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LIMITS OF ARBITRAGE, RISK-NEUTRAL SKEWNESS, AND INVESTOR SENTIMENT

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ABSTRACT

This paper uses individual stock options to examine the effect of limits of arbitrage on the relations between risk-neutral skewness and investor sentiment for the underlying stocks. Empirical results show that the risk-neutral skewness tends to be more (less) negative under bearish (bullish) investor sentiment, and the significant relations become stronger especially when there are more impediments to arbitrage in stock options. In addition, the empirical results show that increased bearishness among market investors who dominate the use of index options increases the extent to which risk-neutral skewness is affected by fluctuations in investor sentiment for the underlying stocks. Empirical results show that the limits of arbitrage have important implications for the role of investor sentiment in explaining risk-neutral skewness.

JEL: G12, G14

KEYWORDS: Risk-Neutral Skewness; Investor Sentiment; Limits of Arbitrage

INTRODUCTION

Options are priced on the basis of the market's view of the distribution of future stock returns. Empirical studies show that the implied risk-neutral distribution extracted from observed option prices tends to be more negatively skewed than the assumptions of the Black–Scholes Model (e.g., Bakshi *et al.*, 1997). Realizing that the skewness of the stock return distribution is important in pricing securities, previous studies have demonstrated that several factors can help explain risk-neutral skewness, including firm-specific variables, such as the level of stock liquidity and firm implied volatility, along with market-wide variables, such as the skewness of the S&P500 and the volatility of market indexes. However, a sufficient explanation for the source of skewness is still lacking to support the development and improvement of option pricing models (e.g., Dennis and Mayhew, 2002; Friesen *et al.*, 2012).

The development of financial markets attracts a broader range of investors to participate in stock markets, resulting in many financial anomalies that do not conform to classical financial theories. A growing body of evidence suggests that investors are not fully rational, and investor sentiment has significant effects on stock returns (e.g., Baker and Wurgler, 2006). This raises an issue of whether investor sentiment may be a potential factor influencing option-implied risk-neutral skewness. Many papers have examined the role of investor sentiment in affecting index option prices. For example, Han (2008) and Coakley *et al.* (2014) provide evidence to show a significant relation between investor sentiment for broad stock market and risk-neutral skewness for index options. They indicate that small investor sentiment is not important in explaining risk-neutral skewness for index options, as they are not main participants in the index options market. However, for individual stock options, empirical studies testing the role of investor sentiment in explaining risk-neutral skewness have produced mixed results. This inconsistency within the extant literature has motivated us to focus on individual stock options to test whether a wave of investor sentiment for the underlying stocks has a significant effect on option-implied risk-neutral skewness. Moreover, this paper examines the impact of impediments to arbitrage on the role of investor sentiment about individual stocks in explaining risk-neutral skewness. And we also examine whether market-wide investor sentiment affects the relations between firm-specific investor sentiment and risk-neutral skewness.

This paper differs from previous studies in two important respects. First, we examine the effect of arbitrage limitations on the role of investor sentiment for individual stocks in explaining the firm-level option-implied risk-neutral skewness. Specifically, we examine whether firms that have higher restrictions on short sales and/or a higher default likelihood and/or a smaller firm size may produce a stronger relationship between investor sentiment and risk-neutral skewness. Firm-level stock options data enables us to examine the impact of individual investors on option prices.

Mispricing of a stock creates an arbitrage opportunity that attracts rational investors to trade accordingly and earn their profit from the subsequent convergence of the market price to fundamentals. However, certain types of arbitrage limits make the arbitrage process risky and costly in reality. Examples of arbitrage limits include trading constraints, information uncertainty and transaction costs. Trading constraints, including short sales restrictions, limit arbitrage in options and prevent arbitrageurs from exploiting market mispricing opportunities. Pessimistic investors who perceive stocks as being overvalued but are unable to sell short because of restrictions will resort to trading in the options market. These investors tend to buy out-of-the-money (OTM) put options, and the sentiment-based demand for OTM puts drives up the prices of low-strike price options (e.g., Buraschi and Jiltsov, 2006). Thus, the pricing impact of investor sentiment increases with impediments to arbitrage; that is, firms that have higher restrictions on short sales are expected to be associated with a stronger relationship between investor sentiment and risk-neutral skewness.

Several empirical studies have shown that arbitrage for small, young, or distressed stocks tends to be particularly risky and costly. Investors trading in such firms rely on scant information and imprecise earnings reports to determine correct stock values, leading to errors in evaluating the fair price for the option and hedge ratio. In addition, investors trade with less liquidity and a higher transaction cost when firms have a higher likelihood of default (e.g., Vassalou and Xing, 2004). Thus, arbitrage in options tends to be particularly risky and costly for firms with a higher likelihood of default. We argue that the pricing impact of investor sentiment is higher under significant impediments to arbitrage. We therefore expect a stronger relationship between investor sentiment for underlying stocks and option-implied risk-neutral skewness when firms are more likely to default.

Second, this paper examines whether the risk-neutral return distribution is more negatively skewed when investor sentiment turns more bearish, particularly in the case of increased bearishness among market investors who dominate the use of index options. Empirical evidence show a significant relation between investor sentiment for broad stock market and risk-neutral skewness for index options (e.g., Han, 2008). Risk-neutral skewness for index options is an important determinant of risk-neutral skewness for individual stocks (e.g., Dennis and Mayhew, 2002). Thus, we would expect market-wide sentiment common to all firms might affect firm-specific investor sentiment as well as the relations between firm-specific investor sentiment and firm-specific risk-neutral skewness.

Empirically, we use the stock and option prices for S&P500 component stocks from January 1, 2003 to December 31, 2012. We compute weekly risk-neutral skewness using the methodology proposed by Bakshi *et al.* (2003) and follow the empirical implications presented by Dennis and Mayhew (2002). The measure of skewness proposed by Bakshi *et al.* (2003) is easy to compute and has the advantage of not relying on any particular option pricing model. We utilize two commonly used proxies for investor sentiment based on trading activity in the options market. The first proxy for investor sentiment is defined as the average open interest of puts divided by the average open interest of all options for each week. A higher open interest ratio of puts to all options suggests that investors are generally more pessimistic. The second proxy for investor sentiment is defined as the average trading volume of puts divided by the average trading volume of all options for each week. Open interest and trading volume capture different types of information; open interest represents the total number of outstanding option contracts that have not been settled, whereas trading volume refers to the total number of trading transactions. Intuitively, investors seek to optimize their portfolios based on their outlook for specific stocks, and they have different demands for puts or calls option because of their various expectations of firm fundamentals. Therefore, we expect that investor sentiment for the underlying stocks affects option-implied risk-neutral skewness. In addition, the sentiment proxy regarding broad stock market is derived from trading activity in S&P500 index options. The measures of market-wide investor sentiment using S&P500 index options are consistent with the measures of firm-specific investor sentiment.

We begin our analysis of risk-neutral skewness by examining the relationship between investor sentiment and risk-neutral skewness. To clarify the robustness of the relation between risk-neutral skewness and investor sentiment, several control variables are included in the model such as logged stock trading volume, option implied volatility and book-to-market ratio. Stock trading volume is used as a proxy for the liquidity of individual stocks, while the option implied volatility is used to measure the volatility of a firm's stock return. The empirical results show that the option-implied risk-neutral distribution is more negatively skewed when investor sentiment for the underlying stocks turns bearish. Furthermore, we construct various portfolios with different levels in terms of short sales restrictions, a firm's default risk, and a firm's market capitalization at the end of each week. The empirical results show that when there are more impediments to arbitrage in stock options, a stronger relationship exists between investor sentiment for the underlying stocks and risk-neutral skewness. In addition, institutional investors tend to buy index put options as portfolio insurance against stock market declines due to hedging demands (e.g., Bollen and Whaley, 2004). The empirical results show that increased bearishness among market investors who dominate the use of index options increases the extent to which risk-neutral skewness is affected by fluctuations in investor sentiment for the underlying stocks.

The remainder of this paper is organized as follows. We first review the related literature, and then describe our data and how our model measures risk-neutral skewness, followed by a description of the proxies for important explanatory variables. Finally, we present the empirical results and conclusions.

LITERATURE REVIEW

The role of investor sentiment in affecting index option prices has been examined in numerous papers. For example, Han (2008) uses S&P500 options to show that investor sentiment about the broad stock market is an important determinant of index risk-neutral skewness. Coakley *et al.* (2014) provide evidence to show the significant relationship between investor sentiment and risk-neutral skewness for seven stock index options comprising either growth or value stocks. However, for individual stock options, empirical studies testing the role of investor sentiment in explaining risk-neutral skewness have produced mixed results. For example, Dennis and Mayhew (2002) do not find evidence to support that investor sentiment about the underlying stocks can explain the movement of risk-neutral skewness. The subsequent work of Taylor *et al.* (2009) finds a negative relationship between investor sentiment for the underlying stocks and risk-neutral skewness. This inconsistency within the extant literature has motivated us to focus on individual stock options to test whether a wave of investor sentiment for the underlying stocks has a significant effect on option-implied risk-neutral skewness.

Bollen and Whaley (2004) state that most trading in S&P500 index options involves puts, whereas most trading in stock options involves calls. Because of hedging demands, institutional investors buy index put options as portfolio insurance against stock market declines. Lakonishok *et al.* (2007) show that hedging trading strategies account for a small fraction of stock option activity. Unsophisticated investors actively trade options on individual stocks to speculate on stock price movements. Empirical work has provided evidence to show that different types of options serve different purposes and are likely to attract different types of traders. Han (2008) examined whether investor sentiment concerning the level of stock market index affects S&P500 option prices. By contrast, firm-level stock options data enables this paper to examine the impact of individual investors on option prices.

Arbitrage is defined as the simultaneous purchase and sale of the same, or essentially similar, securities in two different markets to take advantage of a price gap, thus bringing prices into convergence with fundamental values. Examples of arbitrage limits include trading constraints, information uncertainty and transaction cost (e.g., Gu *et al.*, 2018). Trading constraints, including short sales restrictions, make arbitrage in options more limited (e.g., Ofek *et al.*, 2004), preventing arbitrageurs from exploiting market mispricing opportunities. We take institutional ownership of the stock as the proxy for the market supply of short sales because firms with more institutional holdings are less costly to borrow and sell short. Short sales restrictions are likely to have a greater impact as the value of one minus the fraction of institutional ownership increases (e.g., Hu, 2014). In addition, several empirical studies have shown that arbitrage for small, young, or distressed stocks tends to be particularly risky and costly (e.g., Baker and Wurgler, 2006). Investors trading such firms rely on scant information and imprecise earnings reports to determine the correct stock values. Previous studies of the effect of default risk on equity focused on different default measures as a proxy for default risk. For example, Garlappi, Shu, and Yan (2008) use the expected default frequency of Moody's KMV to show that higher default probability is not related to higher stock returns. Vassalou and Xing (2004) developed a default likelihood indicator to calculate default measures for individual firms. However, their measures require a complicated equation that must be solved by implementing an iterative procedure. This paper uses Bharath and Shumway's (2008) naïve distance to default model to calculate the default likelihood for our target firms.

DATA AND METHODOLOGY

We select component stocks from the S&P500 index for our empirical data. The daily records of options and stocks are from the beginning of January 2003 through the end of December 2012. Market prices for the options written on the stocks of the S&P500 component stocks, and the market information of the corresponding stocks is obtained from Ivy DB OptionMetrics. We define the option prices as the averages of the last bid and ask prices for each option. The filters used to construct our empirical option data were set to the following exclusion criteria: (i) options with price quotes lower than $0.5, the bid or offer price is missing, or the bid price is zero; (ii) options with prices that violate general no-arbitrage constraints; (iii) option contracts that have zero open interests; (iv) options with maturities of less than 7 days or greater than 365 days; and (v) underlying stocks have zero trading volume.

Calculation of Risk-Neutral Skewness

This paper calculates the weekly estimates of risk-neutral skewness for each underlying stock by using the results of Bakshi and Madan (2000) and Bakshi *et al*. (2003). Following Dennis and Mayhew (2002), we calculate the risk-neutral skewness each day for the two different maturities that are greater than one week but closest to 22 trading days. The data have at least two calls and two puts for each maturity. The moneyness is defined as the ratio of the strike price to the stock price. A put option is defined as OTM when the moneyness is between 0.8 and 0.95, while a call option is defined as OTM when the moneyness is between 1.05 and 1.2. In estimating risk-neutral skewness, we use equal numbers of OTM calls and puts for each stock on each day. If there are n OTM puts on day t and $N > n$ OTM calls, we use the n OTM calls that have the most similar distance from stock to strike as the OTM puts for which we have data. In addition, following Conrad *et al.* (2013), we exclude stocks with highly illiquid options by discarding those with fewer than 10 quotes per month.

Bakshi *et al.* (2003) show that the moments of risk-neutral density can be expressed as the time t price of a quadratic, cubic, and quartic payoff received at time $t+\tau$. Let Q denote the probability distribution function under the risk-neutral measure. The τ period's continuously compounded return on the underlying asset $S_{i,t}$ is $R(t,\tau) \equiv ln\,[(S(t+\tau))/(S(t))]$. The time t price of a quadratic, cubic, and quartic payoff received at time $t+\tau$ can be respectively expressed $V(t+\tau) \equiv E^Q[e^{-r\tau}R(t+\tau)^2]$,

$W(t+\tau) \equiv E^{Q}[e^{-r\tau}R(t+\tau)^{3}]$, and $X(t+\tau) \equiv E^{Q}[e^{-r\tau}R(t+\tau)^{4}]$. Bakshi and Madan (2000) demonstrate that any payoff function for the stock price with bounded expectations can be constructed using a set of OTM calls and puts with different strike prices. The risk-neutral moments can be calculated as:

$$Skew_{i,t}^{Q}(\tau) = \frac{e^{r\tau}W_{i,t}(\tau) - 3\mu_{i,t}(\tau)e^{r\tau}V_{i,t}(\tau) + 2\mu_{i,t}(\tau)^{3}}{\left(e^{r\tau}V_{i,t}(\tau) - \mu_{i,t}(\tau)^{2}\right)^{3/2}} \quad (1)$$

Where,

$$V_{i,t}(\tau) = \int_{S_{i,t}}^{\infty} \frac{2\left(1 - ln\left(\frac{K_i}{S_{i,t}}\right)\right)}{K_i^2} C_{i,t}(\tau; K_i)dK_i + \int_{0}^{S_{i,t}} \frac{2\left(1 + ln\left(\frac{S_{i,t}}{K_i}\right)\right)}{K_i^2} P_{i,t}(\tau; K_i)dK_i \quad (2)$$

$$W_{i,t}(\tau) = \int_{S_{i,t}}^{\infty} \frac{6\,ln\left(\frac{K_i}{S_{i,t}}\right) - 3\left(ln\left(\frac{K_i}{S_{i,t}}\right)\right)^2}{K_i^2} C_{i,t}(\tau; K_i)dK_i - \int_{0}^{S_{i,t}} \frac{6\,ln\left(\frac{S_{i,t}}{K_i}\right) + 3\left(ln\left(\frac{S_{i,t}}{K_i}\right)\right)^2}{K_i^2} P_{i,t}(\tau; K_i)dK_i \quad (3)$$

$$X_{i,t}(\tau) = \int_{S_{i,t}}^{\infty} \frac{12\left(ln\left(\frac{K_i}{S_{i,t}}\right)\right)^2 - 4\left(ln\,(\frac{K_i}{S_{i,t}})^3\right)}{K_i^2} C_{i,t}(\tau; K_i)dK_i + \int_{0}^{S_{i,t}} \frac{12\left(ln\left(\frac{S_{i,t}}{K_i}\right)\right)^2 + 4\left(ln\,(\frac{S_{i,t}}{K_i})^3\right)}{K_i^2} P_{i,t}(\tau; K_i)dK_i \quad (4)$$

$$\mu_{i,t}(\tau) = e^{r\tau} - 1 - \frac{e^{r\tau}}{2}V_{i,t}(\tau) - \frac{e^{r\tau}}{6}W_{i,t}(\tau) - \frac{e^{r\tau}}{24}X_{i,t}(\tau). \quad (5)$$

To empirically estimate risk-neutral skewness, we need to approximate the integrals in Eqs. (2), (3), and (4), which are based on the weighted integrals of the OTM call and puts prices. The integrals are taken over all OTM strike prices, but a continuum of strike prices is not available. Thus, we use the trapezoidal approximation proposed by Dennis and Mayhew (2002) and Conrad *et al.* (2013) to construct the skewness measure with discrete option data. A hypothetical option with 22 trading days to maturity is constructed using linear interpolation or extrapolation. Table 1 reports the descriptive statistics for the sample estimates of risk-neutral skewness for the underlying stock. The results show that some individual stocks are negatively skewed. As Bakshi *et al.* (2003) indicate, a skewed risk-neutral distribution implies that the physical distribution is also skewed.

Table 1: Summary Statistics of Risk-Neutral Skewness for the Underlying Stocks

Variable	Mean	SD	Percentile		
			P5	P50	P95
Skewness	-0.910	0.613	−2.470	−0.883	0.729

Table 1 presents the summary statistics of firm-specific risk-neutral skewness. The sample period is from January 1, 2003 to December 31, 2012.

Measures of a Firm's Likelihood of Default

This paper applies Bharath and Shumway (2008) naïve distance to the default model to calculate the default likelihood for our target firms. The naïve distance to default is defined as follows:

$$naiveDD = \frac{ln\left(\frac{M+F}{F}\right) + (r_{i,t-1} - 0.5naive\sigma_v^2)T}{naive\sigma_v\sqrt{T}} \quad (6)$$

where $naive\sigma_v = \frac{M}{M+F}\sigma_s + \frac{F}{M+F}(0.05 + 0.25\sigma_s)$. M is each firm's market capitalization, calculated as the product of the stock price at the end of the month and the number of shares outstanding. F denotes the face value of the firm's debt, computed as the debt in current liabilities plus one-half of the long-term debt. σ_s is the volatility of stock returns which is estimated from the previous year's stock return, and $r_{i,t-1}$ is the stock return of firm i over the previous year. The naive probability estimate is defined as $\pi_{naive} = N(-naiveDD)$, where $N(.)$ is the cumulative standard normal distribution function.

EMPIRICAL RESULTS

Relationship between Risk-Neutral Skewness and Investor Sentiment

We first examine the relationship between risk-neutral skewness and investor sentiment for each investor sentiment proxy about the underlying stocks. The results of Bakshi and Madan (2000) and Bakshi *et al.* (2003) was applied to obtain weekly estimates of risk-neutral skewness for each underlying stock. We use the Fama–MacBeth (1973) type of approach to regress risk-neutral skewness for firm i on investor sentiment for each week in our sample period. These regressions investigate the cross-sectional relations between the dependent and the independent variables for each week and the significance of the time-series estimated coefficients is tested based on Newey-West (1987). The control variables include logged stock trading volume, option implied volatility and book-to-market ratio. The stock trading volume is calculated as the average of daily trading volume in the underlying stock for each week, which proxies the liquidity of the individual stocks. The weekly option implied volatility is calculated by averaging the daily mean option implied volatility over a week, and is used to measure the volatility of a firm's stock return.

Panel A of Table 2 documents the results of regressions on the investor sentiment proxy measured as the open interest of puts options divided by the open interest of all options. As expected, the estimated coefficient of investor sentiment is negative and significant, indicating that the risk-neutral distribution is more negatively skewed when investor sentiment turns bearish. Panel B of Table 2 examines the relationship between risk-neutral skewness and the investor sentiment proxy measured by the trading volume ratio of OTM puts to all options. Similarly, the coefficient of investor sentiment is negative and significant.

Table 2: Relationship between Risk-Neutral Skewness and Investor Sentiment

	Investor Sentiment	**Control**	**Adj R^2**
Panel A: Open Interest of Puts Divided by the Open Interest of all Options			
Coeff.	−0.151	Yes	0.14
t-stat	−4.572 ***		
Panel B: Trading Volume of Puts Divided by the Trading Volume of all Options			
Coeff.	−0.161	Yes	0.14
t-stat	−7.423***		

*Table 2 presents the empirical results of Fama-MacBeth (1973) regression to examine the relationship between risk-neutral skewness and investor sentiment about the underlying stocks. The sample period is from January 1, 2003 to December 31, 2012. ***, ** and * respectively indicate significance at 1%, 5% and 10% levels.*

Short Sales Restrictions, Firm Default Likelihood and Firm Size

Table 3 examines whether firms that have higher restrictions on short sales exhibit an increased correlation between option-implied skewness and investor sentiment for the underlying stocks. We define the proxy for short sales restrictions as one minus the fraction of institutional ownership for stock i at time t. Short sales restrictions are more likely to have an increased impact as one minus the fraction of institutional ownership increases. For each investor sentiment measure, we first construct two different portfolios, sorting all stocks into two portfolios based on the level of short sales restrictions at the end of each week. Portfolio 1 has the highest level of short sales restrictions, ranking in the top 30%, whereas Portfolio 2 constitutes the remaining stocks. For each portfolio, we run the Fama–MacBeth (1973) regression to regress the risk-neutral skewness on each investor sentiment proxy and the control variables for each week and the significance of the time-series estimated coefficients is tested based using Newey-West (1987).

As expected, the risk-neutral distribution is more negatively skewed when investor sentiment turns bearish, that is, the coefficient of investor sentiment is negative and significant. In addition, when firms have a higher level of short sales restrictions, the absolute estimated coefficient of investor sentiment tends to be greater. The empirical results show that stocks that have higher restrictions on short sales are expected to produce a stronger relationship between investor sentiment for the underlying stocks and risk-neutral skewness, regardless of the investor sentiment proxy used.

Table 3: Investor Sentiment and Short-Sales Restrictions

	Investor Sentiment	**Control**	**Adj R^2**
Panel A: Open Interest of Puts Divided by the Open Interest of all Options			
Portfolio 1			
Coeff.	−0.111	Yes	0.22
t-stat	−1.513		
Portfolio 2			
Coeff.	−0.111	Yes	0.15
t-stat	−3.023 ***		
Panel B: Trading Volume of Puts Divided by the Trading Volume of all Options			
Portfolio 1			
Coeff.	−0.186	Yes	0.22
t-stat	−3.845***		
Portfolio 2			
Coeff.	−0.162	Yes	0.15
t-stat	−6.412***		

*Table 3 presents the results of Fama-MacBeth (1973) regression for each portfolio. Portfolio 1 has the highest level of short sales restrictions, ranking in the top 30%, whereas Portfolio 2 constitutes the remaining stocks. The sample period is from January 1, 2003 to December 31, 2012. ** and * respectively ndicate significance at 5% and 10% levels.*

Table 4 presents the results of the relationship between risk-neutral skewness and investor sentiment in the context of likelihood of firm default. We construct two different levels of default risk portfolios. First, we sort all stocks into two portfolios based on the level of the firm's default likelihood at the end of each week. Portfolio 1 comprises stocks with the highest level of default risk, ranked in the top 30%, whereas Portfolio 2 comprises the remaining stocks. For each portfolio, we run the Fama–MacBeth (1973) regression and the *t*-statistics are estimated based on the Newey-West (1987) estimation for each portfolio. As expected, when firms have a higher default likelihood, the absolute estimated coefficient of investor sentiment tends to be greater for both investor sentiment measures. The empirical results show that for firms with a higher default risk, skewness is affected to a greater extent by fluctuations in investor sentiment about the underlying stocks, regardless for the investor sentiment proxy used.

Table 4: Investor Sentiment and a Firm's Default Likelihood

	Investor Sentiment	Control	Adj R^2
Panel A: Open Interest of Puts Divided by the Open Interest of all Options			
Portfolio 1			
Coeff.	−0.216	Yes	0.20
t-stat	−3.579***		
Portfolio 2			
Coeff.	−0.103	Yes	0.14
t-stat	−2.417**		
Panel B: Trading Volume of Puts Divided by the Trading Volume of all Options			
Portfolio 1			
Coeff.	−0.199	Yes	0.20
t-stat	−4.835***		
Portfolio 2			
Coeff.	−0.129	Yes	0.14
t-stat	−4.642***		

*Table 4 presents the results of Fama-MacBeth (1973) regression for each portfolio. Portfolio 1 comprises stocks with the highest level of default risk, ranked in the top 30%, whereas Portfolio 2 comprises the remaining stocks. The sample period is from January 1, 2003 to December 31, 2012. ***,** and * respectively indicate significance at1%, 5% and 10% levels.*

Table 5 shows the effect of firm size on the relation between option-implied skewness and investor sentiment for the underlying stocks. We first sort all stocks into two portfolios based on the level of the logged firm market capitalization at the end of each week. Portfolio 1 comprises stocks with the smallest level of logged firm market capitalization, ranked in the top 30%, whereas Portfolio 2 comprises the remaining stocks. For each portfolio, we run the Fama–MacBeth (1973) regression and the *t*-statistics are estimated based on the Newey-West (1987) estimation for each portfolio. As expected, the empirical results show that stocks for smaller firms are expected to produce a stronger relationship between risk-neutral skewness and investor sentiment for the underlying stocks, regardless of the investor sentiment proxy used.

Table 5: Investor Sentiment and a Firm's Size

	Investor Sentiment	Control	Adj R^2
Panel A: Open Interest of Puts Divided by the Open Interest of all Options			
Portfolio 1			
Coeff.	-0.208	Yes	0.22
t-stat	-3.837***		
Portfolio 2			
Coeff.	-0.171	Yes	0.15
t-stat	-3.910***		
Panel B: Trading Volume of Puts Divided by the Trading Volume of all Options			
Portfolio 1			
Coeff.	-0.175	Yes	0.22
t-stat	-4.506***		
Portfolio 2			
Coeff.	-0.156	Yes	0.15
t-stat	-5.398***		

*Table 5 presents the results of Fama-MacBeth (1973) regression for each portfolio. Portfolio 1 comprises stocks with the smallest level of logged firm market capitalization, ranked in the top 30%, whereas Portfolio 2 comprises the remaining stocks. The sample period is from January 1, 2003 to December 31, 2012. ***,** and * respectively indicate significance at1%, 5% and 10% levels.*

Investor Sentiment Regarding Broad Stock Market

Empirical works provide evidence to show the significant relation between investor sentiment for broad stock market and risk-neutral skewness for index options (e.g., Han, 2008). In addition, risk-neutral skewness for index options is an important determinant of risk-neutral skewness for individual stocks (e.g., Dennis and Mayhew, 2002). Thus, we would expect market-wide sentiment common to all firms might affect firm-specific investor sentiment as well as the relations between firm-specific investor sentiment and firm-specific risk-neutral skewness. Following Dennis and Mayhew (2002), we estimated a pooled time-series cross-sectional regression to test whether the relations between firm-specific investor sentiment and firm-specific risk-neutral skewness are related to the market-wide sentiment. We added an interaction terms of the firm-specific investor sentiment with a dummy variable, set to 1 if the market-wide sentiment proxy is greater than 0.6 and otherwise 0. The sentiment proxy regarding the broad stock market is derived from trading activity in S&P500 index options. Consistent with the definition of firm-specific investor sentiment, one proxy of investor sentiment regarding the broad stock market is the average open interest ratio of puts on an index stock to all index options for each week, while the other is the average trading volume ratio of puts on an index stock to all index options for each week. A higher open interest ratio or higher trading volume ratio suggests that investors are generally more pessimistic.

Table 6: Effect of Sentiment Regarding Broad Stock Market on the Relationship between Risk-Neutral Skewness and Investor Sentiment

	Firm-Specific Sentiment	Firm-Specific Sentiment x Dummy m	Control	Adj R^2
Panel A: Open Interest of Puts Divided by the Open Interest of all Options				
Coeff.	−0.153	-0.172	Yes	0.05
t-stat	−3.233***	-1.965**		
Panel B: Trading Volume of Puts Divided by the Trading Volume of all Options				
Coeff.	−0.047	-0.189	Yes	0.06
t-stat	−1.732*	-3.961***		

*Table 6 presents pooled time-series cross-sectional regression results with the risk-neutral skewness as the dependent variable. Dummy_m is a dummy variable which takes the value of 1 if the market-wide sentiment proxy is greater than 0.6 and otherwise 0.The sample period is from January 1, 2003 to December 31, 2012. Newey-West corrected estimates and t-statistics are reported. ***, ** and * respectively indicate significance at 1%, 5% and 10% levels.*

Table 6 shows the results. The coefficient of the investor sentiment is negative and significant, indicating that the risk-neutral density is more negatively skewed when investor sentiment turns more bearish. It should be noted that the coefficient of the interaction terms of the firm-specific investor sentiment with market-wide sentiment is negative and significant. The empirical results show that increased bearishness among market investors who dominate the use of index options will increase the extent to which risk-neutral skewness is affected by fluctuations in investor sentiment for the underlying stocks, regardless of the investor sentiment proxy used.

CONCLUSION

This paper focuses on individual stock options to test whether a wave of investor sentiment about the underlying stocks has a significant effect on risk-neutral skewness. It attempts to determine whether more impediments to arbitrage in the options market have important implications for the role of investor sentiment for the underlying stocks in explaining option-implied risk-neutral skewness. Specifically, this paper examines whether firms that have higher restrictions on short sales and/or a higher default likelihood and/or a smaller firm size may produce a stronger relationship between investor sentiment and option-implied risk-neutral skewness. In addition, we also examine whether market-wide investor sentiment affects the relations between firm-specific investor sentiment and firm-specific risk-neutral skewness.

Empirically, we use the stock and option prices for S&P500 component stocks from January 1, 2003 to December 31, 2012. We compute weekly risk-neutral skewness using the methodology proposed by Bakshi *et al.* (2003) and follow the empirical implications presented by Dennis and Mayhew (2002). The empirical results support that risk-neutral skewness is more negative under bearish investor sentiment for each investor sentiment proxy. The empirical results show that when firms have a higher level of short sales restrictions, a higher default likelihood or smaller size, the absolute estimated coefficient of investor sentiment tends to be greater for both investor sentiment measures. In addition, the pricing impact of investor sentiment for the underlying stocks on risk-neutral skewness is higher given increased bearishness among market investors who dominate the use of index options. The empirical results highlight that when there are more impediments to arbitrage in the option market, there is a stronger relationship between investor sentiment and risk-neutral skewness, indicating that risk-neutral skewness is affected to a greater extent by fluctuations in investor sentiment about the underlying stocks.

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