Investor Sentiment and Option Prices

Bing Han
McCombs School of Business, University of Texas at Austin

This paper examines whether investor sentiment about the stock market affects prices of the S&P 500 options. The findings reveal that the index option volatility smile is steeper (flatter) and the risk-neutral skewness of monthly index return is more (less) negative when market sentiment becomes more bearish (bullish). These significant relations are robust and become stronger when there are more impediments to arbitrage in index options. They cannot be explained by rational perfect-market-based option pricing models. Changes in investor sentiment help explain time variation in the slope of index option smile and risk-neutral skewness beyond factors suggested by the current models. (*JEL* G12, G13, G14)

Jackwerth and Rubinstein (1996) find a pronounced "smile" effect for S&P 500 options: the Black-Scholes implied volatilities decrease monotonically with the strike price. This is in stark contrast to the Black-Scholes option pricing theory under which implied volatilities for options on the same underlying asset should be identical. Generalizations of the Black-Scholes model within the rational representative-agent perfect-market framework can fit the option data better (e.g., Bakshi, Cao, and Chen, 1997; Pan, 2002). However, there are discrepancies between the properties of index return under the objective measure and the risk-neutral measure that are inconsistent with models' assumptions on the market prices of risks.[1] Further, a growing literature shows that S&P 500 options are mispriced or not efficiently priced relative to a large class of rational option pricing models (Jackwerth, 2000; Ait-Sahalia, Wang, and Yared, 2001; Bondarenko, 2003; Constantinides, Jackwerth, and Perrakis, 2005). These lead to calls for research outside traditional rational option pricing models.[2]

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[1] For example, Bakshi, Cao, and Chen (1997) find that the volatility of volatility coefficient in the stochastic volatility model implied from option prices differs significantly from the one estimated directly from historical returns. Bates (2000) finds that including a jump can improve the model's ability to generate option smile, but in order to do so parameters must be set to unreasonable values that are inconsistent with the time-series properties of underlying asset prices and option prices.

[2] Bates (2003) argues that financial economists should not blithely attribute divergence between objective and risk-neutral probability measures to the free "risk-premium" parameters. Whaley (2003) states that "spending more resources developing more elaborate theoretic models (with even more parameters) seems imprudent, at

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This paper studies whether investor sentiment affects S&P 500 option prices. Investor sentiment is the aggregate error in investor beliefs. Empirically, several proxies are used for investor sentiment about the stock market, based on an investor survey, derivative market trading activity, and valuation errors of the S&P 500. Bollen and Whaley (2004) find that the slope of the option implied volatility smile changes dramatically from month to month. This paper examines whether variation in the slope of the index volatility smile is related to the change in market sentiment. In contrast, other studies focus on the average option pricing errors or the ability of a model to explain the option smile on average.[3]

This paper is motivated by previously documented evidence of limits to arbitrage in the options market, which permit sentiment to affect option prices.[4] It contributes to a growing literature that studies investor behavioral biases and their asset pricing impact in the options market (Stein, 1989; Poteshman, 2001; Poteshman and Serbin, 2003; Mahani and Poteshman, 2004). In particular, Poteshman (2001) finds evidence of options market misreaction to changes in the market volatility that is consistent with the Barberis, Shleifer, and Vishny (1998) model of investor sentiment. By contrast, the current research examines a different facet of investment sentiment constructed in a general way. The sentiment measures used in this study concern the level of the stock market index rather than market volatility.

The empirical tests focus on the time-series relation between sentiment proxies and the skewness of the risk-neutral density of monthly S&P 500 index returns. It is well known that the index option volatility smile is tantamount to negative skewness of the risk-neutral density of index return (e.g., Bakshi, Kapadia, and Madan, 2003). The work of Bakshi and Madan (2000), as well as Bakshi, Kapadia, and Madan (2003), makes it possible to extract accurate and model-free estimates of index risk-neutral skewness on a given date from that date's cross section of index option prices. Since the empirical density of monthly index return is approximately symmetric (Ait-Sahalia and Lo, 1998, 2000; Rosenberg and Engle, 2002), the risk-neutral skewness is determined by the slope of the pricing kernel, or the ratio of the value of the pricing kernel at low-index levels to that at high-index levels.[5] Thus, studying the determinants of index risk-neutral skewness provides useful information about the slope of the asset pricing kernel.

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least in the short-run." He calls for studies that investigate the implication of limits to arbitrage in the options market.

[3] One exception is a contemporaneous paper Garleanu, Pedersen, and Poteshman (2005).

[4] See, for example, Figlewski (1989), Figlewski and Green (1999), Bollen and Whaley (2004), and Ofek, Richardson, and Whitelaw (2004).

[5] Economically, the slope of the pricing kernel measures how much more investors in aggregate are willing to pay for securities that pay off when the stock market index level is low (marginal utility is high) than when the stock market index level is high (marginal utility is low).

If investor sentiment affects index option prices, then Arrow-Drebreu state prices, which can be inferred from option prices (Breeden and Litzenberger, 1978), would also be distorted by sentiment. Hence, the pricing kernel, which is the Arrow-Debreu state price per unit probability, would depend on investor sentiment in addition to state variables that proxy for risks in the real economy. The literature recognizes the possibility that the pricing kernel can be disconnected from the marginal rates of substitution or transformation in the real economy without requiring arbitrage opportunities (Cochrane, 2001). The current study tests whether the slope of the pricing kernel depends on investor sentiment.

This study examines whether sentiment drives variation in the index risk-neutral skewness in order to study the impact of investor sentiment on index option prices and the pricing kernel. When investors are more bearish, they would have a stronger demand and be willing to pay more for state contingent claims that pay off when the index level is low. This leads to a more negatively sloped pricing kernel, and thus a more negative index risk-neutral skewness. This time-series relation between index risk-neutral skewness and investor sentiment is the key test hypothesis.

Previous studies have used S&P 500 option prices to estimate the pricing kernel. For example, Ait-Sahalia and Lo (1998) use a nonparametric method to estimate an *unconditional* state price density using panel data on index options, which leads to an *average* pricing kernel. Rosenberg and Engle (2002) estimate a time-varying pricing kernel from each date's cross-sectional index options data, but they need to make *ex-ante* parametric assumptions on the pricing kernel. In contrast, the current study extracts *conditional* information about the slope of the pricing kernel (as encoded by index risk-neutral skewness) from each date's cross-sectional index option prices, then examines whether its time variation is related to changes in investor sentiment. This approach allows an assessment of whether investor sentiment affects option prices and the pricing kernel, without making any parametric assumptions about, or having to estimate, the pricing kernel that is embodied in the market prices of index options.

Empirically, a variety of proxies for market sentiment are found to be significantly related to the risk-neutral skewness of the index return. The risk-neutral density for the index return is more negatively skewed when the market sentiment turns more bearish. On the other hand, a more bullish market sentiment is associated with a less negative index risk-neutral skewness. These results hold after controlling for a set of rational factors that may be related to the sentiment proxies, and after controlling for variables related to index risk-neutral skewness. The relation between index risk-neutral skewness and sentiment proxies is stronger when there are more impediments to arbitrage in the index options market. Furthermore, several popular rational perfect-market-based option pricing models cannot explain these findings. Finally, the index option volatility smile becomes steeper (flatter) when investor sentiment is more bearish (bullish).

These results support the idea that investor sentiment is an important determinant of index option prices. They complement evidence in other studies that S&P 500 options are mispriced or not efficiently priced relative to a large class of rational option pricing models. Ait-Sahalia, Wang, and Yared (2001) find that state-price density implied from S&P 500 option prices exhibits excessive skewness relative to the time-series state-price density (estimated from index futures return). A regression of the skewness of the option-implied state-price density on the skewness of the time-series state-price density produces an insignificant negative slope coefficient. This contrasts sharply with the null hypothesis that the slope coefficient equals to 1 if investors are rational and know the process governing the index dynamics. However, it is consistent with the hypothesis that investor sentiment importantly affects index option prices.

This paper also complements a large literature that studies whether investor sentiment affects stock prices.[6] Since it is difficult to directly identify sentiment-driven mispricing, researchers investigate whether investor sentiment forecasts stock returns in a manner that is consistent with initial patterns of mispricing correcting themselves over time, or whether change in investor sentiment is an important factor in the data-generating process for stock returns. However, it is not clear what is the appropriate return horizon to examine. Further, there is no guarantee that sentiment-induced mispricing will get corrected over a given horizon because of unpredictable investor sentiment in the future. These add noises to the inferences about the impact of investor sentiment based on the realized stock returns.

This paper sheds new lights on the importance of investor sentiment for asset pricing using index options data. Index options are not redundant securities (e.g., Buraschi and Jackwerth, 2001), and they provide valuable *ex-ante* information about the pricing kernel that is not available from the stock market. Options data also provide the opportunity to study the relative valuation of a rich cross section of options traded on the same underlying asset, since these options are affected differently by investor sentiment.

The rest of this paper is organized as follows. Section 1 describes the data and measurement of the variables used in the tests. Empirical results are presented in Section 2. Section 3 provides some discussions of the empirical results and concludes the paper.

1. Data and Variables

1.1 Option data

This study uses a dataset of S&P 500 options (ticker symbol SPX) provided by the Chicago Board Options Exchange. These SPX options are among the most actively traded derivatives in the world. They are European-style and cash

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[6] See the following recent studies and the references therein: Brown and Cliff (2004, 2005); Kaniel, Saar, and Titman (2004); Kumar and Lee (2006); Baker and Wurgler (2006); and Lemmon and Portniaguina (2006).

settled. The option data contain trading date, expiration month, strike price, trading volume, open interest, high price, low price, and last-sale price. Expiration dates are the three near-term months, followed by three additional months from the March quarterly cycle (March, June, September, and December).[7] Strike prices are spaced at increments of 5 index points for short maturity options, and 25 index points for the distant months. This rich cross section of index options helps estimate index risk-neutral skewness more precisely. The options data used are of daily frequency, and are dated from 4 January 1988 to 24 June 1997.

Following Ait-Sahalia and Lo (1998); Dumas, Fleming, and Whaley (1998); Poteshman (2001); and others, the put-call parity is applied using the calls and puts that are closest to being at the money. This is done to infer an implied futures price on each date, and for each option maturity. For each option maturity, the corresponding dividend-adjusted index level S can be obtained as the interest rate-deflated futures price by the standard cash-futures price relationship.[8] All option observations are excluded that violate obvious no-arbitrage conditions such as $S \geq C \geq \max(0, S - K\mathrm{e}^{-rT})$ for a call option C, where S is the adjusted index level corresponding to maturity T. To avoid microstructure-related bias, options whose prices are less than \$1/8, as well as options with maturities less than one week or more than one year, are also excluded.

1.2 Risk-neutral skewness of index return

The origin of the measure for risk-neutral skewness is Bakshi and Madan (2000), and Bakshi, Kapadia, and Madan (2003). Bakshi and Madan (2000) show that the continuum of characteristic functions of risk-neutral return density and the continuum of options are equivalent classes of spanning securities. Any payoff function with bounded expectation can be spanned by out-of-the-money (OTM) European calls and puts. Based on this insight, Bakshi, Kapadia, and Madan (2003) formalize a mechanism to extract the skewness of the risk-neutral return density from a contemporaneous collection of OTM calls and puts. The date t skewness of the risk-neutral density of the index return over the period $[t, t + \tau]$ can be obtained as

$$\mathrm{Skew}(t,\tau) = \frac{\mathrm{e}^{r\tau}W(t,\tau) - 3\mu(t,\tau)\mathrm{e}^{r\tau}V(t,\tau) + 2\mu(t,\tau)^3}{[\mathrm{e}^{r\tau}V(t,\tau) - \mu(t,\tau)^2]^{3/2}}, \tag{1}$$

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[7] The SPX options mature on the third Friday of the contract month. Trading ceases on the business day preceding the day on which the exercise-settlement value is calculated. However, before 24 August 1992, these options expired at the market close. Therefore, until August 24, 1992, an option's time to maturity is measured as the number of calendar days between trade date and the expiration date. After that date, the number of calendar days remaining less one is used.

[8] The LIBOR rates, with maturities of one week, one month, three months, six months, and one year, are collected from Datastream. LIBOR rates are quoted in annual yields. For each date, the annual yields are translated into continuously compounded rates, and then these rates are linearly interpolated to find the continuously compounded interest rates for all maturities between one week and one year.

where

$$\mu(t,\tau)=e^{r\tau}-1-\frac{e^{r\tau}}{2}V(t,\tau)-\frac{e^{r\tau}}{6}W(t,\tau)-\frac{e^{r\tau}}{24}X(t,\tau), \tag{2}$$

and $V(t,\tau)$, $W(t,\tau)$, and $X(t,\tau)$ are the weighted sums of OTM call option prices $C(t,\tau,K)$ and put option prices $P(t,\tau,K)$, with time to maturity τ and strike price K, given the underlying asset price S_t:

$$V(t,\tau)=\int_{S_t}^{\infty}\frac{2\left(1-\ln\left(\frac{K}{S_t}\right)\right)}{K^2}C(t,\tau,K)\,dK+\int_{0}^{S_t}\frac{2\left(1+\ln\left(\frac{S_t}{K}\right)\right)}{K^2}P(t,\tau,K)\,dK, \tag{3}$$

$$\begin{aligned}W(t,\tau)=&\int_{S_t}^{\infty}\frac{6\ln\left(\frac{K}{S_t}\right)-3\left[\ln\left(\frac{K}{S_t}\right)\right]^2}{K^2}C(t,\tau,K)\,dK\\&-\int_{0}^{S_t}\frac{6\ln\left(\frac{S_t}{K}\right)+3\left[\ln\left(\frac{S_t}{K}\right)\right]^2}{K^2}P(t,\tau,K)\,dK,\end{aligned} \tag{4}$$

$$\begin{aligned}X(t,\tau)=&\int_{S_t}^{\infty}\frac{12\left[\ln\left(\frac{K}{S_t}\right)\right]^2-4\left[\ln\left(\frac{K}{S_t}\right)\right]^3}{K^2}C(t,\tau,K)\,dK\\&+\int_{0}^{S_t}\frac{12\left[\ln\left(\frac{S_t}{K}\right)\right]^2+4\left[\ln\left(\frac{S_t}{K}\right)\right]^3}{K^2}P(t,\tau,K)\,dK.\end{aligned} \tag{5}$$

It is important to note that the Bakshi, Kapadia, and Madan (2003) measure of risk-neutral skewness is *model free*, since it does not require any assumption on the state variables that determine the pricing kernel or the functional form of the pricing kernel. It is an *ex-ante* measure of the conditional skewness of the index return, since it is inferred from the contemporaneous index option prices, which embody investors' expectations of future index levels.

On each date t, the risk-neutral index skewness is estimated using Equations (1) through (5), and the date t last sale prices of OTM index puts and calls. To avoid stale prices, only index options that have positive trading volume on that date are used. The integrals are approximated in Equations (3)–(5) using the trapezoidal method. Given the fine grid of available strike prices for index options, and the fact that the integrand functions rapidly decline toward zero as the strike price deviates further from the spot index level, the approximation error (due to the discreteness of available strike prices) is negligible. This is confirmed by Dennis and Mayhew (2003). A monthly return horizon is used (i.e., $\tau = 1/12$ year). This choice gives enough nonoverlapping observations to do time-series regressions. In addition, options with approximately one month to maturity are the most actively traded. On some dates, there are no traded options with exactly one month until maturity. In such cases, the risk-neutral skewness is first calculated for the two time horizons that are nearest to one month, and then a risk-neutral skewness is linearly interpolated for the one-month index return density. Section 2.3 shows that the empirical results are

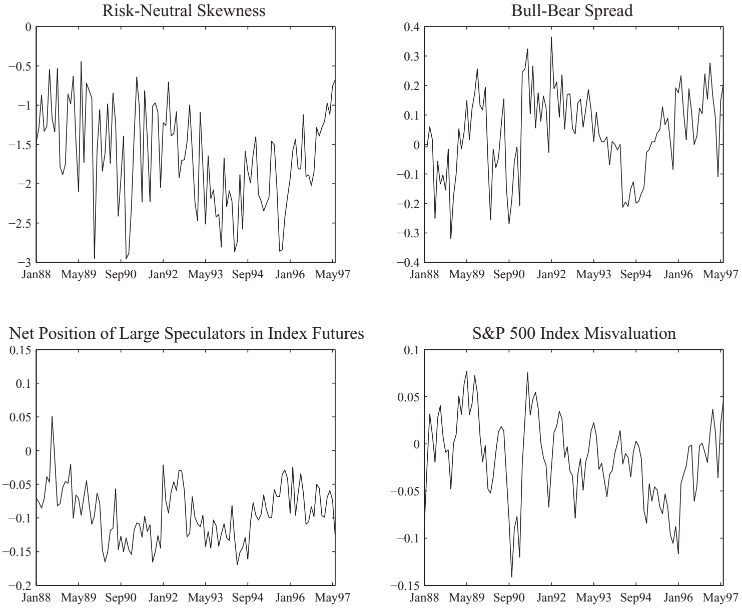

Figure 1
Time series of index risk-neutral skewness and investor sentiment
This figure plots the monthly time series of the index risk-neutral skewness and three measures of investor sentiment between January 1988 and June 1997. The top left panel plots the risk-neutral skewness of the S&P 500 index return over the next month inferred from index option prices according to Bakshi, Kapadia, and Madan (2003). The top right panel plots the proportion of bullish investors minus the proportion of bearish investors based on the survey done by *Investors Intelligence*. The bottom left panel plots the number of long noncommercial contracts minus the number of short noncommercial contracts in S&P 500 futures (scaled by the total open interest) based on the Commodity Futures Trading Commission's Commitments of Traders Report. The bottom right panel plots the fraction deviation of S&P 500 index level from that predicted by the log-linear dynamic growth model of Campbell and Shiller (1988) as implemented by Sharpe (2002).

robust to alternative usage of the options data to compute the risk-neutral skewness.

Figure 1 (top left panel) plots the monthly time series of the risk-neutral skewness of the monthly S&P 500 index return. It shows that the index risk-neutral skewness fluctuates substantially from one month to the next. This is confirmed by the high sample standard deviation of the index risk-neutral skewness as reported in Table 1.

1.3 Investor sentiment proxies

Three investor sentiment proxies are used in the empirical tests. The first proxy is a popular sentiment index based on *Investors Intelligence*'s weekly surveys of approximately 150 investment newsletter writers. Each newsletter is read and marked as bullish, bearish, or neutral, based on the expectations of future market movements.[9] Following Brown and Cliff (2004, 2005), the bull-bear spread—

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[9] Since the newsletters are not written with this survey in mind, they differ somewhat in their forecast horizon, and thus require interpretation regarding categorization. The temporal consistency in interpretation is maintained

Table 1
Summary statistics of variables

Variable	Mean	Standard deviation	Percentile 25%	Percentile 50%	Percentile 75%	Serial correlation
Skew	−1.6475	0.6181	−2.0982	−1.6033	−1.1208	0.4115
BullBear$_{\text{Survey}}$	0.0370	0.1419	−0.0460	0.0405	0.1470	0.5815
LongShort$_{\text{Futures}}$	−0.0638	0.0415	−0.0891	−0.0545	−0.0322	0.7645
Mispricing$_{\text{Index}}$	−0.0157	0.0438	−0.0423	−0.0142	0.0128	0.7384
IndexVolatility	0.1782	0.0535	0.1344	0.1713	0.2057	0.8168
RelativeDemand	2.3850	1.2447	1.5167	2.2251	2.9574	0.1760
IndexRet	0.0554	0.0853	0.0152	0.0590	0.1115	0.7694
Dispersion	−0.1054	0.3324	−0.3004	−0.1363	−0.0035	0.3213
ModelSkew$_{\text{SV}}$	−1.2474	0.5075	−1.6406	−1.2360	−0.9442	0.4170
ModelSkew$_{\text{SVJ}}$	−1.1597	0.5533	−1.4575	−1.1612	−0.8676	0.3477
ModelSkew$_{\text{AJ}}$	−2.2773	1.3947	−3.7166	−2.6122	−1.6162	0.2853
SmileSlope	−1.2194	0.0735	−1.2727	−1.2189	−1.1661	0.2891

This table reports the summary statistics for the variables used in the regressions reported in subsequent tables. There are 114 monthly observations of each variable, measured as closely as possible to the month end. The sample period is from January 1988 to June 1997. Skew is the risk-neutral skewness of the S&P 500 index return over the next month inferred from index option prices according to Bakshi, Kapadia, and Madan (2003). BullBear$_{\text{Survey}}$ is the proportion of bullish investors minus the proportion of bearish investors based on the survey done by *Investors Intelligence*. LongShort$_{\text{Futures}}$ is the net position of large speculators in S&P 500 index futures based on the Commodity Futures Trading Commission's Commitments of Traders Report. It is measured as the number of long "noncommercial" contracts minus the number of short "noncommercial" contracts, scaled by the total open interest in the S&P 500 index futures. Mispricing$_{\text{Index}}$ is the percentage deviation of the S&P 500 index level from that predicted by the log-linear dynamic growth model of Campbell and Shiller (1988) as implemented by Sharpe (2002). IndexVolatility is the CBOE's Volatility Index. RelativeDemand is the ratio of total open interest for out-of-the-money index put options (defined by $-\frac{3}{8} < \Delta_P \leq -\frac{1}{8}$) to that for near and at-the-money index options (defined as call options with $\frac{1}{2} < \Delta_C \leq \frac{5}{8}$ and put options with $-\frac{1}{2} < \Delta_P \leq -\frac{3}{8}$). SmileSlope is the ratio of the average Black-Scholes implied volatility of out-of-the-money index options to the average Black-Scholes implied volatility of near- and at-the-money index options. IndexRet is the S&P 500 index return over the previous six months. Dispersion is the total trading volume for S&P 500 index options (adjusted for a deterministic time trend, and then divided by 100,000). ModelSKew$_{\text{SV}}$, ModelSKew$_{\text{SVJ}}$, and ModelSKew$_{\text{AJ}}$ are model-implied risk-neutral skewness for one-month index return according to (respectively) a stochastic volatility model, a stochastic volatility model with random jump, and an asymmetric jump model.

the fraction of bullish investors minus the fraction of bearish investors—is used as a proxy for sentiment of large investors such as institutions. This is because many of the authors of these newsletters are current or retired market professionals. The bull-bear spread is published weekly in *Barron's* and is often mentioned in the financial press. It is related to many other measures of investor sentiment (Brown and Cliff, 2004). It is also positively related to deviations of large-size firms from their intrinsic values (Brown and Cliff, 2005).

The second investor sentiment proxy is derived from trading activity in the S&P 500 futures. The Commodity Futures Trading Commission (CFTC) requires large traders holding positions above a specified level to report their positions on a daily basis. The CFTC aggregates reported data, and releases the breakdown of each Tuesday's open interest in the Commitments of Traders Report.[10] The report contains the number of long positions and the number of

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because there have been only two editors of *Investors Intelligence* over the sample period. *Investors Intelligence* indicates that the typical forecast horizon of the newsletter is from one to three months.

[10] The Commitments of Traders Report for S&P 500 futures has been available each Friday since October 1992. Prior to that, they were available at mid-month and month-end.

short positions for both “commercial” traders and “noncommercial” traders. Commercial traders are required to register with the CFTC by showing a related cash business for which futures are used as a hedge. The noncommercials are large speculators. The second sentiment proxy is the net position of large speculators in S&P 500 futures, which is calculated as the number of long noncommercial contracts minus the number of short noncommercial contracts, scaled by the total open interest in S&P 500 futures.

The two sentiment proxies above concern large (institutional) investors, who dominate the use of index options (Bates, 2003; Lakonishok et al., 2007). Small investors’ sentiments are not included in this study as they are not important participants in the index options market. Results in an earlier version of this paper show that proxies of individual investors’ sentiment, such as the percentage of bullish investors minus the percentage of bearish investors (according to the survey of the American Association of Individual Investors), are not significantly related to index risk-neutral skewness, and their inclusion does not change the relation between proxies of large investors’ sentiments and the index risk-neutral skewness reported in Section 2.

The third investor sentiment proxy used is Sharpe’s (2002) valuation errors of the S&P 500 index. These errors are the fractional deviation of the S&P 500 index from the level predicted by the log-linear dynamic growth model of Campbell and Shiller (1988). They are the residuals of the log price-earnings ratio of the S&P 500 index regressed on earnings growth expectations, log dividend payout, and several other variables such as expected inflation and real 30-year treasury-bond yield. Positive (negative) error means that according to the Campbell-Shiller model, the S&P 500 index was overvalued (undervalued) relative to the fundamentals. For example, Sharpe finds that the stock index was grossly overvalued during August and September of 1987, just prior to the stock market crash in October 1987. On the other hand, the S&P 500 index was undervalued by more than 10% from late 1990 to early 1991, from late 1995 to early 1996, and around September of 1998.[11]

The three investor sentiment proxies are positively correlated with each other. The correlation of the bull-bear spread and the net position of large speculators in S&P 500 futures is 0.26. The correlation of these two variables with the valuation errors of the S&P 500 index is 0.35 and 0.15, respectively. Thus, the S&P 500 index tends to be more overvalued when newsletter writers and large speculators in S&P 500 futures are more bullish about future market return. This is consistent with previous findings that the bull-bear spread of large investors, and their net position in S&P 500 futures, negatively predict market return (Fisher and Statman, 2000; Brown and Cliff, 2005). All three sentiment proxies display significant temporal movements, and they tend to move in lockstep with the index risk-neutral skewness (see Figure 1). The

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[11] March 1991 is an NBER business cycle trough during the 1990–1991 recession. In the fall of 1998, the stock market dropped significantly out of concerns about the Russian financial crisis and the Long Term Capital Management debacle.

Table 2
Investor sentiment and index risk-neutral skewness

Panel A

Variable	(1)	(2)	(3)	(4)
BullBear$_{\text{Survey}}$	0.9793			0.8727
	(3.0107)			(2.6747)
LongShort$_{\text{Futures}}$		2.4612		2.0202
		(1.9190)		(1.6207)
Mispricing$_{\text{Index}}$			5.2963	3.5744
			(3.4562)	(2.3045)
Lagged dependent	0.3799	0.3889	0.2428	0.2386
	(4.6703)	(4.3918)	(2.5169)	(2.4718)
Adjusted R^2	0.2098	0.1863	0.2175	0.2605

Panel B

Variable	(1)	(2)	(3)	(4)
BullBear$_{\text{Survey}}$	1.1844			1.1787
	(3.0450)			(3.3552)
LongShort$_{\text{Futures}}$		2.8346		1.7875
		(1.5728)		(1.2139)
Mispricing$_{\text{Index}}$			4.2521	5.0031
			(2.3347)	(3.0541)
Lagged dependent	−0.0452	−0.0476	−0.0911	−0.1087
	(−0.5208)	(−0.5317)	(−0.9683)	(−1.2762)
Adjusted R^2	0.0438	0.0017	0.0301	0.0936

This table reports the results for regression models that study the relation between the risk-neutral skewness of the S&P 500 index return and proxies of investor sentiment. In panel A, the dependent variable is the risk-neutral skewness of index return over the next month, implied from index option prices according to Bakshi, Kapadia, and Madan (2003). BullBear$_{\text{Survey}}$ is the proportion of bullish investors minus the proportion of bearish investors from *Investors Intelligence*. LongShort$_{\text{Futures}}$ is the net position of large speculators in S&P 500 index futures scaled by the total open interest in the S&P 500 index futures. Mispricing$_{\text{Index}}$ is the percent deviation of the S&P 500 index level from that predicted by the log-linear dynamic growth model of Campbell and Shiller (1988) as implemented by Sharpe (2002). In panel B, the dependent variable is the AR(1) residuals of the index risk-neutral skewness. The regressors are the AR(1) residuals of the sentiment proxies. For each time series x_t, the AR(1) residual refers to the ϵ term in the following specification $x_{t+1} = a + bx_t + \epsilon_{t+1}$. The data consist of 114 month-end observations of each variable from January 1988 to June 1997. Standard errors are adjusted for heteroskedasticity and serial correlation according to Newey and West (1987), and the t-statistics are reported in parentheses below the coefficients.

correlation between the sentiment proxies and the index risk-neutral skewness ranges from 0.29 to 0.48. In Section 2, this relation is studied in more detail.

2. Empirical Results

2.1 Basic results

Panel A of Table 2 reports the results for the regression models that study the relation between index risk-neutral skewness and the investor sentiment proxies. The regressions employ monthly time-series observations. The dependent variable for all regressions is the risk-neutral skewness of index return over the next month inferred from contemporaneous index option prices, as evaluated on the last trading day of each month. The sentiment proxies are measured on or prior to that date, using the latest available data. A lagged-dependent variable is included as a regressor to control for its positive autocorrelation.

The t-statistics of the parameter estimates are obtained from standard errors that have been adjusted for heteroskedasticity and serial correlation according to Newey and West (1987).

Panel A of Table 2 shows that all three investor sentiment proxies are significantly related to the risk-neutral skewness of index return. Positive coefficient estimates for the sentiment proxies imply that a more bearish market sentiment (or lower values for the sentiment proxies) is related to a more negative index risk-neutral skewness. On the other hand, the risk-neutral density of index return becomes less negatively skewed when there is a bullish shift in market sentiment.

The impact of sentiment proxies is also economically significant. For example, based on the coefficient estimates in panel A of Table 2, when the bull-bear spread variable drops by one sample standard deviation (a bearish shift in sentiment), the index risk-neutral skewness becomes more negative by about a 0.23 sample standard deviation. Similarly, when the S&P 500 index becomes more depressed relative to its fundamental value by one sample standard deviation (which is about 4.38%), the index risk-neutral skewness becomes more negative by about a 0.38 sample standard deviation. Table 1 shows that the sample standard deviation of monthly index risk-neutral skewness is 0.6181. Thus, a one standard-deviation move in the sentiment proxies leads to a change in index risk-neutral skewness by about 0.14–0.24, which is about 8.7%–14.4% of the average magnitude of index risk-neutral skewness. This turns out to be much larger than possible fluctuation in skewness caused by measurement errors in option prices such as bid-ask bounce.[12]

The serial correlation in the dependent variable in Table 2 (panel A) regressions is 0.41 at the monthly level and for the three sentiment proxies is 0.58, 0.76, and 0.74, respectively (see Table 1). To examine whether the results are potentially affected by the positive serial correlation in the dependent and independent variables, an AR(1) model is estimated for the index risk-neutral skewness and for the investor sentiment proxies, and panel A regressions are rerun using the AR(1) residual of each series. Regression results in panel B of Table 2 are similar to those in panel A. Thus, the significant time-series relation between index risk-neutral skewness and the sentiment proxies is not spuriously induced by persistence in data.

2.2 Robustness to control variables

Table 3 checks the robustness of the relation between index risk-neutral skewness and the investor sentiment proxies documented in Table 2, by including several variables as additional regressors. The control variables are chosen in part because they are related to the index option volatility smile, and thus may

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[12] For example, 1,000 simulations are done using options bid-ask data from OptionMetrics and last sale price from CBOE for 3 January 1997 (results on other dates are similar). In each round of simulation, the last sale price of each index option is shocked by one half of its bid-ask spread. The standard deviation of the skewness estimate across the 1,000 simulations is 0.0485.

Table 3
Investor sentiment and index risk-neutral skewness: robust to control variables

Model	(1)	(2)	(3)	(4)	(5)	(6)
$\text{BullBear}_{\text{Survey}}$		1.1924	1.0343	1.1505	1.1254	1.0846
		(4.0042)	(3.1331)	(3.0518)	(3.3670)	(3.1033)
$\text{LongShort}_{\text{Futures}}$		2.5734	2.9837	1.9274	2.9553	2.9818
		(1.9208)	(2.3816)	(1.3857)	(2.3962)	(2.4052)
$\text{Mispricing}_{\text{Index}}$		4.1568	3.1183	3.1613	3.4480	3.3768
		(2.9950)	(2.4541)	(2.4749)	(2.4852)	(2.3138)
IndexVolatility	4.3747	4.9232	4.5342	4.5353	4.5892	4.3019
	(4.6975)	(6.0679)	(5.4389)	(3.4466)	(5.6149)	(5.2639)
RelativeDemand	−0.3342		−0.3525	−0.3184	−0.3615	−0.3784
	(−3.0143)		(−3.1850)	(−2.4873)	(−3.3874)	(−3.5266)
IndexRet	3.0327		1.4971	1.7415	1.3012	1.3392
	(4.2366)		(2.4124)	(2.2455)	(2.1084)	(2.0680)
Lagged dependent	0.2141	0.0612	0.0461	0.0231	0.0340	0.0508
	(2.2957)	(0.6313)	(0.4869)	(0.2217)	(0.3534)	(0.5083)
Adjusted R^2	0.3639	0.3976	0.4534	0.4442	0.4572	0.4522

This table reports the results of monthly regressions that examine the robustness of the relation between index risk-neutral skewness and sentiment proxies. The dependent variable for all regressions is the risk-neutral skewness of index return over the next month as implied from index option prices. Models 1 to 3 add control variables including index return volatility, past-six-month index return, and relative demand of out-of-the-money index put options to near and at-the-money index options. Model 4 includes the following variables as additional regressors: the logarithmic growth in aggregate industrial production over the last 12 months, the 1-month treasury-bill rate, the spread between yields on the 10-year treasury bond and the 3-month treasury bill, and difference in yields on Baa and Aaa corporate bonds. The regression coefficients for these additional control variables are omitted for brevity. In Model 5 (6), each of the investor sentiment proxies ($\text{BullBear}_{\text{Survey}}$, $\text{LongShort}_{\text{Futures}}$, and $\text{Mispricing}_{\text{Index}}$) is first regressed on one-month (three-month) ahead index return, and the residuals are then used as independent variables in the risk-neutral skewness regressions. The data consist of 114 month-end observations of each variable from January 1988 to June 1997. Standard errors are adjusted for heteroskedasticity and serial correlation according to Newey and West (1987), and the t-statistics are reported in parentheses below the coefficients.

affect the index risk-neutral skewness, since a negative index risk-neutral skewness is closely related to the index option volatility smile (Bakshi, Kapadia, and Madan, 2003).

The first control variable is the instantaneous volatility of index return. Theoretically, this variable is the key determinant of risk-neutral skewness under rational models with stochastic volatility (see Section 2.5). Empirically, Li and Pearson (2005) find that it is related to the slope of the S&P 500 option volatility smile. The CBOE Volatility Index (VIX) is used as a proxy for the instantaneous volatility of index return. During the sample period, the VIX represents the average implied volatility of the at-the-money index options 30 days before expiration. The results are the same when the implied volatility state variable in the Heston (1993) stochastic volatility model is used instead of VIX.

The second control variable is stock market momentum, measured by the most recent six-month index return (similar results are obtained with a three-month or a twelve-month index return). Recent return is the most important determinant of market sentiment (Brown and Cliff, 2004). But stock market momentum also affects the relative valuation of index options (Amin, Coval, and Seyhun, 2004).

The relative demand of index options is also controlled for. Bollen and Whaley (2004) find that an option's implied volatility increases with its net buying pressure. Garleanu, Pedersen, and Poteshman (2005) find that the level of net end-user demand impacts the slope of the implied volatility smile as well. Given the close relationship between the slope of the option smile and risk-neutral skewness of the underlying asset return density, demand pressure for index options can be expected to be correlated with index risk-neutral skewness. To control for such an effect, Table 3 includes as a regressor the ratio of the open interest for the out-of-money index put options to the open interest for the near and at-the-money index options. Following Bollen and Whaley (2004), out-of-money puts are classified as those options whose *delta* satisfy $-\frac{3}{8} < \Delta_P \leq -\frac{1}{8}$. The near and at-the-money options include call options with $\frac{1}{2} < \Delta_C \leq \frac{5}{8}$ and put options with $-\frac{1}{2} < \Delta_P \leq -\frac{3}{8}$.

Model 1 in Table 3 shows that these control variables are significantly related to index risk-neutral skewness in the expected manner. For example, index risk-neutral skewness is less negative when market volatility is higher. This is consistent with the prediction of stochastic volatility models (see Equation (12)). Furthermore, index risk-neutral skewness becomes more negative when there is a higher demand for the out-of-the-money index put options relative to the near and at-the-money index options. This is consistent with the relation between the relative demand of index options and the slope of the index option smile (Garleanu, Pedersen, and Poteshman, 2005). Finally, the results indicate that index risk-neutral skewness is positively related to past-six-month return of the S&P 500 index. This is consistent with the findings of Amin, Coval, and Seyhun (2004) that the index option smile becomes flatter following an up-market.

Models 2 and 3 in Table 3 show that the relation between the sentiment proxies and index risk-neutral skewness remains significant—both statistically and economically—in the presence of the control variables. The impact of sentiment proxies becomes weaker after controlling for the option demand-pressure effect. This is reasonable since sentiment may affect option prices through the demand-pressure effect.

The significance of the relation between the sentiment proxies and index risk-neutral skewness is also confirmed after controlling for the dispersion of beliefs among investors.[13] Buraschi and Jiltsov (2006) estimate a heterogeneous-belief model using index option prices and option trading volume. They find that a higher value for the option-implied difference in beliefs leads to a steeper volatility smile, and that option trading volume is an excellent proxy for the dispersion of beliefs. In unreported monthly regressions, when the total trading

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[13] The sentiment proxies bull-bear spread and large speculators' net position in the index futures differ from the dispersion of investors' beliefs, although they are all related to investor heterogeneity. To see this, compare the following two scenarios. In the first, 70% of the investors are bullish and 30% are bearish. In the second, 30% of the investors are bullish and 70% are bearish. The dispersion in beliefs is the same in the two cases, but not for the bull-bear spread.

volume in the SPX options (adjusted for a deterministic time trend) is added as an independent variable to model 3 in Table 3, index risk-neutral skewness tends to be more negative when the dispersion of beliefs is larger, although this relation is not statistically significant. In weekly time-series regressions (see model 1 in Table 6), the coefficient for the dispersion of beliefs proxy becomes statistically significant.[14] More importantly, in (both monthly and weekly) index risk-neutral skewness regressions, the coefficients for the investor sentiment proxies remain significant in the presence of the dispersion of beliefs.

2.3 Alternative measurement of risk-neutral skewness

Table 4 examines the robustness of the relation documented before to noise that might be introduced in the estimation of the index risk-neutral skewness. All the regressions reported in Table 4 have the same specifications as model 3 in Table 3. They differ only in the measurement of the dependent variable—the index risk-neutral skewness. Note that in general, noise in the dependent variable works against finding statistically significant coefficients in the regressions.

The last sale prices of index options and the Bakshi, Kapadia, and Madan (2003) algorithm have been used to compute the index risk-neutral skewness. Table 4 uses the same algorithm, but different options data. Model 1 assesses—via simulations—the impact of option bid-ask spreads on the results.[15] In each round of simulations, price for an option on date t is its last sale price minus (plus) one-half of the estimated bid-ask spread, if the trade is buyer (seller) initiated. A trade is buyer (seller) initiated if the corresponding random draw from a binomial distribution with parameter p_t has a realization of one (zero), where $p_t = 0.5 + s_t - \text{mean}(s)$, s is the bull-bear spread variable. The simulation is done 1,000 times.

The impact of option bid-ask spreads on risk-neutral skewness is not economically significant.[16] The month-to-month variation in the risk-neutral skewness is more than one magnitude larger than the possible noise in the risk-neutral skewness caused by reasonable measurement errors of option prices. The mean difference between the original skewness (used throughout the paper) and the skewness estimated from the simulated option prices that take into consideration the option bid-ask spreads is approximately zero. Their average correlation

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[14] Similarly, Table 7 shows that the dispersion of belief measure is significantly related to the slope of index option smile in weekly regression, but not in monthly regression. These results are consistent with Buraschi and Jiltsov (2006), who find that the impact of difference in beliefs on index option smile fades out quickly over time, and becomes statistically insignificant after about nine days.

[15] The CBOE data do not have bid-ask information. The best bid and ask prices for index options are obtained from Ivy DB of OptionMetrics (for a later sample period). The percentage bid-ask spread is regressed on $M - 1$ and $|M - 1|$, where M is the option moneyness. Only out-of-the-money index options with short maturity [the same index options employed to estimate the index risk-neutral skewness following the Bakshi, Kapadia, and Madan (2003) approach] are used in the regression. The fitted value from the bid-ask spread regression is taken as the estimated bid-ask spread in the sample.

[16] Intuitively, the percentage bid-ask spreads are high for deep out-of-the-money options, but these options matter very little for the risk-neutral skewness, as can be seen from the integrals involved in the calculation of risk-neutral skewness [see Equations (3), (4), and (5)].

Table 4
Investor sentiment and index risk-neutral skewness: robust to measurement of the skewness

Model	(1)	(2)	(3)	(4)
$\text{BullBear}_{\text{Survey}}$	0.8005	0.9918	0.6044	1.5163
	(1.8496)	(2.0986)	(2.1566)	(2.9888)
$\text{LongShort}_{\text{Futures}}$	3.4790	3.2720	2.4972	2.6949
	(2.3907)	(2.1579)	(2.7139)	(1.9906)
$\text{Mispricing}_{\text{Index}}$	2.6774	2.7374	3.2366	3.1765
	(2.0396)	(1.9940)	(3.5146)	(2.4454)
IndexVolatility	4.5310	3.5864	3.6009	5.3565
	(5.3946)	(4.2715)	(5.1378)	(6.7348)
RelativeDemand	−0.3369	−0.2852	−0.2383	−0.2001
	(−3.0350)	(−2.6150)	(−2.6213)	(−1.9351)
IndexRet	1.6142	0.2838	1.2548	1.6564
	(2.5106)	(0.4767)	(2.3096)	(2.6842)
Lagged dependent	0.0706	0.1259	0.2243	0.0802
	(0.7518)	(1.3479)	(2.4425)	(0.9303)
Adjusted R^2	0.4017	0.3287	0.4175	0.4266

All the regressions reported in this table have identical specifications as model 3 in Table 3. They only differ in the measurement of the dependent variable, the index risk-neutral skewness. All skewness measures are obtained using the Bakshi, Kapadia, and Madan (2003) approach, but with different data input. Model 1 examines the impact of option bid-ask spreads on the relation between investor sentiment and index risk-neutral skewness. The dependent variable in model 1 is the average risk-neutral skewness across 1,000 simulated datasets of option prices. In each round of simulations, the price for an option on date t is its last sale price minus (plus) one half of the estimated bid-ask spread, if the trade is buyer (seller) initiated. A trade is buyer (seller) initiated if the corresponding random draw from a binomial distribution with parameter p_t has a realization of one (zero), where $p_t = 0.5 + s_t - \text{mean}(s)$, s is the bull-bear spread variable. In model 2, the average of the daily high price and the daily low price of each index option on the last trading day of each month is used to compute index risk-neutral skewness on that date. Model 3 uses the monthly average risk-neutral skewness as the dependent variable. Model 4 uses data sampled around the middle of each month when there are options with exactly one-month time to maturity. There are 114 monthly observations of each variable from January 1988 to June 1997. Standard errors are adjusted for heteroskedasticity and serial correlation according to Newey and West (1987), and the t-statistics are reported in parentheses below the coefficients.

is 0.9690. The mean absolute difference is 0.0453. In comparison, the average (median) absolute monthly change in the index risk-neutral skewness is 0.5129 (0.4151). Thus, it is not surprising that the monthly time-series regression relation between the index risk-neutral skewness and the sentiment proxies is not sensitive to the influence of option bid-ask spreads. When the average risk-neutral skewness (averaged across the 1,000 simulations on each date) is used as the dependent variable in model 1 in Table 4 , the result is very similar to model 3 in Table 3.[17] Similarly, using the average of the daily high price and the daily low price (instead of last sale price) of each index option to

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[17] Multiplying the estimated option bid-ask spreads by a factor of two increases the dispersion of risk-neutral skewness across simulations. But it does not materially change the significant relation between index risk-neutral skewness and the investor sentiment proxies.

calculate index risk-neutral skewness does not alter the results (see model 2 in Table 4).

In all the previous regressions, the risk-neutral skewness is estimated once a month using options data on the last trading day of each month. To make sure that the results are not unique to the month end, in Table 4 model 3, the dependent variable used is the average (over all trading days in a month) of the risk-neutral skewness calculated from each trading day's cross section of index option prices. Alternatively, in model 4 in Table 4, the index risk-neutral skewness is computed using index options data sampled on a date (around the middle of each month) when there are options with exactly one month left to maturity. Recall that at the month's end, the risk-neutral skewness of index return over the next month must be interpolated due to the lack of traded index options with exactly one month until maturity. In both models 3 and 4 of Table 4, there is still a significant relation between the index risk-neutral skewness and the sentiment proxies, just as in Tables 2 and 3.

To summarize, Table 4 shows that the significant relation between the sentiment proxies and index risk-neutral skewness is not affected by potential noise in the estimation of the index risk-neutral skewness.

2.4 Errors in beliefs or rational updating?

The significant relation between the investor sentiment proxies and index risk-neutral skewness is consistent with the impact of aggregate error in investors' beliefs on index option prices. However, the sentiment proxies may include rational components. For example, the results of investor surveys may reflect both the error in investors' beliefs, as well as new information that is correctly being incorporated into the investors' subjective probabilities. Thus, an alternative rational interpretation is that the time-series relation documented above could reflect rational updating of beliefs about the conditional density of index return.

To deal with the possibility that the investor sentiment proxies could be correlated with variables that proxy for investment opportunities and predict market return, one can decompose the sentiment proxies by regressing each sentiment proxy on a set of rational predictors of index return, and then regress index risk-neutral skewness on the residual sentiment proxies. Baker and Wurgler (2006) use this approach to decompose investor sentiment proxies in studying the pricing effect of sentiment in the stock markets. Model 4 in Table 3 adopts this approach and controls for the logarithmic growth in the aggregate industrial production over the last year, the one-month treasury-bill rate, the spread between yields on the ten-year treasury bond and the three-month treasury bill, and difference in yields on Baa and Aaa corporate bonds (these variables are motivated by previous studies such as Chen, 1991; and Ferson and Harvey, 1991). If the relation between index risk-neutral skewness and the bull-bear spread is driven by the non-sentiment-related component, then it will weaken substantially (or disappear) in the presence of these rational control variables.

However, this is not the case in the data. Model 4 in Table 3 shows that the bull-bear spread and the index misvaluation are still significantly related to the index risk-neutral skewness. The magnitudes of their coefficient estimates barely change in the presence of the rational predictors of index return.

In another attempt to disentangle rational updating about index return distribution from errors in beliefs, the investor sentiment proxies are decomposed by regressing each sentiment proxy on one-month (three-month) ahead index return, and then the residuals are used as independent variables in the risk-neutral skewness regressions (together with control variables).[18] Models 5 and 6 in Table 3 show that there is still a positive and statistically significant relation between the risk-neutral skewness of index return and the residual sentiment proxies cleansed of rational updating.

2.5 Can the results be explained by rational models?

This section examines whether the significant time-series relation between the sentiment proxies and index risk-neutral skewness can be explained by several rational option pricing models. One way to generate negative skewness in return is to allow the instantaneous volatility of return to be stochastic and negatively correlated with the innovation in return. For example, the Heston (1993) model assumes the following risk-neutral dynamics for asset price S_t and the instantaneous variance V_t of asset return:

$$dS_t = r_t S_t \,\mathrm{d}t + \sqrt{V_t} S_t \,\mathrm{d}W_t \tag{6}$$

$$dV_t = \kappa(\theta - V_t)\,\mathrm{d}t + \eta\sqrt{V_t}\,\mathrm{d}B_t, \tag{7}$$

where $\mathrm{d}W_t$ and $\mathrm{d}B_t$ are two correlated Brownian motions with correlation ρ. If $\rho < 0$, then variances tend to be high when returns are low. The left tail of the return distribution is more spread out than the right tail, and this creates a negative skewness.

The possibility of a negative jump in the return process also generates negative skewness for the return density. Consider a model with an asymmetric jump as proposed by Dupoyet (2004), where the risk-neutral process of the instantaneous asset return is determined by

$$\frac{\mathrm{d}S_t}{S_t} = \left(r - \frac{\lambda_u}{\gamma_u - 1} + \frac{\lambda_d}{\gamma_d + 1}\right)\mathrm{d}t + \sigma\,\mathrm{d}W_t + J_u(t)\,\mathrm{d}q_u(t) + J_d(t)\,\mathrm{d}q_d(t), \tag{8}$$

where λ_u and λ_d are (respectively) the frequency of upward and downward jumps per year for the Possion jump counters $q_u(t)$ and $q_d(t)$; and $J_u(t)$ and $J_d(t)$ are the percentage up-jump and down-jump sizes occurring conditionally

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[18] An anonymous referee provided this suggestion.

on a jump:

$$J_u(t) = x_u(t) - 1, \quad x_u(t) \sim \text{Pareto}(r_u),$$
$$J_d(t) = x_d(t) - 1, \quad x_d(t) \sim \text{Beta}(r_d, 1).$$

Stochastic volatility and jump can also be combined. Consider the jump-diffusion model of Bakshi, Cao, and Chen (1997), with the following risk-neutral dynamics for index return:

$$\frac{\mathrm{d}S_t}{S_t} = (r_t - \lambda\mu_J)\,\mathrm{d}t + \sqrt{V_t}\,\mathrm{d}W_t + J_t\,\mathrm{d}q_t \tag{9}$$

$$\mathrm{d}V_t = (\theta_v - \kappa_v V_t)\,\mathrm{d}t + \sigma_v\sqrt{V_t}\,\mathrm{d}B_t \tag{10}$$

$$\ln(1 + J_t) \sim \mathcal{N}\big(\ln(1 + \mu_J) - 0.5\sigma_J^2, \sigma_J^2\big), \tag{11}$$

where q_t is a Possion jump counter with constant intensity λ, and J_t is the percentage jump size with time-invariant lognormal distribution. $q(t)$ and $J(t)$ are not correlated with each other, or with Brownian motions W_t and B_t, while $\text{Cov}[\mathrm{d}W,\ \mathrm{d}B] = \rho\,\mathrm{d}t$.

Under the rational models, the risk-neutral skewness of the asset return is completely determined by the specified risk factors and model parameters. For example, under the Heston (1993) model, the date t risk-neutral skewness of the asset return over the horizon $[t, t + \tau]$ is (see Das and Sundaram, 1999):

$$\text{Skew}(t, \tau) = \left(\frac{3\eta\rho e^{0.5\kappa\tau}}{\sqrt{\kappa}}\right)\left[\frac{\theta(2 - 2e^{\kappa\tau} + \kappa\tau + \kappa\tau e^{\kappa\tau}) - V_t(1 + \kappa\tau - e^{\kappa\tau})}{(\theta[1 - e^{\kappa\tau} + \kappa\tau e^{\kappa\tau}] + V_t[e^{\kappa\tau} - 1])^{3/2}}\right]. \tag{12}$$

For a given set of model parameters, the risk-neutral skewness under the Heston (1993) model is an increasing function of, and uniquely determined by, the volatility state variable. Change in some model parameters, such as the correlation between index return and its instantaneous volatility in stochastic volatility models, or the jump intensity parameters in jump-diffusion models, would also lead to variation in the model-implied return skewness.

Investor sentiment proxies may appear to be related to index risk-neutral skewness just because they are correlated with the risk factors in the rational models or model parameters that importantly affect the skewness of return density. Table 5 tests whether the rational models above can explain the relation between the sentiment proxies and index risk-neutral skewness by explicitly controlling for the conditional risk-neutral skewness of index return implied by these rational models. If the relation between the sentiment proxies and index risk-neutral skewness only reflects rational updating of beliefs about the index return density under these models, then sentiment would have no incremental power to explain the risk-neutral skewness after controlling for the model-implied risk-neutral skewness. On the other hand, if at least part of the relation reflects the impact of aggregate belief errors on the option prices, then it should

Table 5
Investor sentiment and index risk-neutral skewness: controlling for rational option pricing models

		Stochastic volatility		Stochastic volatility with jump		Asymmetric jump	
Model	(1)	(2)	(3)	(4)	(5)	(6)	(7)
$\text{BullBear}_{\text{Survey}}$	1.5163		1.4756		1.5006		1.5380
	(2.9888)		(3.6270)		(3.0999)		(2.9755)
$\text{LongShort}_{\text{Futures}}$	2.6949		1.3810		2.2650		2.6696
	(1.9906)		(1.5149)		(1.9130)		(1.9678)
$\text{Mispricing}_{\text{Index}}$	3.1765		3.0290		3.1199		3.1462
	(2.4454)		(2.9138)		(2.7336)		(2.4395)
IndexVolatility	5.3565		5.9346		4.5398		4.9403
	(6.7348)		(8.2866)		(4.6558)		(5.7405)
RelativeDemand	−0.2001		−0.1670		−0.2282		−0.2147
	(−1.9351)		(−1.9502)		(−2.3109)		(−2.0314)
IndexRet	1.6564		0.1237		1.0604		1.5836
	(2.6842)		(0.1703)		(1.4897)		(2.4433)
ModelSkew		0.6299	0.6072	0.4558	0.3076	0.1396	0.0379
		(4.7532)	(4.4941)	(3.5191)	(2.0667)	(3.3645)	(1.3281)
Lagged dependent	0.0802	0.3644	0.0635	0.3368	0.0670	0.3245	0.0825
	(0.9303)	(4.5091)	(0.7817)	(3.9793)	(0.7745)	(3.4090)	(0.9250)
Adjusted R^2	0.4266	0.3407	0.5541	0.2650	0.4641	0.2209	0.4364

Regressions presented in this table examine whether the relation between investor sentiment and index risk-neutral skewness can be explained by three rational models based on representative-agent and perfect-market assumptions: the stochastic-volatility model of Heston (1993), the stochastic-volatility random-jump model of Bakshi, Cao, and Chen (1997), and the asymmetric jump model of Dupoyet (2004). All regressions use monthly data sampled around the middle of each month when there are traded options with one-month time to maturity. On each date, these models are recalibrated to best fit the prices of index options with one-month time to maturity. Model parameter estimates are then used to compute the skewness of one-month index return (ModelSkew) based on the assumed risk-neutral return dynamics for the S&P 500 index under each model. The dependent variable in all regressions reported in this table is the risk-neutral skewness of one-month index return extracted from prices of one-month maturity index options according to Bakshi, Kapadia, and Madan (2003). Model 1 is the same as model 4 in Table 4 and is presented for ease of comparison. The data consist of 114 monthly observations of each variable from January 1988 to June 1997. Standard errors are adjusted for heteroskedasticity and serial correlation according to Newey and West (1987), and the t-statistics are reported in parentheses below the coefficients.

still remain significant after controlling for the risk-neutral skewness implied by the rational models.

The dependent variable for all monthly regressions reported in Table 5 is the model-free conditional risk-neutral skewness of one-month index return inferred from the contemporaneous prices for a set of index options according to the algorithm of Bakshi, Kapadia, and Madan (2003). To obtain the index risk-neutral skewness under the three rational models above, each model is calibrated on each date by minimizing the sum of squared fitted option pricing errors. Implied state variables and model parameter estimates obtained from the calibration are then used to calculate the skewness of the one-month index return. The index risk-neutral skewness under the Heston (1993) model is calculated via Equation (12) with $\tau = 1/12$. For the Bakshi, Cao, and Chen (1997) jump-diffusion model and the Dupoyet (2004) asymmetric jump model, the risk-neutral skewness of index return over the next month is calculated by using Monte Carlo simulations to generate 10,000 paths of index level one month into the future (based on the assumed risk-neutral dynamics for the S&P 500 index, discretized at daily frequency).

Models 2, 4, and 6 in Table 5 show that the risk-neutral skewness implied by each of the three rational models is significantly and positively related to the model-free skewness estimate. Models 3, 5, and 7 show that there is still a significant relation between the model-free index risk-neutral skewness and the sentiment proxies, after controlling for the rational models. Compared to model 1 in Table 5, the addition of the model-implied skewness raises the regression R^2, but only slightly reduces the magnitude of the regression coefficients for the sentiment proxies. Thus, the relation between the sentiment proxies and index risk-neutral skewness documented is largely independent of the rational models considered.

2.6 Limits to arbitrage

The behavioral interpretation of the relation between the investor sentiment proxies and index risk-neutral skewness implies that it should be stronger when there are more significant impediments to arbitrage in the index options market. This is because the pricing impact of investor sentiment is higher during these periods.

There are three predictions that are based on this hypothesis. One, the sample is split into two subperiods: the first from January 1988 to September 1992, and the second from October 1992 to June 1997. It is reasonable to expect limits to arbitrage to be reduced in the second part of the sample as the index options market develops. Thus, a weaker relation between the sentiment proxies and index risk-neutral skewness is expected during this time.

Two, arbitrage in index options is more limited when there is higher uncertainty about market volatility. Arbitrageurs in the index options market need to form accurate forecasts of market volatility, which becomes more difficult during periods of higher uncertainty. Mistakes in forecasting volatility cause both option value and hedge ratio to be wrong. The impact on hedging accuracy is most significant for the out-of-the-money options (Figlewski, 1989). In addition, when there is a lot of uncertainty about the market volatility, arbitrageurs face greater volatility risk, which can produce very large losses (Figlewski and Green, 1999). Hedging volatility risk tends to reduce arbitrage profits (Bollen and Whaley, 2004). Thus, there are more severe limits to arbitrage in index options when uncertainty about market volatility is higher. So a stronger relation between the sentiment proxies and index risk-neutral skewness is expected during periods of high uncertainty about market volatility.

Three, there should be higher limits to arbitrage in index options following a market downturn. It is known that market makers and arbitrageurs are net short in the index put options (e.g., Lakonishok, Lee, Pearson, and Poteshman, 2007). They lose money following a market downturn and become more capital-constrained in their arbitrage activities going forward. Thus, a stronger relationship between the sentiment proxies and index risk-neutral skewness is expected when the stock market has not done well.

Table 6
Investor sentiment and index risk-neutral skewness: interaction with limits to arbitrage

	(1)	(2)	(3)	(4)		(5)	
	Full	First	Second	Volatility uncertainty		Past index return	
Model	sample	half	half	Low	High	High	Low
$\text{BullBear}_{\text{Survey}}$	0.5965	0.6646	0.4382	0.1735	0.8834	0.4887	0.6585
	(2.9488)	(2.8628)	(1.3022)	(0.6139)	(3.8433)	(1.4933)	(2.4753)
$\text{LongShort}_{\text{Futures}}$	1.5741	2.0255	1.2981	0.7847	1.3563	1.1450	1.9919
	(2.1698)	(2.6942)	(1.1724)	(0.9116)	(1.4137)	(1.1126)	(2.4414)
IndexVolatility	3.1871	2.9831	5.2581	4.9010	3.6813	3.6850	3.2979
	(7.3602)	(4.2294)	(5.1288)	(5.6678)	(6.2946)	(5.0895)	(6.3455)
RelativeDemand	−0.2045	−0.1298	−0.2466	−0.1495	−0.2517	−0.2103	−0.1725
	(−3.4404)	(−1.9386)	(−3.8997)	(−3.0781)	(−3.7482)	(−3.0209)	(−2.2092)
IndexRet	1.1570	1.2347	0.6514	0.9193	1.2079	0.7597	1.3071
	(3.5240)	(3.1263)	(1.0443)	(1.5379)	(2.7189)	(1.2770)	(2.8467)
Dispersion	−0.1855	−0.3608	−0.1745	−0.1218	−0.2639	−0.2764	−0.1077
	(−2.1668)	(−1.7210)	(−1.8377)	(−1.1089)	(−2.7834)	(−2.7478)	(−0.8991)
Lagged dependent	0.4114	0.3630	0.3831	0.3969		0.4028	
	(9.2849)	(6.5308)	(6.4966)	(9.5340)		(9.3410)	
Adjusted R^2	0.4883	0.3230	0.5230	0.5198		0.4868	

All regressions reported in this table employ weekly time-series data. Model 1 uses the full sample from 4 January 1988 to 27 June 1997, while models 2 and 3 use respectively the first part and the second part of the sample. The dependent variable in all models is the risk-neutral skewness of the S&P 500 index return over the next month computed from contemporaneous index option prices on the last trading day of each week. The independent variables include two proxies for investor sentiment (the bull-bear spread based on investor surveys, and net position of large speculators in index futures), index return volatility, relative demand for out-of-the-money to at-the-money index options, past-six-month return on the S&P 500 index, and a proxy for the dispersion of beliefs among investors. All independent variables are measured on or prior (but as close as possible) to the last trading day of each week. Model 4 adds the interaction of all independent variables (except the lagged dependent variable) with a dummy that takes a value of 1 on dates when a proxy for limits to arbitrage in the index options market is higher than the sample median. This proxy captures the amount of uncertainty about market volatility and is taken to be the parameter denoting the volatility of instantaneous variance of the index return in the Heston (1993) stochastic volatility model (recalibrated on each date). Model 5 adds the interaction of all independent variables (except the lagged dependent variable) with a dummy that takes a value of 1 on dates when past one-year index return is lower than the sample median. Standard errors are adjusted for heteroskedasticity and serial correlation according to Newey and West (1987), and the t-statistics are reported in parentheses below the coefficients.

Table 6 tests the three predictions above, by comparing the relation between the sentiment proxies and index risk-neutral skewness across subsamples. In order to increase the statistical power of the subsample tests, all the regressions reported in Table 6 employ weekly time-series observations (as opposed to monthly data as used in the rest of the paper). The weekly regressions here also check the robustness of the results with respect to the sample frequency. The index risk-neutral skewness is calculated on the last trading day of each week from contemporaneous index option prices.[19] All independent variables are measured on or immediately prior to the last trading day of each week. Since the index mispricing variable is available only at a monthly frequency, it is omitted from the weekly regressions in Table 6.

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[19] In unreported regressions, using weekly data sampled on Wednesdays instead of Fridays does not change any of the results in Table 6. Furthermore, using weekly data, the relation between index risk-neutral skewness and sentiment proxies is robust to measurement errors in the skewness, similar to the results reported in Table 4.

Model 1 in Table 6 shows that the significant relation between index risk-neutral skewness and sentiment proxies holds in weekly regressions. Models 2 and 3 show that this relationship is most prominent in the first part of the sample when there are more limits to arbitrage in the index options market. In contrast, the parameter estimate and t-statistic for the coefficient of index return volatility are stronger in the second part of the sample. Recall from Section 2.5 that index return volatility is the key determinant for the index risk-neutral skewness under rational models with stochastic volatility. Thus, the results above are consistent with investor sentiment (rational factors) being more important when arbitrage in index options is relatively less (more) effective.

Models 4 and 5 in Table 6 test the second and the third predictions above. Model 4 includes as additional regressors the interaction of sentiment proxies (and other control variables) with a dummy variable that takes a value of 1 on dates when a proxy for the uncertainty about market volatility is higher than its sample median. This proxy is taken to be the parameter in the Heston (1993) model that measures the volatility of the instantaneous variance of the index return.[20] Model 5 adds the interaction of sentiment proxies (and other control variables) with a dummy that takes a value of 1 on dates when past one-year index return is lower than the sample median.

When the amount of uncertainty about market volatility is higher than usual, the relation between the investor sentiment proxies and index risk-neutral skewness is stronger. On the other hand, this relation is no longer statistically significant in a low volatility uncertainty environment. During such periods, the index volatility, a rational factor, becomes a more important determinant of index risk-neutral skewness. The relation between the sentiment proxies and index risk-neutral skewness is also statistically more significant and economically stronger following a poor market return. These results provide further evidence that the relation between the sentiment proxies and index risk-neutral skewness depends significantly on limits to arbitrage in the index options market. They are difficult to understand under rational models, but support the idea that the relation between the sentiment proxies and index risk-neutral skewness manifests the influence of investor sentiment on index option prices. The impact of sentiment is stronger when there are more limits to arbitrage in the index options.

2.7 Sentiment and index options volatility smile

Index risk-neutral skewness is closely related to the index option volatility smile (Bakshi, Kapadia, and Madan, 2003). The slope of the index option volatility smile changes dramatically from month to month (Bollen and Whaley, 2004). This section tests whether change in investor sentiment is related to fluctuation in the slope of the index option smile. A more pessimistic belief about the stock

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[20] The Heston model is recalibrated for each date using the cross-sectional index option prices. Similar results are obtained when uncertainty about market volatility is calculated each week from the daily high and low of the VIX index using the extreme value method of Parkinson (1980).

market would increase investors' demand for hedging securities that pay off when the stock index level is low. If sentiment affects option prices, then a decrease in investor sentiment would increase the prices of out-of-money put options proportionally more than the prices of at-the-money options. Thus, a more bearish sentiment is expected to be associated with a steeper index option smile.

Following Bollen and Whaley (2004), the smile slope is measured as the ratio of average implied volatility for the out-of-the-money puts (those with $-\frac{3}{8} < \Delta_P \leq -\frac{1}{8}$) to the average implied volatility for the near and at-the-money options (including call options with $\frac{1}{2} < \Delta_C \leq \frac{5}{8}$ as well as put options with $-\frac{1}{2} < \Delta_P \leq -\frac{3}{8}$). This is multiplied by -1 so that the slope of the index options smile takes negative values just like index risk-neutral skewness.[21]

Table 7 reports the results for regressing the slope of the index option volatility smile on the sentiment proxies and control variables. The control variables are factors such as stock market momentum (Amin, Coval, and Seyhun, 2004), demand pressure for index options (Garleanu, Pedersen, and Poteshman, 2005), and the dispersion of beliefs among investors (Buraschi and Jiltsov, 2006) that have been found to be related to the steepness of the index option volatility smile.

Table 7 shows that in both monthly and weekly regressions, the sentiment proxies are significantly and positively related to the slope of the index option volatility smile. More bullish investor sentiment is associated with a flatter index option smile, and more bearish sentiment is associated with a steeper smile. This relation is robust to controlling for index return volatility, the demand-pressure effect, the stock market momentum effect, and the dispersion of investors' beliefs. These results are consistent with the significant relation between risk-neutral skewness and investor sentiment. They further confirm that investor sentiment affects option prices.

3. Discussion and Conclusions

This paper provides evidence that investor sentiment helps explain both the shape of the S&P 500 option volatility smile, and the risk-neutral skewness of the index return extracted from the index option prices (based on Bakshi and Madan, 2000; Bakshi, Kapadia, and Madan, 2003). The risk-neutral skewness of the monthly index return becomes significantly more negative, and the

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[21] In unreported regressions, another measure is used for the smile slope and produces similar results to those reported in Table 7. Following Bakshi, Kapadia, and Madan (2003) the following regression is fitted to each date's cross section of index option implied volatilities:

$$\ln(\sigma_{\tau,K}) = \alpha + \beta_1 \ln(K/S) + \beta_2 \tau + \beta_3 \tau \ln(K/S) + \epsilon_{\tau,K},$$

where τ and K are the time to maturity (in years) and the strike price of the option, and S is the spot level of the underlying index. Using the parameters estimated from date t's cross section of index options, the second measure of the smile slope at date t is $\hat{\beta}_1 + \hat{\beta}_3/12$, which is the elasticity of option-implied volatility to the moneyness for value of options with a time to maturity of one month. Using alternative specifications for the structure of option implied volatilities (such as the quadratic function in moneyness used by Dumas, Fleming, and Whaley, 1998) does not materially change the results.

Table 7
Investor sentiment and slope of index options volatility smile

	Monthly regressions				Weekly regressions	
Model	(1)	(2)	(3)	(4)	(5)	(6)
$\text{BullBear}_{\text{Survey}}$	0.1195			0.0601	0.0994	0.0739
	(2.5183)			(1.1349)	(3.3784)	(2.5241)
$\text{LongShort}_{\text{Futures}}$		0.4419		0.4603	0.3123	0.2978
		(2.5824)		(2.7135)	(3.0789)	(2.9966)
$\text{Mispricing}_{\text{Index}}$			0.3901	0.3203		
			(3.0507)	(2.0997)		
IndexVolatility				0.2897		0.2245
				(1.9061)		(3.0601)
RelativeDemand				−0.0237		−0.0106
				(−1.8187)		(−2.0087)
IndexRet				0.0914		0.1563
				(0.8037)		(3.7995)
Dispersion				−0.0378		−0.0298
				(−1.2665)		(−2.6569)
Lagged dependent	0.2223	0.2218	0.2202	0.1465	0.2785	0.2360
	(2.1707)	(1.9512)	(2.3522)	(1.7948)	(4.4909)	(3.7459)
Adjusted R^2	0.1159	0.1245	0.1152	0.2451	0.1957	0.2400

This table reports the results for regression models that study the relation between the slope of the index options volatility smile and investor sentiment. The dependent variable in all regressions is the slope of the index option volatility smile, measured as (−1) times the ratio of average implied volatility for out-of-the-money puts (those with $-\frac{3}{8} < \Delta_P \leq -\frac{1}{8}$) to the average implied volatility for near and at-the-money options (including call options with $\frac{1}{2} < \Delta_C \leq \frac{5}{8}$ as well as put options with $-\frac{1}{2} < \Delta_P \leq -\frac{3}{8}$). $\text{BullBear}_{\text{Survey}}$ is the proportion of bullish investors minus the proportion of bearish investors based on the surveys done by *Investors Intelligence*. $\text{LongShort}_{\text{Futures}}$ is the net position of large speculators in S&P 500 index futures. $\text{Mispricing}_{\text{Index}}$ is index pricing errors obtained by Sharpe (2002). Other independent variables are index volatility, past-six-month index return, and relative demand for out-of-the-money index put options to near and at-the-money index options, and a proxy of investors' disagreement. Models 1–4 use 114 monthly observations of each variable from January 1988 to June 1997. Models 5 and 6 use 497 weekly observations of each variable during the same period. $\text{Mispricing}_{\text{Index}}$ is omitted from the weekly regressions since it is only available monthly. Standard errors are adjusted for heteroskedasticity and serial correlation according to Newey and West (1987), and the t-statistics are reported in parentheses below the coefficients.

index option volatility smile is steeper, when (1) investor survey indicates that more market professionals are bearish, (2) large speculators take bigger short positions in S&P 500 futures, and (3) the S&P 500 index level is more depressed relative to the fundamental. Conversely, when investor sentiment is more bullish, the index risk-neutral skewness becomes less negative and the index option volatility smile is flatter. The impact of investor sentiment becomes stronger when there are larger impediments to arbitrage in the index options.

These results cannot be explained by several popular rational option pricing models. The rational representative-agent perfect-market framework needs to be extended to incorporate imperfect market and/or imperfect rationality. Important progress has already been made along this line. For example, Garleanu, Pedersen, and Poteshman (2005) develop a model of competitive risk-averse intermediaries who cannot perfectly hedge their option positions and show that end-user demand for options will impact option prices. One channel for investor sentiment to affect option prices is through this demand-pressure effect. The ideal measure for such demand-pressure effect is the net non-market-maker demand for options, as used in Garleanu, Pedersen, and Poteshman (2005).[22] The demand-pressure effect is controlled here by using a noisy proxy, the total option open interests. Even with this noisy proxy, there is strong evidence that the relative demand pressure of options helps explain time-series variation in index risk-neutral skewness, consistent with the empirical findings of Garleanu, Pedersen, and Poteshman. The relation between index risk-neutral skewness and sentiment proxies becomes weaker but is still statistically significant after controlling for the option demand-pressure effect.

Investor sentiment may also affect option prices beyond the demand-pressure effect. In a model where some investors' subjective probabilities deviate from the true objective probability, if the rational investors are risk averse and the market is imperfect or incomplete,[23] the equilibrium asset prices (both options and the underlying) would reflect a weighted average of the beliefs of rational as well as irrational investors. For example, Shefrin (2005) constructs a model where the asset pricing kernel can be decomposed into a fundamental component and a sentiment component capturing the aggregate error in investor beliefs. The slope of the pricing kernel, which captures how much more investors are willing to pay for securities that pay off when stock market falls, becomes steeper when investor sentiment is more bearish. This would lead to a more negative index risk-neutral skewness. Thus, the empirical evidence in this paper is consistent with a model where the slope of the asset pricing kernel depends on investor sentiment. Since the pricing kernel provides a unifying framework for all asset pricing theories (e.g., Cochrane, 2001), such a model also implies that sentiment is an important conditioning variable for determining stock returns. This idea is supported by Baker and Wurgler (2006). Vanden (2004, 2006) also concludes that factors driving the pricing of index options are also important for pricing equities. Therefore, the finding that sentiment affects index option prices has broader implications.

This paper focuses on the impact of investors' sentiment about the broad stock market on index option prices. It would be interesting to study whether prices of individual stock options are affected by market-wide sentiment or sentiment about the underlying stock. This seems promising, as Garleanu, Pedersen, and Poteshman (2005) find similar demand-pressure effects for index options and equity options. More generally, future research should better understand how investor sentiment affects the valuation of both options and the underlying security.

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[22] Their sample period from 1996 to 2001 is almost nonoverlapping with this paper.

[23] Bollen and Whaley (2004) as well as Garleanu, Pedersen, and Poteshman (2005) show that trading strategies that take advantage of the index options smile are quite risky.

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