is found by applying a cubic spline, to the zero-rate data for date t_0 and find the interpolated zero-rate for matruity t_τ.

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