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

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

**Abstract**

We investigate the pricing of risk-neutral skewness in the stock options market by creating *skewness assets* comprised of two option positions (one long and one short) and a position in the underlying stock. The assets are created such that exposure to changes in the underlying stock price (delta), and exposure to changes in implied volatility (vega) are removed, isolating the effect of skewness. We find a strong negative relation between risk-neutral skewness and the skewness asset returns, consistent with a positive skewness preference. The returns are not explained by well-known market, size, book-to-market, momentum, short-term reversal, volatility, or option market factors.

## I. Introduction

Arditti (1967), Kraus and Litzenberger (1976), Kane (1982), and Harvey and Siddique (2000) 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 with higher (lower) systematic skewness are more (less) desirable and command lower (higher) expected returns. Barberis and Huang (2008) and Mitton and Vorkink (2007) develop models in which investors have similar preferences for idiosyncratic skewness.

Empirical studies testing the ability of skewness (or related measures) to predict cross-sectional variation in stock returns have produced mixed results. Xing, Zhang, and Zhao (2010), Cremers and Weinbaum (2010), and Rehman and Vilkov (2012) find a theoretically contradictory positive relation between skewness and future returns, while Bali, Cakici, and

Whitelaw (2011) and Conrad, Dittmar, and Ghysels (2013) find a theoretically consistent negative relation. Boyer, Mitton, and Vorkink (2010) demonstrate that historical based estimates of skewness provide poor forecasts of future skewness.[1]

In this paper, we present evidence of positive skewness preference by analyzing the returns of *skewness assets*. The *skewness assets* are combinations of stock and option positions that collectively form a long skewness position. Just as a long straddle position is considered a long volatility position because it increases (decreases) in value when the volatility of the underlying security increases (decreases), our *skewness assets* increase (decrease) in value when the skewness of the underlying security increases (decreases). To mitigate the issues of measurement error in skewness associated with historical based estimates, we use a distribution-free risk-neutral measure of skewness developed by Bakshi and Madan (2000) and Bakshi, Kapadia, and Madan (2003) calculated from option prices. Options are priced based on the market's view of the distribution of future returns. Thus, using an option implied measure of skewness overcomes the shortcomings of historical based measures.

We analyze the cross-sectional relation between the returns of the skewness assets and implied risk-neutral skewness. The results indicate a strong, negative relation between implied risk-neutral skewness and skewness asset returns, consistent with a preference for positively skewed assets (investors accept a lower expected return on assets with positive skewness). We show that the cross-sectional return pattern is due to the market's pricing of the left side of the risk-neutral distribution. Specifically, we 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 the left side of risk-neutral distribution), but the relation disappears when trading OTM and ATM calls (call prices are

[1]We find that physical skewness, measured as the the skewness of daily returns over the past one year, fails to predict future equity and skewness asset portfolio returns. The results are discussed in Section I of the online appendix.

affected only by the right side of risk-neutral distribution). We find no evidence that the observed return pattern is due to compensation for exposure to previously established priced risk factors.

This work 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 (2013) find that delta-hedged option returns are negative for most stocks, and decrease with total and idiosyncratic volatility. We 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 our 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 II. describes the creation of the skewness assets. Section III. describes the main variables and presents the data. Section IV. demonstrates the strong negative relation between implied risk-neutral skewness and skewness asset returns. In Section V., we check the robustness of the main result to the inclusion of several different control variables and investigate a potential risk-based explanation of our findings. Section VI. concludes.

## II. 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 large down-move in the stock (negative skewness). To analyze the pricing of implied risk-neutral skewness in the market for stock options, we 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.[2]

To construct the skewness assets, we begin by finding the ATM put and call contracts. We define the ATM put (call) contract to be the contract with a delta closest to -0.5 (0.5).[3] We use delta to identify the ATM contracts instead of finding the strike that is closest to the spot price because many of the stocks in the data set pay dividends, thus the current spot price may not be close to the mean of the distribution of the stock price at expiration.

We define the OTM put (call) contract to be the contract with a delta closest to -0.1

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

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

(0.1).[4,5] We 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. We define $K$ to be the strike price of an option, $\Delta$ to be the delta of an option, $\upsilon$ 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. We use subscripts of the form $OptionType, Moneyness$ to indicate which option we are referring to. For example, $\Delta_{P,OTM}$ refers to the delta of the OTM put contract.

## A. PUTCALL Asset

The first skewness asset, which we 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 $Pos^{PC}_{P,OTM} = -\upsilon_{C,OTM}/\upsilon_{P,OTM}$ contracts (a short position) in the OTM put, and a stock position of

[4] As discussed in Section B., our findings remain intact when the OTM put (call) contract is defined as the option with delta closest to -0.2 (0.2).

[5] We 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. We use a simple example to illustrate 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.

$Pos_S^{PC} = -\left(Pos_{C,OTM}^{PC}\Delta_{C,OTM} + Pos_{P,OTM}^{PC}\Delta_{P,OTM}\right)$ shares of the underlying stock.[6] 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 an increase the value of the OTM put. The short position in the OTM put results in a decrease in the value of the PUTCALL asset. Thus, we see that 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.

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

## B. PUT Asset

The PUT asset consists of a position of $Pos^P_{P,OTM} = -1$ contract of the OTM put, a position of $Pos^P_{P,ATM} = \upsilon_{P,OTM}/\upsilon_{P,ATM}$ 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. The PUT asset is insensitive to large positive underlying stock returns.

## C. CALL Asset

The final skewness asset, which we name the CALL asset, consists of a position of $Pos^C_{C,OTM} = 1$ contract of the OTM call, a position of $Pos^C_{C,ATM} = -\upsilon_{C,OTM}\upsilon_{C,ATM}$ 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. The CALL asset is insensitive to large negative underlying stock returns.

Figure 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. 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, we see that the CALL asset payoff is most sensitive to large up-moves in the stock price. With all assets, we see that a large up-move (down-move) in the stock price corresponds to a high (low) payoff.

# III. Data and Variables

Data used in this paper come from IvyDB's OptionMetrics database. OptionMetrics provides option price data and Greeks for the period from January 1, 1996 through October 31, 2010. We include in our dataset all options for securities listed as common stocks in the OptionMetrics database. We 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. We use stock data, also from OptionMetrics, from those same dates as well as the expiration date of the options being considered.[7] The stock price at expiration is used to calculate the payoff of the skewness asset. We remove any incomplete or incorrect option data from the sample.[8] We take the price of an option to be the average of the bid and offer prices.[9] The OptionMetrics data is augmented with stock price and return data for 1995 from the Center for Research in Security Prices (CRSP).[10] 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 signal generation and asset creation.

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 Bakshi et al.

[7] We 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.

[8] Specifically, we 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). We 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 option with the same underlier/strike/expiration combination on the same date. Options with missing or bad Greeks or implied volatilities are removed, as the Greeks (delta and vega) are necessary to create the skewness assets. Finally, we remove options that violate basic arbitrage conditions. For calls, we 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, we 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.

[9] In section C. we analyze the effects of paying different percentages of the spread on our analyses.

[10] 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 us to include option data from 1996 in these analyses. For a stock/expiration combination to gain entry into the sample, we 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.

(2003) (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.

## A. *RNSkew*

Each month, we 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 $\mu = e^{rt} - 1 - (e^{rt}/2)V - (e^{rt}/6)W - (e^{rt}/24)X$, 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. 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 $RNSkew$, we modify these discrete formulae slightly. First, instead of using the current spot price in the calculations, we use the spot price minus the present value of all dividends with ex-dates on or before the expiration date ($PVDivs$).[11] Second, the discrete

[11]Calculation of the applicable risk-free rate and present value of dividends is described in Section II of the online appendix.

formulae in BKM assume that option prices are available with strikes that are equally spaced above and below the current spot price. We modify the formulae slightly to allow the use of all available options data. Thus, we define $V$, $W$, and $X$ as

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

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

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

where $i$ indexes the OTM call and put options with available price data. In the calculations, we 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, we set $\Delta K_i^P = K_{i-1}^P - K_i^P$ for $2 \le i \le n^P$, $\Delta K_1^P = Spot^* - K_1^P$, $\Delta K_i^C = K_i^C - K_{i-1}^C$ for $2 \le i \le n^C$, and $\Delta K_1^C = K_1^C - Spot^*$. Allowing the $\Delta K$ 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, we calculate $RNSkew$

for each stock/expiration combination. In each calculation, we 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.

## B. 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. We 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, we 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.

## C. Summary Statistics

To create the sample, we begin with all securities listed as common stocks in the OptionMetrics database. We 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.[12] 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 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 cross-section of stocks.

Table 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%.[13] The positions sizes of the securities comprising the assets and the deltas of the options in the assets exhibit significant variation. Even though

[12]As discussed in Section B., our findings persist when we repeat our analyses using 2-month options.

[13]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. We demonstrate in Section A. that using a CBOE margin requirement-based return calculation produces qualitatively similar results to the price-based return calculation.

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, we see that 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.

# IV. Portfolio Analysis

We begin our analysis of 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*. The portfolios are held until the next monthly expiration, at which time the option positions expire.[14] By using a risk-neutral options' implied measure of skewness to investigate the

[14]For example, the July 1996 expiration falls on the 20$^{\text{th}}$ day of the month (all expirations are Saturdays), and the August 1996 expiration falls on the 17$^{\text{th}}$ day of August. Thus, on Monday July 22nd (the first trading day after the July expiration), we calculate *RNSkew*. Then, on Tuesday, July 23rd, we create the skewness assets using options that expire on August 17$^{\text{th}}$. 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$^{\text{th}}$ (actually August 16$^{\text{th}}$ as this is the last trading day before expiration).

cross-sectional predictability of stock/option portfolio returns, we are able to accurately measure the market's view of the skewness of the distribution of *future* returns.

Table 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).[15] 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.

The PUTCALL and PUT assets demonstrate a strong negative relation between $RNSkew$ and future skewness asset 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 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 asset 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. We arrive at this second conclusion because the negative relation holds for the PUTCALL asset (prices both tails of the risk-neutral

[15]The $MKT$ (market), $SMB$ (size), $HML$ (book-to-market), and $UMD$ (momentum) factors are described and available at Kenneth French's online data library.

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 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, Bali, and Cakici (2013), 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. (2013) find a negative relation between BKM implied skewness and future stock returns, while Rehman and Vilkov (2012) find a position relation. Given the evidence that implied skewness has predictive power over stock returns, it is possible that the 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, we 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, we 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 alphas for the return breakdowns are presented in Table 3.

Table 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 3 is that the option portion of the asset does play the largest role in the asset return. More interesting perhaps, is that the standard deviation of the monthly 10-1 raw returns for the PUTCALL asset is 4.06% is lower than that of either the option (6.23%) or stock portion (4.91%). 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 3 also provides strong evidence that the hedges inherent in the asset design are working as desired.

## A. Margin Requirements

As mentioned previously, another concern with the returns from Table 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. The Chicago Board Options Exchange (CBOE) requires member firms entering into option positions to put forth a margin requirement to protect against potential losses on the position. According to the CBOE's margin manual, the initial margin requirement for any long option position is the entire price of the option, and the initial margin requirement for a short position is "100% of option proceeds plus 20% of underlying security value less out-of-the-money amount, if any, to a minimum for calls of option proceeds plus 10% of the underlying security value, and a minimum for puts of option proceeds plus 10% of the puts exercise price."[16] To make sure the results are not driven by the use of the absolute value of the skewness asset price in the denominator of the return calculation, we calculate the skewness asset returns using the CBOE initial margin requirements in the denominator. We calculate the margin requirement for the entire skewness asset to be the sum of the margin requirements for each of the option positions in the asset plus the absolute price of the stock position in the asset.[17]

Table 4 presents the CBOE initial margin requirement-based returns of the skewness asset portfolios.[18] Because the margin requirements (and therefore returns) for long skewness asset positions are different from those for short skewness asset positions, both sets of results are presented. The table demonstrates that the results using margin-based returns for long skewness asset positions are very similar to those using price-based returns. The relation between $RNSkew$ and margin-based returns for both the PUTCALL and PUT assets remains significantly negative. The statistical significance of the margin-based cross-sectional relation is very similar to, and in the case of the PUT asset even stronger than, the results using

[16]The CBOE margin manual is available at http://www.cboe.com/LearnCenter/pdf/margin2-00.pdf.

[17]This assumes that a long stock position is paid for in full, and that the margin requirement for a short stock position is 100% of the value of the stock shorted.

[18]To save space, we present only the FFC4 alphas. Raw returns, CAPM, and FF3 alphas are qualitatively similar. We adopt this convention for the remainder of the paper.

price-based returns. Consistent with the price-based return results, the cross-sectional relation is not present in the margin-based returns of the CALL asset. 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. Consistent with previous analyses, the results fulfill this expectation for the PUTCALL and PUT assets, and remain insignificant for the CALL asset.

The results from Tables 2, 3, and 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.

# V. 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, we now perform several analyses that control for the effects of other potential determinants of skewness asset returns. First, we check for a peso problem by analyzing the relation between $RNSkew$ and skewness asset returns in several different market conditions. Next, we consider the possibility that the asset returns are related to characteristics of the skewness asset construction, such as the deltas, vegas, or time to expiration of the options used to create the skewness assets. We then check whether the results are driven by market frictions such as liquidity and transaction costs. We then control for potential relations between other moments of the risk-neutral distribution (mean, volatility, and kurtosis) and skewness asset returns. Finally, we assess the possibility of a risk-based explanation for the return pattern.

## A. Market Conditions

A potential concern with the results presented in the previous section is that the results are particular to the time period covered by the study. While the sample period, January 1996 through October 2010, does contain a variety of different market conditions, with two substantial periods of market decline (the bursting of the dot-com bubble in 2000 through 2002 and the subprime crisis of 2007 and 2008), it is possible that the market conditions present during the 1996 through 2010 were, on average, favorable to the skewness investment strategy under investigation.

To rule out this potential peso problem, we begin by plotting the cumulative sum of log monthly returns for the strategy that is long the decile 1 portfolio and short the decile 10 portfolio, for each of the skewness assets, over the entire sample period. Figure 2 shows that the returns for all three assets are reasonably steady, with no extreme gains or losses in any month that would cause inferential problems in statistical analyses. Furthermore, the gains for the PUTCALL and PUT assets appear to be consistent across the different types of market conditions that existed during the sample period.

To more rigourously analyze the effect of market conditions on the relation between $RNSkew$ and skewness asset returns, we break the sample into months corresponding to above average economic growth, below average growth, and recession. We identify months corresponding to each market condition using the Chicago Fed National Activity Index (CFNAI). The CFNAI is an indicator of economic activity with values above (below) 0 corresponding to periods of above (below) average economic growth and values below -0.7

corresponding to recession.[19] We also analyze the most recent period corresponding to the subprime lending crisis and its aftermath, July 2007 through October 2010. Table 5 demonstrates that the main results persist regardless of the economic environment. The 10-1 portfolio FFC4 alphas remain negative and statistically significant for the PUTCALL and PUT assets, and insignificantly different from 0 for the CALL asset.[20]

As a final check that our results are not due to a peso problem, we analyze the returns of the strategy during the worst stock market months of the sample. The worst holding period month in our sample begins at market close on September 23, 2008 and end on October 17, 2008. During this time, the $MKT$ factor realized a excess return of -22.73%, and the portfolio that is long PUTCALL, PUT, and CALL assets for decile 1 and short the assets for decile 10 of $RNSkew$ returned 15.68%, 23.99%, and 2.41% respectively. The second lowest holding period return for the market was the very next month (holding period ending on November 21, 2008). During this period, the $MKT$ factor realized an excess return of -18.16%, while the long decile 1 and short decile 10 PUTCALL, PUT, and CALL asset portfolios produced returns of 6.45%, 9.36%, and 1.35% respectively. Compounding the returns from both months, the $MKT$ factor return was -36.75%, while the PUTCALL, PUT, and CALL portfolios produced returns of 21.12%, 31.10%, and 3.72% respectively.

[19]The CFNAI is a weighted average of 85 existing monthly indicators of national economic activity. It is constructed to have an average value of zero and a standard deviation of one. Since economic activity tends toward trend growth rate over time, a positive index reading corresponds to growth above trend and a negative index reading corresponds to growth below trend. The 85 economic indicators that are included in the CFNAI are drawn from four broad categories of data: production and income; employment, unemployment, and hours; personal consumption and housing; and sales, orders, and inventories. Each of these data series measures some aspect of overall macroeconomic activity. The derived index provides a single, summary measure of a factor common to these national economic data.

[20]The one exception is that the cross-sectional relation between $RNSkew$ and the CALL asset returns becomes statistically significant during periods of recession.

Finally, during the period following these catastrophic months (ending December 19, 2008), the market return was 4.81%, and the PUTCALL, PUT, and CALL portfolios returned 6.75%, 1.84%, and 16.75%, providing no evidence that the market changed it's pricing of skewness risk as a result of the market turmoil.

## B. Skewness Asset Construction

The choice to target options with absolute deltas of 0.1 when creating the skewness assets was completely arbitrary, as was the use of 1-month options. Table 6 presents the decile returns for skewness assets created using a target absolute delta of 0.2, as well as decile portfolio returns for skewness assets created using 2-month options.[21] 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.

When creating the original skewness assets, even though an absolute delta of 0.1 was targeted, Table 1 indicated that there is substantial variation in the deltas (and vegas) of the options actually comprising the assets. As the deltas and vegas determine the sizes of the positions in the skewness assets, position sizes also vary. To make sure that it is not cross-sectional variation in the option greeks or position sizes that is driving the results, we perform Fama and MacBeth (1973) (FM) regressions of the skewness asset returns on $RNSkew$ and the deltas, vegas, non-redundant option position, and stock position of the assets. Panel A of Table 7 indicates 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 of Table 7 demonstrate that after controlling for cross-sectional variation in asset construction, the negative relation between $RNSkew$ and

[21] For the 2-month option sample, $RNSkew$ is also calculated using 2-month options and the skewness asset holding period is 2 months long. The 2-month sample has a total of 83,303 stock/expiration combinations over 176 monthly return periods.

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.

## C. Market Frictions

Market frictions are 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. We begin our analysis of the effect of market frictions on the relation between $RNSkew$ and skewness asset returns by restricting the sample to stock/month combinations where market frictions should be less of an issue. First, we define the *Open Interest* sample to be stock/expiration combinations where all options (OTM and ATM call and put) have positive open interest. The *Open Interest* sample has 47,899 (compared to 57,535 for the full sample) stock/expiration data points. We also create a *Large Stocks* sample that contains 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). This sample includes 25,824 stock/expiration observations. Finally, we create the *Large Stocks Small Spreads* sample by reducing the *Large Stocks* 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 less than \$0.15. This is quite a stringent restriction, and there are very few observations before 2001 that meet these criteria, thus we begin this analysis in July 2001. This sample contains only 5,377 stock/expiration observations, down from 37,120 for the corresponding period in the full sample. Table 8 demonstrates that for each of these restricted samples, the negative relation between $RNSkew$ and skewness asset returns persists for the PUTCALL and PUT assets, and remains insignificant for the CALL asset.

As an additional check that market frictions are not driving the relation between $RNSkew$

and skewness asset returns, we perform FM regressions of the skewness asset returns on $RNSkew$ and several proxies for liquidity and transaction costs. First, we use the open interest of the options used to create the assets ($OpenInt$). Second, we use three different measures of option spreads. We 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. As both the $Spread\$$ and $SpreadVol$ would be expected to be larger for options with higher implied volatilities (or equivalently higher priced options), we scale $SpreadVol$ by the implied volatility of the option to find the percentage of implied volatility encompassed by the spread ($Spread\%Vol$). Finally, as options on smaller stocks tend to be less liquid, we include the log of market capitalization ($lnMktCap$) of the stock, calculated on the day after the most recent option expiration, as our final liquidity control.[22]

Panel A of Table 9 demonstrates that liquidity is much lower in decile 10 of $RNSkew$ than in decile 1. The FM regressions presented in Panel B confirm that the negative relations between $RNSkew$ and returns of the PUTCALL and PUT skewness assets are not explained by market frictions. The relation remains insignificant for the CALL asset.

The results above indicate that cross-sectional variation in market frictions does not explain the relation between $RNSkew$ and the returns of the PUTCALL or PUT assets. We have not, however, assessed how much of the quoted spread an investor could pay and still have the strategy remain profitable. To do this, we calculate the returns realized by an investor who pays a certain percentage (0%, 25%, 50%, 75%, and 100%) of the quoted half-spread to enter into the option positions. Table 10 presents the FFC4 alphas of the after transaction cost returns for a portfolio that is long (short) skewness assets for decile 1 (10)

[22]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.

of $RNSkew$ using both price-based and CBOE initial margin-based returns.

The results in Table 10 indicate that for the PUTCALL asset an investor can pay 25% of the quoted half-spread and realize a statistically significant alpha. For the PUT asset, the alphas become negative even when paying only 25% of the half-spread. The sensitivity of the returns to paying transaction costs demonstrated in Table 10 indicates that an investor attempting to capture the premium demonstrated throughout this paper may need to employ a sophisticated execution algorithm geared towards reducing transaction costs.

## D. Mean, Volatility, and Kurtosis of Stock Returns

Option prices are determined by all moments of the distribution of stock returns. To ensure that the relation between $RNSkew$ and skewness asset returns are not driven by other moments of the distribution of future stock returns, we 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. We 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, we include the return of the stock during the period for which the asset is held ($RetHldPer$). We 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 ($RVHldPer$).[23] Finally, we control for the implied volatility and kurtosis by including the BKM implied volatility ($BKMIV$)

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

and BKM implied kurtosis ($BKMKurt$) as control variables.[24] As additional controls for volatility, we use the implied volatilities of the options comprising the skewness assets.

The decile portfolio averages for each of the control variables are presented in Table 11, Panel A. 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, presented in Panel B of Table 11, 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. The one exception is the PUT asset return regression using the *ShortOptionIV* (OTM Put IV). This result actually supports the main conclusion. The significant $RNSkew$ coefficient when controlling for the *LongOptionIV* (ATM Put IV), and insignificant $RNSkew$ coefficient when controlling for *ShortOptionIV* (OTM Put IV), indicates that the main result is driven by the difference between the ATM and OTM Put IVs. This difference is, effectively, skewness. 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 *ShortOptionIV*, (ATM Call IV), the coefficient on $RNSkew$ becomes significantly negative. This is an indication that the negative

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

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 11, 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.

## E. Is There a Risk-Based Explanation?

The analyses presented in previous sections indicate that standard risk models do not fully explain the difference in returns between the decile 1 and decile 10 portfolios. Here, we examine the possibility that the predictability in skewness asset returns can be explained by cross-sectional differences in the risk of the decile portfolios. To save space, the details of the analyses and results are discussed in Section III of the online appendix. Here, we summarize.

We 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 for each of the 10 decile portfolios. If a risk explanation exists, then we would expect to see a strong cross-sectional pattern in these risk measures across the deciles of $RNSkew$. The results, presented in Table II of the online appendix, give no indication of a cross-sectional pattern in the risk of the $RNSkew$ based decile portfolios of skewness assets.

We continue by looking for patterns in the factor loadings of the decile portfolios on the factors in the most commonly used risk models. Table III in the online appendix presents the factor loadings for each of the decile portfolios using the CAPM, FF3 factor, FFC4 factor, and FFC4 factor plus short term reversal risk models.[25] The results reveal no patterns in the factor loadings on the decile portfolios that could provide a risk-based explanation for the results.

Finally, we attempt to explain the results by including several additional factors in the risk models. Goyal and Saretto (2009) find that the difference between realized and implied volatility ($RV - IV$) predicts future straddle returns. We therefore create $RV - IV$ based straddle and stock return factors. Bali and Hovakimian (2009) and Cremers and Weinbaum (2010) show that the difference between ATM call implied volatility ($CIV$) and ATM put implied volatility ($PIV$) predicts future stock performance, so we form stock and straddle return factors based on the $CIV - PIV$ signal. We also include the aggregate volatility ($MN$) and crash-neutral aggregate volatility ($CNMN$) factors developed by Cremers, Halling, and Weinbaum (2012).[26] Finally, we control for the possibility that the 10-1 portfolio returns load on index option returns with factors whose returns are equal to the return on an S&P straddle position ($S\&PStraddle$) and the return on an OTM S&P put contract ($S\&PPut$, see Du and Kapadia (2011)). Table IV in the online appendix demonstrates that, regardless of the factors included in the risk model, the alpha of the 10-1 portfolio remains negative and significant for the PUTCALL and PUT assets, and insignificant for the CALL asset. In summary, the main results of the paper hold after controlling for a wide array of stock and option market factors.

[25] 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.

[26] These factors are calculated as the returns of a market-neutral straddle portfolio ($MN$), and a crash-neutral market-neutral straddle portfolio ($CNMN$). We thank Martijn Cremers, Michael Halling, and David Weinbaum for providing us with the factor returns.

# VI. Conclusion

Using stock options from 1996-2010, we 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 (2012), 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 market conditions, choice of skewness asset construction, market frictions, and other moments of the return distribution. 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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**Table 1: Summary Statistics for Skewness Assets, Implied Skewness, and Size**

This table shows the mean, minimum, maximum, and $5^{\text{th}}$, $25^{\text{th}}$, $50^{\text{th}}$, $75^{\text{th}}$, and $95^{\text{th}}$ 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 |

**Table 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, FF3, and 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 following Newey and West (1987) with lag of 6 months. The sample covers the period January 1996 - 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 |

**Table 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 4: CBOE Margin Requirement Based Portfolio Returns**

This table shows the average monthly CBOE margin-based returns for long (top panel) and short (bottom panel) portfolios of skewness assets formed on deciles of $RNSkew$. The long and short CBOE margin-based returns are calculated using initial CBOE based margin requirements. $RNSkew$ 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 Fama-French-Carhart 4-factor alphas (FFC4 Alpha) for the margin-based returns. The 10-1 column represents the difference between the alpha for decile 10 and decile 1. The 10-1 t-stat column is the t-statistic testing the null hypothesis that the alpha of the 10-1 portfolio is equal to zero. The t-statistics are adjusted following Newey and West (1987) with lag of 6 months. The sample covers the period January 1996 through October 2010.

| **Long Skewness Asset Positions** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** | **10-1** | **10-1 t-stat** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| PUTCALL Asset | 0.14 | 0.02 | -0.03 | -0.32 | -0.26 | -0.23 | -0.56 | -0.55 | -0.80 | -1.01 | -1.15 | -5.51 |
| PUT Asset | 0.71 | 0.44 | 0.38 | 0.09 | 0.11 | 0.13 | -0.13 | -0.10 | -0.37 | -0.07 | -0.78 | -4.25 |
| CALL Asset | -0.41 | -0.19 | -0.13 | -0.24 | -0.16 | -0.09 | -0.25 | -0.19 | -0.26 | -0.67 | -0.25 | -1.32 |

| **Short Skewness Asset Positions** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** | **10-1** | **10-1 t-stat** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| PUTCALL Asset | -0.15 | -0.03 | 0.02 | 0.34 | 0.24 | 0.22 | 0.58 | 0.51 | 0.77 | 0.93 | 1.08 | 5.70 |
| PUT Asset | -0.74 | -0.46 | -0.39 | -0.07 | -0.09 | -0.13 | 0.15 | 0.09 | 0.36 | 0.05 | 0.79 | 4.09 |
| CALL Asset | 0.34 | 0.15 | 0.12 | 0.18 | 0.14 | 0.11 | 0.23 | 0.17 | 0.24 | 0.63 | 0.29 | 1.71 |

**Table 5: Subperiod Analysis**

The table below presents the average monthly returns for portfolios of skewness assets formed on deciles of $RNSkew$ for period of above average economic growth (CFNAI $>$ 0), below average economic growth (CFNAI $<$ 0), recessions (CFNAI $<$ -0.7), and during the subprime financial crisis period and it's aftermath (7/2007-10/2010). $RNSkew$ 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 FFC4 alphas. The 10-1 column represents the FFC4 alpha difference between deciles 10 and 1. The 10-1 t-stat column is the t-statistic testing the null hypothesis that the alpha of the 10-1 portfolio is equal to zero. The t-statistics are adjusted following Newey and West (1987) with 6 lags.

| **CFNAI > 0** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** | **10-1** | **10-1 t-stat** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| PUTCALL Asset | -0.02 | 0.12 | -0.18 | -0.77 | -0.07 | -0.39 | -0.45 | -0.36 | -1.11 | -1.54 | -1.52 | -4.10 |
| PUT Asset | 1.15 | 1.44 | 0.65 | 0.06 | 0.33 | 0.32 | 0.40 | 0.29 | -0.55 | 0.10 | -1.04 | -2.33 |
| CALL Asset | -1.20 | -1.00 | -0.53 | -1.42 | -0.02 | -0.07 | -0.61 | 0.27 | -0.13 | -1.93 | -0.73 | -1.00 |
| **CFNAI < 0** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** | **10-1** | **10-1 t-stat** |
| PUTCALL Asset | 0.14 | -0.53 | -0.36 | -0.74 | -1.35 | -0.62 | -1.64 | -1.48 | -1.65 | -1.79 | -1.93 | -4.59 |
| PUT Asset | 0.98 | -0.56 | 0.30 | -0.22 | -0.48 | -0.27 | -1.21 | -0.86 | -1.08 | -0.82 | -1.80 | -3.57 |
| CALL Asset | -0.97 | -0.44 | -0.52 | -0.74 | -1.56 | -0.45 | -1.04 | -1.21 | -1.23 | -1.87 | -0.91 | -1.40 |
| **CFNAI < -0.7** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** | **10-1** | **10-1 t-stat** |
| PUTCALL Asset | -0.15 | -0.63 | -0.02 | -1.95 | -1.46 | -1.21 | -1.52 | -2.29 | -2.32 | -2.43 | -2.28 | -3.97 |
| PUT Asset | 0.38 | -0.89 | 0.13 | -1.53 | -0.57 | -1.02 | -1.18 | -1.93 | -1.73 | -1.23 | -1.60 | -2.77 |
| CALL Asset | -0.62 | -0.39 | 0.08 | -1.76 | -1.71 | -1.41 | -1.18 | -2.55 | -2.63 | -3.14 | -2.53 | -2.11 |
| **7/2007-10/2010** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** | **10-1** | **10-1 t-stat** |
| PUTCALL Asset | 0.21 | -0.05 | 0.27 | -0.86 | -1.43 | -0.37 | -1.41 | -1.89 | -1.85 | -1.59 | -1.80 | -3.24 |
| PUT Asset | 0.71 | -0.22 | 0.79 | -0.53 | -0.51 | 0.11 | -1.12 | -1.37 | -1.42 | -0.94 | -1.65 | -3.27 |
| CALL Asset | -0.13 | 0.28 | -0.45 | -0.34 | -1.85 | -0.33 | -0.98 | -1.61 | -0.95 | -1.06 | -0.93 | -1.16 |

**Table 6: Asset Construction Portfolios**

The table below presents the average monthly returns for portfolios of skewness assets formed on deciles of $RNSkew$. The skewness assets are formed using a target absolute delta for OTM options of 0.2 (20 Delta), or using 2-month options (2-Month). For the 2-month option sample, $RNSkew$ is calculated using 2-month options as well. The table shows Fama-French-Carhart 4-factor alphas (FFC4 alpha) of the portfolios returns. The 10-1 column represents the difference between the FFC4 alpha for decile 10 and decile 1. The 10-1 t-stat column is the t-statistic testing the null hypothesis that the FFC4 alpha of the 10-1 portfolio is equal to zero. The t-statistics are adjusted following Newey and West (1987) with lag of 6 months.

| **20 Delta** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** | **10-1** | **10-1 t-stat** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| PUTCALL Asset | -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 | 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 | -1.13 | -0.64 | -0.62 | -0.79 | -0.49 | -0.04 | -0.81 | -0.71 | -0.60 | -1.57 | -0.44 | -0.94 |

| **2-Month** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** | **10-1** | **10-1 t-stat** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| PUTCALL Asset | -1.02 | -1.34 | -1.61 | -1.74 | -1.79 | -2.36 | -1.89 | -2.71 | -2.14 | -2.61 | -1.60 | -4.18 |
| PUT Asset | 0.09 | -0.21 | -0.89 | -0.73 | -0.74 | -1.49 | -0.89 | -1.77 | -1.33 | -1.50 | -1.59 | -3.76 |
| CALL Asset | -0.08 | -0.12 | -0.33 | -0.46 | -0.37 | -0.33 | -0.48 | -0.94 | -0.39 | -0.54 | -0.46 | -0.65 |

**Table 7: Controls for Asset Construction**

The table below shows the effects of controlling for skewness asset construction in analyzing the ability of $RNSkew$ 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 independent variables are winsorized at the 1% level. The t-statistics are adjusted using Newey and West (1987) with 6 lags.

**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** | **PUT Asset** | **CALL Asset** |
|---|---|---|---|
| | **Price Excess Return** | **Price Excess Return** | **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) |

**Table 8: Market Friction Portfolios**

The table below presents the average monthly returns for portfolios of skewness assets formed on deciles of $RNSkew$ using samples of skewness assets expected to have very low market frictions. The *Open Interest* sample is constructed by requiring that all options in the skewness assets have positive open interest. The *Large Stocks* sample is formed using only skewness assets for the largest 500 stocks by market capitalization. The *Large Stocks Small Spreads* sample is formed by restricting the sample to the largest 500 stocks and requiring that all options used to form the skewness assets have spreads 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. The table shows Fama-French-Carhart 4-factor alphas (FFC4 alpha) of the portfolios returns. The 10-1 column represents the difference between the FFC4 alpha for decile 10 and decile 1. The 10-1 t-stat column is the t-statistic testing the null hypothesis that the FFC4 alpha of the 10-1 portfolio is equal to zero. The t-statistics are adjusted following Newey and West (1987) with lag of 6 months.

| **Open Interest** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** | **10-1** | **10-1 t-stat** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| PUTCALL Asset | 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 | 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 | -1.05 | -0.78 | -0.76 | -0.90 | -0.95 | -0.99 | -0.42 | -0.45 | -0.90 | -1.51 | -0.46 | -0.95 |

| **Large Stocks** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** | **10-1** | **10-1 t-stat** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| PUTCALL Asset | -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 | 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 | -0.62 | -0.66 | -0.78 | -0.35 | -0.65 | -1.48 | -1.23 | -0.75 | -0.84 | -1.03 | -0.41 | -0.89 |

| **Large Stocks Small Spreads** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** | **10-1** | **10-1 t-stat** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| PUTCALL Asset | 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 | 1.66 | 1.35 | -0.78 | 1.49 | -1.20 | 0.53 | -1.54 | -0.40 | -0.13 | -0.05 | -1.71 | -2.17 |
| CALL Asset | -0.15 | -0.20 | -1.03 | -1.00 | -0.14 | -0.68 | -1.08 | -1.27 | -1.09 | -2.27 | -2.12 | -1.57 |

**Table 9: Market Frictions Regressions**

The tables below show the effects of controlling for market frictions 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 Fama and MacBeth (1973) regressions controlling for each of the variables. All independent variables are winsorized at the 1% level. The t-statistics are Newey and West (1987) adjusted using lag of 6 months.

**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.** Fama-MacBeth 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) |

**Table 10: Transaction Cost Portfolios**

The tables below show the FFC4 alphas, after paying 0%, 25%, 50%, 75%, and 100% of the quoted half-spread on the option positions, for portfolios that are long the decile 1 and short the decile 10 portfolios of skewness assets. Results are presented for use both the price-based and CBOE margin-based returns. The t-statistics are adjusted using Newey and West (1987) with lag of 6 months.

| | Price Returns | | | | | CBOE Margin Returns | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | **0%** | **25%** | **50%** | **75%** | **100%** | **0%** | **25%** | **50%** | **75%** | **100%** |
| PUTCALL Asset | 1.65 | 0.60 | -0.45 | -1.50 | -2.54 | 1.07 | 0.39 | -0.30 | -0.99 | -1.68 |
| | (5.52) | (2.03) | (-1.49) | (-4.85) | (-7.90) | (5.55) | (2.00) | (-1.54) | (-4.83) | (-7.74) |
| PUT Asset | 1.34 | -0.27 | -1.88 | -3.49 | -5.10 | 0.76 | -0.05 | -0.86 | -1.67 | -2.48 |
| | (3.38) | (-0.68) | (-4.53) | (-7.84) | (-10.50) | (4.12) | (-0.27) | (-4.42) | (-7.97) | (-10.78) |
| CALL Asset | 0.67 | -1.32 | -3.31 | -5.31 | -7.30 | 0.22 | -0.55 | -1.31 | -2.07 | -2.84 |
| | (1.40) | (-2.68) | (-6.21) | (-8.88) | (-10.78) | (1.25) | (-3.10) | (-6.98) | (-10.09) | (-12.41) |

**Table 11: 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 ($BKMIV$), the implied volatilities of the options comprising the skewness assets ($OTMPutIV$, $OTMCallIV$, $ATMPutIV$, $ATMCallIV$), 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). We control for kurtosis using the implied kurtosis calculated with the methodology of BKM ($BKMKurt$). Panel A shows the monthly average for each variable across the deciles of $RNSkew$. Panel B shows the results of Fama and MacBeth (1973) regressions controlling for each of the variables. All independent variables are winsorized at the 1% level. The t-statistics are Newey and West (1987) adjusted using lag of 6 months.

**Panel A.** Decile Portfolio Means for Variables Proxying for 1$^{st}$, 2$^{nd}$, and 4$^{th}$ Moments of the Stock Return Distribution

| | **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.** Fama-MacBeth Regressions of Skewness Asset Returns on *RNSkew* and Controls for Other Moments

| | 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) |

**Figure 1: Summary of Skewness Assets**

The figure below indicates the construction of the skewness assets (Positions), indicates the portion of the future return distribution that the skewness asset is sensitive to (Detects Pricing Of:), and plots the payoff function of the skewness asset (Payoff Function) for each of the PUTCALL, PUT, and CALL skewness assets.

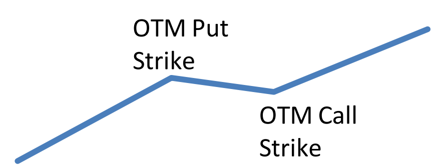
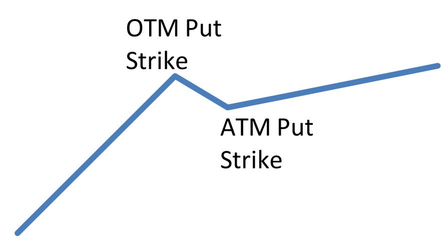
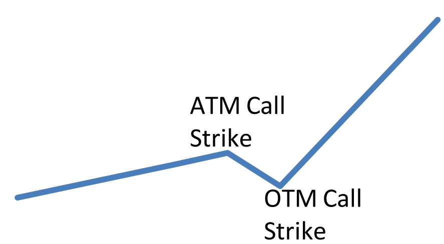
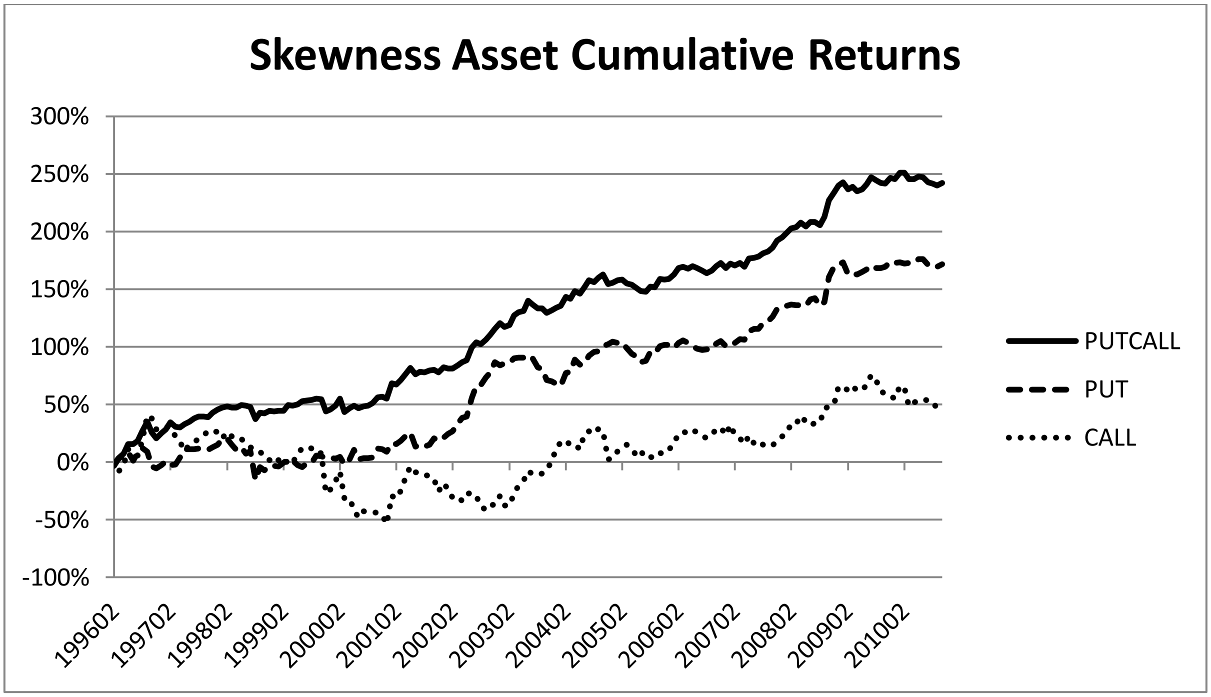
| | Positions | Detects Pricing Of: | Payoff Function |
|---|---|---|---|
| **PUTCALL Asset** | Long 1 OTM Call<br><br>Short OTM Puts (hedges vega)<br><br>Short Stock (hedges delta) | Either the extreme left tail, extreme right tail, or both tails of the risk-neutral distribution. |  |
| **PUT Asset**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

**Figure 2: Skewness Asset 1-10 Cumulative Returns**

The figure below presents the cumulative sum of log monthly returns for a portfolio that is long skewness assets for decile 1 of $RNSkew$ and short skewness assets for decile 10 of $RNSkew$.



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

## Online Appendix

This Version: July 9, 2013

# I Physical Skew and Future Returns

We examine the ability of physical (historical) skewness to predict the future returns of both stocks and skewness assets. Each month, on the first trading day following the monthly expiration, historical skewness is calculated as the skewness of the daily log returns over the past year. On the second day after the monthly expiration, portfolios of stocks and skewness assets are formed based on deciles of historical skewness. The skewness assets are formed using 1-month options. The portfolios are held until the options in the skewness assets expire approximately one month later. Table I presents the average raw returns, along with the CAPM (CAPM), Fama-French 3-factor (FF3 Alpha) and Fama-French-Carhart 4-factor (FFC4 Alpha) alphas following Fama and French (1993) and Carhart (1997). 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 0. The t-statistics are adjusted following Newey and West (1987) with lag of 6 months. None of the 10-1 alphas exhibit a statistically significant difference from 0. Thus, we find no evidence in our sample that physical skewness can predict the future returns of stocks or skewness assets.

# II 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 $\tau$, 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 $\tau$, and $t_\tau$ be the time, in years, between dates $t_0$ and $\tau$, then we have.

$$PVDivs = \sum_{t_0 \leq \tau \leq t_1} e^{-r_\tau t_\tau} Div_{e,\tau} \tag{1}$$

OptionMetrics provides zero-rate data for each date $t_0$ and a series of maturities. $r_\tau$, for any specific value of $t_0$ and $\tau$, is found by applying a cubic spline to the zero-rate data for date $t_0$ and find the interpolated zero-rate for matruity $t_\tau$.

# III Is There a Risk-Based Explanation?

We 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, we 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 ($STRev$).[1] We complete the risk-analysis by augmenting the standard risk models using several additional option and stock market based factors.

## III.A 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

[1] 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.

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).[2] 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, we calculate the value-at-risk for a given probability $p$, $VaR\,(p)$, to be the $p^{\text{th}}$ 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, Delbaen, Eber, and Heath (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. 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.

Table II 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, we also calculate the 5% $VaR$ and 5% $ES$ for portfolios of short skewness assets.[3] Remember that when holding short skewness asset

[2] 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.

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

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 II gives no support for a risk-based explanation of the skewness asset returns.

## III.B Portfolio Sensitivities to Known Factors

It is possible that there exists a cross-sectional pattern in the factor sensitivities of the skewness asset portfolios to these risk factors. To test this, Table III presents 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, we also presents factor sensitivities calculated using a model that includes the 4 Fama-French-Carhart factors along with the short-term reversal factor.

The results in Table III 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.

## III.C 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 we control for such exposures. To do so, we 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 $RV - IV$.[4] We call this factor $RV - IVStraddle$.

As option portfolio returns are intimately connected to the return on the underlying stocks, we 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 $RV - IV$. We name this factor $RV - IVStock$.

[4] 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. We 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. We 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). We require that the absolute values of the option deltas used to calculate $IV$ are between 0.4 and 0.6.

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. We form two additional factors based on the $CIV - PIV$ signal.[5] 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). We 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 we 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, we calculate a proxy for such a factor, which we name $CIV-PIVStraddle$, by taking the returns of a portfolio that is long (short) ATM straddles for stocks in the highest (lowest) third of $CIV - PIV$.

In addition to these stock and option market factors, we control for the aggregate volatility ($MN$) and crash-neutral aggregate volatility ($CNMN$) factors developed by Cremers, Halling, and Weinbaum (2012). 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.[6] There are therefore only 144 (instead of 177) monthly return periods for models using the $MN$ or $CNMN$ factor.

Finally, we control for the possibility that the long-short portfolio returns are related

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

[6] We thank Martijn Cremers, Michael Halling, and David Weinbaum for providing us 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.

index option returns by creating an S&P index straddle factor ($S\&PStraddle$) and an S&P crash factor ($S\&PPut$, see Du and Kapadia (2011)). The $S\&PStraddle$ factor is calculated the as the return of an at-the-money S&P straddle created in exactly the same manner as the single stock straddles used for the $RV - IVStraddle$ and $CIV - PIVStraddle$ factors. The $S\&PPut$ factor is calculated as the return of an out-of-the-money put option with target delta -0.2.

In Table IV, we 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.[7] With two exceptions, the alphas for the 10-1 CALL asset portfolios remain, in almost all models, insignificant. In summary, the main results of the paper hold after controlling for a wide array of stock and option market factors.

[7] 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.

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**Table I: Relation between Physical Skewness and Future Returns**

This table shows the average monthly returns for portfolios of stocks and skewness assets formed on deciles of historical skewness. Historical skewness is calculated for each stock on the first trading day after each monthly expiration using daily data from the past 1 year. The skewness asset and stock portfolios are formed on the second day after each monthly expiration using options that expire in the next month, and 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 | -0.92 | -0.82 | -0.82 | -0.66 | -0.93 | -0.87 | -1.25 | -0.45 | -0.63 | -0.30 | 0.62 | 1.36 |
| CAPM Alpha | -0.83 | -0.82 | -0.82 | -0.59 | -0.91 | -0.79 | -1.18 | -0.41 | -0.56 | -0.25 | 0.58 | 1.35 |
| FF3 Alpha | -0.89 | -0.89 | -0.91 | -0.66 | -0.95 | -0.87 | -1.19 | -0.45 | -0.59 | -0.30 | 0.59 | 1.34 |
| FFC4 Alpha | -0.98 | -0.91 | -0.95 | -0.67 | -0.98 | -0.92 | -1.24 | -0.51 | -0.58 | -0.32 | 0.67 | 1.53 |

| **PUT Asset** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** | **10-1** | **10-1 t-stat** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Excess Return | -0.09 | 0.02 | -0.20 | 0.29 | 0.02 | 0.04 | -0.24 | -0.22 | -0.10 | 0.23 | 0.31 | 0.85 |
| CAPM Alpha | -0.00 | -0.01 | -0.22 | 0.37 | 0.03 | 0.12 | -0.20 | -0.16 | -0.03 | 0.30 | 0.30 | 0.76 |
| FF3 Alpha | -0.01 | -0.05 | -0.31 | 0.34 | 0.02 | 0.09 | -0.18 | -0.16 | -0.02 | 0.32 | 0.33 | 0.83 |
| FFC4 Alpha | -0.08 | -0.09 | -0.36 | 0.29 | -0.02 | 0.03 | -0.24 | -0.20 | -0.00 | 0.35 | 0.43 | 1.08 |

| **CALL Asset** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** | **10-1** | **10-1 t-stat** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Excess Return | -1.34 | -0.93 | -0.83 | -0.92 | -0.95 | -1.20 | -1.65 | 0.21 | -0.21 | -0.46 | 0.88 | 1.04 |
| CAPM Alpha | -1.27 | -0.92 | -0.80 | -0.89 | -0.92 | -1.12 | -1.53 | 0.24 | -0.13 | -0.44 | 0.83 | 1.06 |
| FF3 Alpha | -1.35 | -1.03 | -0.86 | -0.95 | -1.00 | -1.25 | -1.60 | 0.14 | -0.24 | -0.57 | 0.78 | 0.97 |
| FFC4 Alpha | -1.49 | -1.05 | -0.90 | -0.89 | -1.04 | -1.33 | -1.68 | 0.05 | -0.25 | -0.61 | 0.88 | 1.09 |

| **Stock Return** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** | **10-1** | **10-1 t-stat** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Excess Return | 0.53 | 0.65 | 0.99 | 0.54 | 0.65 | 0.74 | 0.71 | 0.97 | 0.70 | 1.16 | 0.64 | 1.23 |
| CAPM Alpha | -0.14 | -0.02 | 0.31 | -0.13 | -0.04 | 0.05 | 0.02 | 0.25 | 0.04 | 0.48 | 0.62 | 1.26 |
| FF3 Alpha | -0.24 | -0.12 | 0.23 | -0.17 | -0.08 | 0.02 | -0.04 | 0.23 | -0.01 | 0.41 | 0.66 | 1.33 |
| FFC4 Alpha | -0.07 | -0.11 | 0.22 | -0.23 | -0.03 | 0.05 | -0.01 | 0.23 | 0.03 | 0.34 | 0.41 | 0.94 |

**Table II: Is There a Risk Based Explanation of Returns?**

The table below presents the standard deviation ($\sigma$) 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.

| **PUTCALL Asset** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** |
|---|---|---|---|---|---|---|---|---|---|---|
| $\sigma$ | 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** |
| $\sigma$ | 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** |
| $\sigma$ | 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 |

**Table III: Factor Sensitivities**
The tables below present factor sensitivities (t-statistics in parentheses) for portfolios of skewness assets formed on deciles of $RNSkew$ for the CAPM (Panel A), FF3 (Panel B), FFC4 (Panel C), and FFC4 + Short Term Reversal (STRev, Panel D) risk factor models. Returns and alphas are in percent. Newey and West (1987) t-statistics are reported in parentheses.

**Panel A.** 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 B.** 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 C.** 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) |

**Panel C.** FFC4 Factor Sensitivities - Continued

| **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 D.** 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 D.** 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) |

**Table IV: 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 (2012). The S&P Straddle and S&P Put factors are calculated as the returns on an ATM S&P Index straddle and OTM S&P Index put contract respectively.

Tables begin on next page.

**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)** | **(14)** | **(15)** | **(16)** | **(17)** | **(18)** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 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 | -1.641 | -1.669 | -1.669 | -1.409 | -1.83 |
| | (-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) | (-5.22) | (-5.23) | (-5.22) | (-3.54) | (-4.24) |
| 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 | 0.260 | 0.238 | 0.213 | 0.215 | 0.286 |
| | (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) | (3.17) | (2.57) | (2.43) | (2.18) | (2.57) |
| 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 | 0.198 | 0.188 | 0.188 | 0.203 | 0.324 |
| | | (-1.85) | (-1.78) | (-1.75) | (-1.76) | (-1.62) | (-1.74) | (-1.72) | (-1.55) | (-2.21) | (-2.33) | (-2.38) | (-2.29) | (1.99) | (1.81) | (1.83) | (1.95) | (3.64) |
| 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 | -0.158 | -0.163 | -0.150 | -0.124 | -0.194 |
| | | (1.30) | (2.01) | (1.92) | (1.94) | (2.40) | (2.04) | (2.00) | (2.09) | (2.53) | (2.39) | (2.91) | (3.96) | (-1.83) | (-1.80) | (-1.74) | (-1.50) | (-2.19) |
| UMD | | | 0.151 | 0.139 | 0.152 | 0.148 | 0.149 | 0.153 | 0.144 | 0.243 | 0.240 | 0.261 | 0.272 | 0.149 | 0.149 | 0.142 | 0.138 | 0.267 |
| | | | (1.96) | (1.78) | (1.99) | (1.95) | (1.96) | (1.98) | (1.85) | (2.91) | (2.87) | (3.25) | (3.60) | (1.99) | (1.91) | (1.80) | (1.73) | (3.63) |
| STRev | | | | -0.075 | | | | | -0.046 | | | | 0.045 | | | | -0.039 | 0.048 |
| | | | | (-1.26) | | | | | (-0.77) | | | | (0.71) | | | | (-0.66) | (0.79) |
| RV-IV Straddle | | | | | -0.011 | | | | -0.012 | | | | 0.011 | | | | -0.014 | 0.007 |
| | | | | | (-0.46) | | | | (-0.57) | | | | (0.46) | | | | (-0.72) | (0.31) |
| RV-IV Stock | | | | | | 0.139 | | | 0.122 | | | | 0.154 | | | | 0.119 | 0.166 |
| | | | | | | (1.37) | | | (1.17) | | | | (1.40) | | | | (1.14) | (1.51) |
| CIV-PIV Straddle | | | | | | | 0.012 | | 0.011 | | | | 0.007 | | | | 0.013 | 0.006 |
| | | | | | | | (0.40) | | (0.37) | | | | (0.23) | | | | (0.42) | (0.18) |
| CIV-PIV Stock | | | | | | | | -0.031 | -0.036 | | | | -0.029 | | | | -0.049 | -0.029 |
| | | | | | | | | (-0.16) | (-0.18) | | | | (-0.13) | | | | (-0.24) | (-0.13) |
| MN | | | | | | | | | | 0.001 | | 0.118 | 0.122 | | | | | 0.118 |
| | | | | | | | | | | (0.11) | | (3.04) | (3.00) | | | | | (2.91) |
| CNMN | | | | | | | | | | | -0.006 | -0.131 | -0.135 | | | | | -0.134 |
| | | | | | | | | | | | (-0.58) | (-3.02) | (-2.95) | | | | | (-2.96) |
| S&P Straddle | | | | | | | | | | | | | | 0.001 | | 0.005 | 0.005 | 0.003 |
| | | | | | | | | | | | | | | (0.25) | | (0.82) | (0.83) | (0.49) |
| S&P Put | | | | | | | | | | | | | | | -0.001 | -0.002 | -0.002 | 0.000 |
| | | | | | | | | | | | | | | | (-0.36) | (-0.96) | (-0.75) | (0.18) |
| n | 177 | 177 | 177 | 177 | 177 | 177 | 177 | 177 | 177 | 144 | 144 | 144 | 144 | 177 | 177 | 177 | 177 | 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)** | **(14)** | **(15)** | **(16)** | **(17)** | **(18)** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 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 | -1.417 | -1.394 | -1.393 | -1.033 | -1.50 |
| | (-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) | (-3.51) | (-3.30) | (-3.35) | (-2.45) | (-3.38) |
| 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 | 0.276 | 0.248 | 0.315 | 0.261 | 0.471 |
| | (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) | (2.81) | (2.46) | (3.10) | (2.11) | (4.95) |
| 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 | 0.204 | 0.212 | 0.213 | 0.143 | 0.299 |
| | | (-0.52) | (-0.53) | (-0.53) | (-0.53) | (-0.74) | (-0.37) | (-0.57) | (-0.61) | (-0.90) | (-1.03) | (-1.04) | (-1.09) | (1.57) | (1.56) | (1.55) | (1.06) | (2.21) |
| 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 | -0.101 | -0.071 | -0.108 | -0.113 | -0.199 |
| | | (1.37) | (1.85) | (1.81) | (1.70) | (1.77) | (1.91) | (1.62) | (1.35) | (2.00) | (1.81) | (2.31) | (1.98) | (-0.78) | (-0.56) | (-0.85) | (-0.91) | (-1.33) |
| UMD | | | 0.129 | 0.127 | 0.134 | 0.131 | 0.120 | 0.137 | 0.135 | 0.217 | 0.213 | 0.243 | 0.233 | 0.140 | 0.125 | 0.147 | 0.141 | 0.247 |
| | | | (1.65) | (1.49) | (1.72) | (1.69) | (1.52) | (1.70) | (1.57) | (2.09) | (2.03) | (2.43) | (2.21) | (1.80) | (1.47) | (1.81) | (1.62) | (2.50) |
| STRev | | | | -0.014 | | | | | -0.023 | | | | 0.050 | | | | -0.042 | 0.035 |
| | | | | (-0.20) | | | | | (-0.31) | | | | (0.46) | | | | (-0.54) | (0.33) |
| RV-IV Straddle | | | | | -0.032 | | | | -0.035 | | | | 0.009 | | | | -0.022 | 0.019 |
| | | | | | (-1.12) | | | | (-1.14) | | | | (0.43) | | | | (-0.87) | (0.93) |
| RV-IV Stock | | | | | | -0.099 | | | -0.115 | | | | -0.172 | | | | -0.136 | -0.176 |
| | | | | | | (-0.71) | | | (-0.78) | | | | (-1.12) | | | | (-0.93) | (-1.16) |
| CIV-PIV Straddle | | | | | | | 0.058 | | 0.074 | | | | 0.093 | | | | 0.078 | 0.089 |
| | | | | | | | (1.59) | | (1.70) | | | | (1.90) | | | | (1.73) | (1.84) |
| CIV-PIV Stock | | | | | | | | -0.122 | -0.205 | | | | -0.246 | | | | -0.183 | -0.218 |
| | | | | | | | | (-0.61) | (-0.86) | | | | (-0.93) | | | | (-0.76) | (-0.83) |
| MN | | | | | | | | | | -0.007 | | 0.171 | 0.193 | | | | | 0.217 |
| | | | | | | | | | | (-0.59) | | (2.36) | (2.68) | | | | | (3.05) |
| CNMN | | | | | | | | | | | -0.019 | -0.200 | -0.223 | | | | | -0.244 |
| | | | | | | | | | | | (-1.14) | (-2.40) | (-2.64) | | | | | (-2.98) |
| S&P Straddle | | | | | | | | | | | | | | -0.011 | | -0.014 | -0.012 | -0.016 |
| | | | | | | | | | | | | | | (-1.70) | | (-2.48) | (-1.98) | (-2.94) |
| S&P Put | | | | | | | | | | | | | | | -0.002 | 0.002 | 0.001 | 0.005 |
| | | | | | | | | | | | | | | | (-0.72) | (0.57) | (0.20) | (2.05) |
| n | 177 | 177 | 177 | 177 | 177 | 177 | 177 | 177 | 177 | 144 | 144 | 144 | 144 | 177 | 177 | 177 | 177 | 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)** | **(14)** | **(15)** | **(16)** | **(17)** | **(18)** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 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 | -0.543 | -0.642 | -0.643 | -0.906 | -1.33 |
| | (-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) | (-1.06) | (-1.26) | (-1.29) | (-1.59) | (-2.28) |
| 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 | 0.260 | 0.243 | 0.095 | 0.167 | 0.132 |
| | (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) | (1.76) | (1.38) | (0.62) | (1.14) | (0.62) |
| 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 | 0.228 | 0.192 | 0.190 | 0.311 | 0.430 |
| | | (-3.11) | (-3.01) | (-3.01) | (-3.11) | (-3.44) | (-3.20) | (-3.02) | (-3.75) | (-2.48) | (-2.58) | (-2.49) | (-3.51) | (1.49) | (1.19) | (1.27) | (2.19) | (1.90) |
| 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 | -0.417 | -0.469 | -0.386 | -0.334 | -0.355 |
| | | (0.19) | (1.11) | (1.05) | (1.35) | (1.70) | (1.09) | (1.37) | (2.12) | (1.03) | (0.96) | (1.07) | (2.33) | (-2.94) | (-3.03) | (-2.72) | (-3.25) | (-2.88) |
| UMD | | | 0.325 | 0.304 | 0.318 | 0.318 | 0.332 | 0.317 | 0.297 | 0.468 | 0.459 | 0.476 | 0.510 | 0.307 | 0.327 | 0.280 | 0.272 | 0.486 |
| | | | (2.44) | (2.39) | (2.43) | (2.52) | (2.52) | (2.38) | (2.29) | (2.98) | (2.91) | (3.04) | (3.99) | (2.40) | (2.45) | (2.15) | (2.12) | (3.93) |
| STRev | | | | -0.132 | | | | | -0.071 | | | | 0.058 | | | | -0.030 | 0.081 |
| | | | | (-1.05) | | | | | (-0.62) | | | | (0.46) | | | | (-0.26) | (0.62) |
| RV-IV Straddle | | | | | 0.044 | | | | 0.044 | | | | 0.048 | | | | 0.026 | 0.031 |
| | | | | | (0.96) | | | | (1.10) | | | | (0.93) | | | | (0.68) | (0.64) |
| RV-IV Stock | | | | | | 0.386 | | | 0.364 | | | | 0.506 | | | | 0.376 | 0.525 |
| | | | | | | (2.15) | | | (2.17) | | | | (2.27) | | | | (2.27) | (2.37) |
| CIV-PIV Straddle | | | | | | | -0.047 | | -0.073 | | | | -0.108 | | | | -0.071 | -0.104 |
| | | | | | | | (-0.89) | | (-1.58) | | | | (-2.26) | | | | (-1.37) | (-2.01) |
| CIV-PIV Stock | | | | | | | | 0.132 | 0.229 | | | | 0.343 | | | | 0.169 | 0.306 |
| | | | | | | | | (0.39) | (0.70) | | | | (0.86) | | | | (0.56) | (0.81) |
| MN | | | | | | | | | | 0.036 | | 0.092 | 0.091 | | | | | 0.057 |
| | | | | | | | | | | (1.91) | | (1.26) | (1.38) | | | | | (0.80) |
| CNMN | | | | | | | | | | | 0.035 | -0.062 | -0.061 | | | | | -0.032 |
| | | | | | | | | | | | (1.77) | (-0.83) | (-0.88) | | | | | (-0.44) |
| S&P Straddle | | | | | | | | | | | | | | 0.017 | | 0.031 | 0.027 | 0.024 |
| | | | | | | | | | | | | | | (2.20) | | (3.02) | (2.67) | (2.31) |
| S&P Put | | | | | | | | | | | | | | | 0.001 | -0.008 | -0.005 | -0.006 |
| | | | | | | | | | | | | | | | (0.58) | (-3.50) | (-2.11) | (-1.95) |
| n | 177 | 177 | 177 | 177 | 177 | 177 | 177 | 177 | 177 | 144 | 144 | 144 | 144 | 177 | 177 | 177 | 177 | 144 |