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Skewness, short interest and the efficiency of stock prices

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ABSTRACT
We examine the association between return skewness, short interest and the efficiency of stock prices. Since preferences for skewness have been shown to impact asset prices, we examine how skewness relates to market efficiency. We find that stocks with positive skewness are less efficient, which might be explained by investor preferences for positive skewness. Next, we document that short interest reduces both total skewness and idiosyncratic skewness. Finally, while research has shown that short selling can improve the efficiency of markets generally, we show that short interest's ability to improve market efficiency is strongest in stocks with the highest skewness.

KEYWORDS
Skewness; short interest; market efficiency; idiosyncratic skewness

JEL CLASSIFICATION
G00; G10; G12

I. Introduction

A number of studies have shown that some investors have preferences for stocks that resemble lotteries. Using prospect theory, Barberis and Huang (2008) argue that some investors might overweight the tails in return distributions, which can lead to strong preferences for positive skewness and affect asset prices in a meaningful way. Empirical studies are supportive of the idea that some investors have preferences for stocks with return distributions that resemble lotteries. For example, Mitton and Vorkink (2007) show that some retail investors sacrifice mean-variance efficiency by intentionally under diversifying their portfolios in order to attain higher skewness. Additionally, more recent research provides support for the ideas in Barberis and Huang (2008) as stocks with positive skewness exhibit price premiums and subsequent underperformance (see Zhang 2005; Kumar 2009; Boyer, Mitton, and Vorkink 2010; Kumar, Page, and Spalt 2011; Green and Hwang 2012).

With this literature on skewness preferences as a backdrop, this study tests three hypotheses. First, we test whether stocks with the greatest skewness have the least efficient prices. This first hypothesis is motivated by the idea that investor preferences for lottery-like stocks can lead to contemporaneous overvaluation. The price premiums associated with lottery preferences may affect the price efficiency of stocks that resemble lotteries. To the extent that skewness is negatively related to the efficiency of stock prices, our second set of tests attempts to identify factors that might reduce the level of skewness in stocks. Specifically, we test whether short interest can reduce skewness in returns. The motivation for these tests relies on theory in Xu (2007), which nicely develops the relation between short interest and return skewness by presenting a model where short-sale constraints cause an important asymmetry in the price response to information signals. In particular, when differences in opinion exist, constraints induce equilibrium prices that react more to good news than to bad news resulting in price convexity across the information signal. Since skewness is a convex transformation, price convexity across signals will lead to greater skewness in the distribution of stock returns. We test whether short selling can reduce this skewness. Our final hypothesis naturally follows our first two sets of tests. In particular, we hypothesize that the reduction in skewness caused by short interest can improve the informational efficiency of stock prices. Our third hypothesis is based on a broad literature that discusses the implications of short-sale constraints on the efficiency of financial markets. Theory in Miller (1977) suggests that, in the presence of heterogeneous beliefs, short-sale constraints can lead to overvaluation. On the other hand, Diamond and Verrecchia (1987) show that in a rational

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expectations framework, short-sale constraints do not bias prices upward, but constraints markedly reduce the speed of the flow of information into prices. Empirical research examining the relation between short selling and price efficiency seems to support the idea that short selling can improve the efficiency of financial markets (Chang, Cheng, and Yu 2007; Bris, Goetzmann, and Zhu 2007; Saffi and Sigurdsson 2011; Battalio and Schultz 2011; Blau, 2012; Boehmer and Wu 2013). While research generally supports the idea that short interest can reduce frictions in the flow of information, our third hypothesis suggests that short interest can improve the efficiency of stock prices through the mechanism of reducing skewness. Said differently, we determine whether the positive relation between price delay and skewness is reduced when conditioning on the level of short interest.

In tests of our first hypothesis, we examine the price delay of stocks with high skewness, where price delay identifies the friction in information flow. As presented in Hou and Moskowitz (2005), price delay captures the difficulty a particular stock has incorporating market-wide information and therefore measures the inefficiency of stock prices. If positively skewed stocks indeed have less informational efficiency than other types of stocks, our first hypothesis predicts a positive relation between price delay and skewness. Consistent with this prediction, we find that positive skewness is associated with higher price delay. In economic terms, our multivariate tests show that for every one SD increase in total skewness, price delay increases by more than 4%. Similar results are found when we focus our tests on idiosyncratic skewness instead of total skewness. While theory is agnostic about whether normality in the return distribution is a necessary condition for efficient prices, investor preferences for skewness have been shown to affect asset prices (as in Barberis and Huang 2008), which, according to the results of our first tests, could lead to less efficiency.

With respect to our second set of tests, we find, similar to Harvey and Siddique (1999, 2000) and Chen, Hong and Stein (2001), that stocks exhibit positive skewness, on average. Consistent with our second hypothesis, we find that short interest is negatively related to total skewness. In economic terms, we find that a one SD increase in short interest is associated with a reduction in total skewness of nearly 12%. Again, we find similar results when we examine idiosyncratic skewness instead of total skewness. We recognize that a contemporaneous relation between short interest and skewness does not identify causality. Therefore, we replicate our analysis using lagged values of short interest as a measure of robustness. Again, we find that higher short interest reduces both future total skewness and future idiosyncratic skewness, which is indicative of causality. In other unreported tests, we conduct a series of Granger-like causality tests and, in general, we find that the negative relation between short interest and skewness flows from short interest to skewness and not the other way around.

However, we still recognize the possibility that our results are subject to endogeneity. To alleviate these concerns, we examine the effect of an exogenous shock to the level of short-selling activity on skewness. In May 2005, the US Securities and Exchange Commission (SEC) randomly selected 1000 stocks (pilot stocks) to participate in a pilot programme where the uptick rule would be relaxed. Using this exogenous shock, we conduct two sets of tests. First, we test whether the return skewness of pilot stocks decrease after the suspension of the uptick rule. Second, we focus on the period after the suspension of the uptick rule took place and compare the skewness of pilot stocks to the skewness of non-pilot stocks. We generally find evidence that the skewness of pilot stocks decreased during the period when the uptick rule was suspended suggesting that this exogenous relaxation of this constraint on short selling resulted in a decrease in skewness. Further, we find that during the period of the rule suspension, the skewness of pilot stocks is markedly lower than the skewness of non-pilot stocks. These results are robust to tests using both total skewness and idiosyncratic skewness and indicate that the relaxed constraints on short selling influence the skewness of stock returns.[1]

Thus far, we have established a link between skewness and the inefficiency of stock prices, as well as a link between short interest and the level

[1]Another important exogenous shock to short-sale constraints occurred during the recent financial crisis. The SEC restricted short selling on all financial stocks in late 2008. However, this ban only occurred over a 14-day period. Therefore, obtaining accurate estimates of higher order moments in the return distribution is troublesome.

of skewness. In our last set of tests, we examine how the interaction between short interest and skewness affects the efficiency of stock prices. Consistent with our third hypothesis, we find that the positive relation between skewness and price delay is greatest for stocks with the least short interest. In fact, our empirical estimates show that a one SD increase in short interest is associated with nearly a 30% reduction in the relation between total skewness and price delay. Qualitatively similar results are found when we examine idiosyncratic skewness.

Combined, the results from our tests not only contribute to the existing literature regarding skewness preferences, the informational efficiency of stock prices and the role of short selling in financial markets but our findings also have important policy implications. For instance, our results suggest that short selling, which has been shown to improve the efficiency of financial markets, does so through the process of reducing positive skewness and thus normalizing return distributions. The rest of this article proceeds as follows. Section II describes our data. Section III presents the results from our empirical tests and Section IV concludes.

II. Data description

Our sample consists of NASDAQ-listed stocks from January 1998 to June 2007.[2],[3] We obtain our data from several sources. From the Center for Research in Security Prices (CRSP), we gather monthly stock prices, shares outstanding and volume which we aggregate to the quarterly level. From Bloomberg, we use 13f filings to calculate institutional ownership (the proportion of shares outstanding held by institutions) and ownership breadth (the number of institutional shareholders). We also obtain monthly short interest data directly from NASDAQ. Throughout the analysis, we have three important variables of interest. The first variable is total return skewness. Using daily CRSP raw returns, we follow Xu (2007) and require at least 40 daily observations for each estimate of skewness. We do so to seek greater accuracy in estimating these higher order moments. Skewness is the scaled third moment and is estimated using the following formula.

$$Skew = \frac{t}{(t-1)(t-2)}\left(\frac{\sum_{j=1}^{t}(r_j - \bar{r})^3}{\hat{\sigma}^3}\right) \tag{1}$$

From CRSP, we obtain the raw return r_t for a particular stock on day t, the mean return is denoted as $\bar{r}$ and $\hat{\sigma}$ is the estimate of the SD of returns for the stock during the quarter.

The second variable of interest is idiosyncratic return skewness. To define idiosyncratic skewness, we estimate Equation (1) using residual (market-adjusted) returns instead of raw returns. Residual returns are obtained from estimating a daily market model, where the market index is the daily value-weighted CRSP index. The results from estimating Equation (1) using residual returns are denoted as idiosyncratic skewness.

Because we need to provide a link between skewness and price efficiency, our third variable of interest is a measure of price delay. We closely follow Hou and Moskowitz (2005) and estimate a parsimonious measure of delay. To calculate this measure of price inefficiency, we create weekly, Wednesday-to-Wednesday returns using daily CRSP returns.[4] Using these returns, we estimate Equation (2).

$$R_{i,t} = \alpha_i + \beta_i Rm_t + \sum_{n=1}^{4}\delta_{i,t-n}Rm_{t-n} + \varepsilon_{i,t} \tag{2}$$

In Equation (2), the dependent variable is the weekly return for each firm i during week t. The independent variables are the concurrent market return $Rm_{i,t}$ and four lagged weekly market returns. $Rm_{i,t-n}$ is the market return during week $t-n$, where $n = \{1, 2, 3 \text{ or } 4\}$. After estimating Equation (2) and allowing for the four lagged market returns, we extract the R^2, which Hou and Moskowitz denote as the unrestricted R^2. We then estimate Equation (2) but do not include the four lagged

[2]The short interest data are obtained by purchase directly from NASDAQ. Therefore, our time period is constrained based on the availability of this data.

[3]We recognize the need to control for the technology bubble which, following Ofek and Richardson (2003) and Battalio and Schultz (2006), occurred from first quarter of 1998 until the first quarter of 2000. In unreported tests, we replicate the entire analysis while including controls for this time period. The conclusions that we draw from these unreported tests are similar to those in this article. So for brevity, we do not report these tests in the current version of the article. Instead, we are sure to control for fixed effects by quarter in all of our multivariate tests.

[4]Hou and Moskowitz (2005) discuss the use of Wednesday-to-Wednesday returns. In particular, these returns are used to control for autocorrelations that are apparent in Friday-to-Friday returns and Monday-to-Monday returns (see e.g. Chordia and Swaminathan 2000).

weekly market returns (thus restricting $\delta_{i,t-n} = 0$). From this restricted regression, we obtain the restricted R^2s. Hou and Moskowitz (2005) define their measure of price delay in the following way:

$$Delay = 1 - \frac{Restricted\, R^2}{Unrestricted\, R^2} \quad (3)$$

Delay is equal to 1 minus the ratio of the restricted R^2 to the unrestricted R^2 and can be thought of as the relative increase in explanatory power caused by including lagged market returns in Equation (2). Stocks with higher delay have more difficulty incorporating market-wide information. Hou and Moskowitz (2005) denote the estimates obtained from Equation (3) as first-stage delay. Recognizing the potential noisiness of the estimates, they use a portfolio approach and sort stocks into deciles first by market capitalization and then by first-stage delay. They then estimate delay for each portfolio and assign stocks within each portfolio this new measure of portfolio delay. Accordingly, we use this portfolio delay measure throughout our analysis although unreported tests using first-stage delay are qualitatively similar to those reported below. After merging these data together, we have 874 stocks and 31,143 stock-quarter observations in our sample.[5]

Table 1 reports descriptive statistics for the entire sample. Panel A reports summary statistics while Panel B reports the Pearson correlation matrix. *Size* is the market capitalization while *Instown* is the ratio of shares held by institutions to total shares outstanding. *Breadth* is the number of unique institutional shareholders. *Turn* is the average daily turnover – or daily volume scaled by shares outstanding – while *Rvolt* is the return volatility, which is the SD of daily CRSP returns. *RSI* is the relative short interest, which is the short interest obtained directly from NASDAQ scaled by shares outstanding. In Panel A, we find that the average stock in our sample has a market cap of approximately $2.09 billion, institutional ownership of more than 40% and nearly 80 unique institutional shareholders. Further, the average stock has a turnover of 4.39%, return volatility of 3.5%, total skewness (*Skew*) of 0.3402 and idiosyncratic skewness (*Iskew*) of 0.3177. The mean delay is 0.2250 and the mean relative short interest is 0.0720.

Table 1. Summary statistics and correlations.

	Size	*Instown*	*Breadth*	*Turn*	*Rvolt*	*Skew*	*ISkew*	*Delay*	*RSI*
	[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]
Panel A. Summary statistics									
Mean	2.0897	0.4070	0.7837	0.0439	0.0350	0.3402	0.3177	0.2250	0.0720
Median	0.1861	0.3616	0.3900	0.0227	0.0299	0.2821	0.2564	0.1188	0.0227
SD	16.1465	0.2967	1.2349	0.0796	0.0216	1.0881	1.1354	0.2519	0.1185
Min	0.0003	0.0000	0.0100	0.0001	0.0023	−2.9606	−3.2645	0.0006	0.0000
Max	526.29654	0.9223	15.5500	3.7725	0.5696	3.8276	3.9584	0.9791	0.5769
Panel B. Correlation matrix									
Size	1.0000	0.0773** (0.000)	0.7028** (0.000)	0.0356** (0.000)	−0.0447** (0.000)	−0.0139* (0.016)	−0.0088 (0.127)	−0.0710** (0.000)	−0.0044 (0.442)
InstOwn		1.0000	0.4813** (0.000)	0.2581** (0.000)	−0.1990** (0.000)	−0.1190** (0.000)	−0.0978** (0.000)	−0.4065** (0.000)	0.5131** (0.000)
Breadth			1.0000	0.1939** (0.000)	−0.1467** (0.000)	−0.0654** (0.000)	−0.0511** (0.000)	−0.3075** (0.000)	0.2241** (0.000)
Turn				1.0000	0.2185** (0.000)	0.0714** (0.000)	0.0816** (0.000)	−0.0929** (0.000)	0.3990** (0.000)
Rvolt					1.0000	0.2765** (0.000)	0.2711** (0.000)	0.2769** (0.000)	−0.0084 (0.142)
Skew						1.0000	0.9532** (0.000)	0.1313** (0.000)	−0.0448** (0.000)
ISkew							1.0000	0.1170** (0.000)	−0.0252** (0.000)
Delay								1.0000	−0.2629** (0.000)
RSI									1.0000

The table reports statistics that describe the sample of stocks used in the analysis. Panel A reports the summary statistics while Panel B provides the Pearson correlation matrix. *Size* is the market capitalization in $ billions, *Instown* is the ratio of shares held by institutions to total shares outstanding. *Breadth* is the number of institutional shareholders in 100s. *Turn* is the number shares traded during a quarter divided by shares outstanding in per cent. *Rvolt* is the return volatility of SD of daily returns during each quarter. *Skew* is the skewness of daily returns during each quarter. Following Xu (2007), we require at least 40 observations during each quarter because the accuracy of the third moment depends on the number of observations in our sample. *ISkew* is the idiosyncratic skewness of market adjusted returns. *Delay* is Hou and Moskowitz (2005) measure of price delay. *RSI* is the relative short interest obtained from NASDAQ. *p* Values are reported in parentheses and * and ** denote statistical significance at the 0.05 and 0.01 levels, respectively.

[5]Some stock-quarter observations were excluded because fewer than 40 daily observations were available to calculate skewness.

Panel B reports the correlation coefficients for each of these variables. A few of the estimates are noteworthy. First, we find that delay is negatively correlated with market cap, institutional ownership, ownership breadth and turnover and positively correlated with return volatility. Similar results are found in Hou and Moskowitz (2005). However, we also find that delay is directly related to both total skewness and idiosyncratic skewness. Given the broad literature that discusses price premiums associated with skewness, our results suggest that positively skewed stocks tend to be less efficient. Second, we also find that relative short interest is negatively related to delay. Similar findings are reported in Blau (2012) and Boehmer and Wu (2013) and suggest that short selling activity reduces price inefficiencies. Finally, Panel B also shows that relative short interest is inversely related to both total skewness and idiosyncratic skewness. These univariate correlation coefficients provide some preliminary support for our prediction that short interest can reduce skewness, which can impact the informational efficiency of stock prices. However, we recognize the need to control for a variety of other factors that might influence both total skewness and idiosyncratic skewness; thus, we conduct a number of multivariate tests below.

III. Results

In this section, we conduct three sets of tests. First, we provide some initial tests examining whether skewness is directly related to price delay. Second, we examine whether short interest reduces skewness in the distribution of returns. Third, we determine whether the negative relation between skewness and delay is driven by stocks with the least short interest.

The link between skewness and the efficiency of stock prices

We test our first hypothesis by examining the relation between skewness and price delay. As mentioned above, we contend that skewness decreases the efficiency of stock prices. The inverse relation between skewness and price efficiency is likely to be explained by investor preferences for skewness, which could lead to overvalued stock prices.

To determine the relation between skewness and price efficiency, we estimate the following equation using pooled stock-quarter observations.

$$\begin{aligned} Delay_{i,q} = \beta_0 + \beta_1 ret_{i,q-4,q-1} + \beta_2 price_{i,q} + \beta_3 turn_{i,q} \\ + \beta_4 r\_volt_{i,q} + \beta_5 B/M_{i,q} + \beta_6 size_{i,q} \\ + \beta_7 instown_{i,q} + \beta_8 breadth_{i,q} + \beta_9 RSI_{i,q} \\ + \beta_{10} skew_{i,q} + \beta_{11} Iskew_{i,q} + \varepsilon_{i,q} \end{aligned} \tag{4}$$

The dependent variable in Equation (4) is the Hou and Moskowitz (2005) measure of price delay ($Delay_{i,q}$). We include as independent variables the prior year's return ($ret_{i,q-4,q-1}$), the natural log of price ($price_{i,q}$), the contemporaneous share turnover ($turn_{i,q}$), the return volatility ($r\_volt_{i,q}$), the book-to-market ratio ($B/M_{i,q}$), the natural log of market cap ($size_{i,q}$), the natural log of institutional ownership, ($instown_{i,q}$), the number of institutions holding the stock in hundreds ($breadth_{i,q}$), the current relative short interest ($RSI_{i,q}$), the level of total skewness ($skew_{i,q}$) and the level of idiosyncratic skewness ($Iskew_{i,q}$). In unreported tests, we explicitly control for the technology bubble period with an indicator variable capturing the bubble period as defined in Ofek and Richardson (2003) and find results that are qualitatively similar to those reported here. A Hausman test rejects the presence of random effects while an F-test reveals observed differences across both stocks and quarters, so we report the two-way fixed effects estimates. We do note that similar results are obtained using pooled OLS with Thompson (2006) SEs. Table 2 reports the results from estimating Equation (4).[6]

In column [1], we find that past returns, share turnover and return volatility are each directly related to price delay. Further, share prices, book-to-market ratios, market cap, institutional ownership and

[6]We note the possibility of multicollinearity throughout our analysis. As seen in the correlation matrix in Table 1, several of the control variables are highly correlated. These results are consistent with the literature that discusses the positive relationship between volume and returns (see the review in Karpoff 1987) and the large literature that discusses the relation between volatility, volume and returns (see e.g. Chen, Firth, and Rui 2001). We conduct a series of unreported tests, where we estimate various econometric specifications while including subsets of control variables to ensure that the conclusions we draw in this study are robust. We also estimate variance inflation factors in each of our specifications to determine whether multicollinearity influences the size of the SEs. In each case, we find that inflation factors are small indicating that SEs seem to be unaffected by potential collinearity. These unreported tests are available from the authors upon request.

Table 2. Panel regressions – price delay.

	[1]	[2]	[3]
intercept	0.1769** (0.000)	0.1730** (0.000)	0.1429** (0.000)
$ret_{q-4,q-1}$	0.0099** (0.000)	0.0101** (0.000)	0.0100** (0.000)
$price_q$	−0.0163** (0.000)	−0.0170** (0.000)	−0.0168** (0.000)
$turn_q$	0.0331** (0.003)	0.0317** (0.004)	0.0320** (0.004)
B/M_q	0.5397** (0.000)	0.4642** (0.000)	0.4767** (0.000)
r_volt_q	−0.0268** (0.000)	−0.0274** (0.000)	−0.0273** (0.000)
$size_q$	−0.0692** (0.000)	−0.0703** (0.000)	−0.0703** (0.000)
$instown_q$	−0.0125 (0.096)	−0.0114 (0.127)	−0.0116 (0.121)
$breadth_q$	−0.0459** (0.000)	−0.0447** (0.000)	−0.0449** (0.000)
RSI_q	−0.0343** (0.000)	−0.0322** (0.001)	−0.0325** (0.001)
$skew_q$		0.0044** (0.000)	
$Iskew_q$			0.0035** (0.000)
Adj. R^2	0.7825	0.7828	0.7827
Stock FE	Yes	Yes	Yes
Qtr FE	Yes	Yes	Yes

The table reports the results of estimating the following equation.

$$Delay_{i,q} = \beta_0 + \beta_1 ret_{i,q-4,q-1} + \beta_2 Price_{i,q} + \beta_3 turn_{i,q} + \beta_4 r\_volt_{i,q} + \beta_5 B/M_{i,q} + \beta_6 Size_{i,q} + \beta_7 instown_{i,q} + \beta_8 breadth_{i,q} + \beta_9 RSI_{i,q} + \beta_{10} skew_{i,q} + \beta_{11} Iskew_{i,q} + \varepsilon_{i,q}$$

The dependent variable is the Hou and Moskowitz (2005) measure of Price Delay ($Delay_{i,q}$). We include as independent variables the prior year's return ($ret_{i,q-4,q-1}$), the natural log of price ($Price_{i,q}$), the contemporaneous share turnover ($turn_{i,q}$), the return volatility ($r\_volt_{i,q}$), the book-to-market ratio ($B/M_{i,q}$), the natural log of market cap ($size_{i,q}$), the natural log of institutional ownership, ($instown_{i,q}$), the number of institutions holding the stock in hundreds ($breadth_{i,q}$), the current relative short interest ($RSI_{i,q}$), the level of return skewness ($skew_{i,q}$) and the level of idiosyncratic skewness ($Iskew_{i,q}$). A Hausman test reveals observed differences across stocks and quarters, so we report the two-way fixed effects estimates. Similar results are obtained using pooled OLS with Thompson (2006) SEs. p Values are reported in parentheses. Statistical significance at 0.01 level is denoted by **.

ownership breadth are negatively related to delay. Interestingly, we find that relative short interest is also negatively related to price delay. These results are similar to those found in Blau (2012) and Boehmer and Wu (2013) and seem to indicate that short interest reduces the level of price delay and improves the efficiency of markets. Column [2] extends the specification in column [1] by including total skewness. Results show that the estimate for skewness is 0.0044 (p value = 0.000). In economic terms, a one SD increase in skewness corresponds to a 50 basis point increase in price delay. To the extent that investors' preferences for skewness create misvalued stocks, our results seem to indicate that stocks with higher skewness are less efficient at incorporating market-wide information than stocks with lower skewness.

Column [3] reports the results when we include idiosyncratic skewness in the specification. Consistent with our expectations, we find that this variable produces a positive and significant estimate (estimate = 0.0035, p value = 0.000). After controlling for several other factors that influence delay, this estimate suggests that a one SD increase in idiosyncratic skewness is associated with a 40 basis point increase in price delay. Combined with our findings in column [2], these results support the univariate correlations in Table 1 and suggest that positively skewed stocks have more difficulty incorporating market-wide information into their prices, which supports our first hypothesis.[7]

Is skewness negatively related to short interest?

This section tests our second hypothesis that skewness relates inversely with short interest. Prior research discusses the implications of binding short-sale constraints on skewness (Diamond and Verrecchia 1987; Hong and Stein 2003; Xu 2007). In this subsection, we examine whether, after controlling for short-sale constraints, short interest reduces skewness. Proper tests of this hypothesis, therefore, must control for other factors that have been shown to influence skewness. To conduct these tests, we run the following regression using pooled stock-quarter observations:

$$\begin{aligned} skew_{i,q} \text{ or } Iskew_{i,q} = \beta_0 &+ \beta_1 ret_{i,q} + \beta_2 ret_{i,q-1} \\ &+ \beta_3 ret_{i,q-2} + \beta_4 ret_{i,q-3} \\ &+ \beta_5 turn_{i,q} + \beta_6 r\_volt_{i,q} \\ &+ \beta_7 size_{i,q} + \beta_8 instown_{i,q} \\ &+ \beta_9 breadth_{i,q} + \beta_{10} RSI_{i,q} + \varepsilon_{i,q} \end{aligned} \quad (5)$$

The dependent variable is either total skewness ($skew_{i,q}$) or idiosyncratic skewness ($Iskew_{i,q}$) for each stock during each quarter. Closely following Xu (2007), we include as independent variables the contemporaneous ($ret_{i,q}$) and lagged ($ret_{i,q-1}$, $ret_{i,q-2}$ and $ret_{i,q-3}$) returns as well as the contemporaneous turnover ($turn_{i,q}$), return volatility ($r\_volt_{i,q}$), the natural logs of market capitalization

[7]The results in Tables 1 and 2 produce both univariate and multivariate evidence that stocks with the most skewness are the least efficient. Kumar (2009) and Kumar, Page and Spalt (2011) provide another identification of lottery stocks. They argue that stocks with most idiosyncratic skewness, the most idiosyncratic volatility and the lowest stock prices are most likely to resemble lotteries. Following this definition, we create an indicator variable that equals unity for stocks with idiosyncratic skewness greater than the median, idiosyncratic volatility greater than the median and stocks with prices lower than the median. After replicating the analysis in Tables 1, we find that the correlation between delay and this dummy variable is 0.2366 (p value = 0.000). When we include this indicator variable in Equation (4) (instead of our measures of skewness), we find a coefficient equal to 0.01 (p value = 0.000). These results suggest that our results are robust to an alternative definition for lottery-type stocks.

($size_{i,q}$) and institutional ownership ($instown_{i,q}$).[8] We also include the number of institutional shareholders in hundreds ($breadth_{i,q}$). The variable of interest is the relative short interest ($RSI_{i,q}$). As before, we control explicitly for the bubble period in unreported tests and find qualitatively similar results to those reported in this study. Various test statistics show differences across stocks and quarters, so we again report two-way fixed effect estimates. As in Chen, Hong and Stein (2001) and Xu (2007), the proxies for short-sale constraints are *size, instown* and *breadth*. If, after holding constraints constant, short interest helps reduce skewness, then the estimate for β_{10} is expected to be negative. Table 3 reports pooled regression results from estimating Equation (5). Columns [1]–[3] report the results when the dependent variable is defined as total skewness while columns [4]–[6] show the results for idiosyncratic skewness. Further, we report variants of Equation (5) that control for some of the independent variables while including the variable of interest *RSI*. Results in the table allow us to make qualitatively similar inferences, so we only discuss the results in columns [3]–[6].

In column [3], we find that contemporaneous returns produce a positive and significant estimate while lagged returns produce negative estimates that are reliably different from zero. We also find that *turn* and *r_volt* produce positive and significant estimates. Likewise, we find that the estimate for *size* is positive and significant while the estimates for *instown* and *breadth* are significantly negative. Similar results are found in Xu (2007). Interestingly, we find that the estimate for *RSI* is negative and significant (estimate = − 0.3931, p value = 0.000). This result suggests that, after controlling for factors that approximate short-sale constraints, short interest reduces the skewness of individual stock returns. In economic terms, a one SD increase in *RSI* results in a decrease in skewness of 0.04. This represents an approximate 12% decline in mean skewness (relative to mean skewness in Table 1). These results suggest that the coefficient on *RSI* is not only statistically significant but it is also economically meaningful.

In column [6], we find that coefficients on the control variables are similar in sign and magnitude to the corresponding coefficients in column [3]. Further, we also find that the estimate for *RSI* is again negative and significant (estimate = − 0.4177,

Table 3. Panel regressions.

	Skewness			*Idiosyncratic skewness*		
	[1]	[2]	[3]	[4]	[5]	[6]
intercept	2.4314** (0.000)	2.3585** (0.000)	2.6656** (0.000)	2.7522** (0.000)	2.6720** (0.000)	2.9117** (0.000)
ret_q	1.4378** (0.000)	1.4282** (0.000)	1.4075** (0.000)	1.5122** (0.000)	1.5016** (0.000)	1.4855** (0.000)
ret_{q-1}	−0.1524** (0.000)	−0.1567** (0.000)	−0.1635** (0.000)	−0.1466** (0.000)	−0.1513** (0.000)	−0.1567** (0.000)
ret_{q-2}	−0.0838** (0.000)	−0.0862** (0.000)	−0.0889** (0.000)	−0.0969** (0.000)	−0.0994** (0.000)	−0.1016** (0.000)
ret_{q-3}	−0.0521* (0.019)	−0.0639** (0.004)	−0.0887** (0.000)	−0.0657** (0.004)	−0.0787** (0.001)	−0.0981** (0.000)
$turn_q$	0.2298* (0.012)	0.2308* (0.012)	0.2617** (0.004)	0.1883* (0.049)	0.1895* (0.047)	0.2135* (0.026)
r_volt_q	0.8372** (0.000)	0.8340** (0.000)	0.8582** (0.000)	0.9048** (0.000)	0.9013** (0.000)	0.9202** (0.000)
$size_q$	0.0339 (0.114)	0.0659** (0.003)	0.1470** (0.000)	0.0381 (0.087)	0.0733** (0.002)	0.1366** (0.000)
$instown_q$		−0.1240** (0.000)	−0.0518* (0.039)		−0.1362** (0.000)	−0.0799** (0.002)
$breadth_q$			−0.1379** (0.000)			−0.1077** (0.000)
RSI_q	−0.5393** (0.000)	−0.4926** (0.000)	−0.3931** (0.000)	−0.5466** (0.000)	−0.4953** (0.000)	−0.4177** (0.000)
Adj. R^2	0.2184	0.2192	0.2203	0.2226	0.2234	0.2241
Stock FE	Yes	Yes	Yes	Yes	Yes	Yes
Qtr FE	Yes	Yes	Yes	Yes	Yes	Yes

The table reports the results of estimating the following equation.

$$skew_{i,q} \text{ or } Iskew_{i,q} = \beta_0 + \beta_1 ret_{i,q} + \beta_2 ret_{i,q-1} + \beta_3 ret_{i,q-2} + \beta_4 ret_{i,q-3} + \beta_5 turn_{i,q} + \beta_6 r\_volt_{i,q} + \beta_7 size_{i,q} + \beta_8 instown_{i,q} + \beta_9 breadth_{i,q} + \beta_{10} RSI_{i,q} + \varepsilon_{i,q}$$

The dependent variable is total skewness ($skew_{i,q}$) in columns [1]–[3] and idiosyncratic skewness ($Iskew_{i,q}$) in columns [4]–[6]. We include as independent variables contemporaneous ($ret_{i,q}$) and lagged ($ret_{i,q-1}$, $ret_{i,q-2}$ and $ret_{i,q-3}$) returns and contemporaneous turnover ($turn_{i,q}$), the natural log of market cap ($size_{i,q}$), the natural log of institutional ownership, ($instown_{i,q}$), the number of institutions holding the stock in hundreds ($breadth_{i,q}$) and the current relative short interest ($RSI_{i,q}$). A Hausman test reveals observed differences across stocks and quarters, so we report the two-way fixed effects estimates. Similar results are obtained using pooled OLS with Thompson (2006) SEs. p Values are reported in parentheses. Statistical significance at the 0.05 and 0.01 levels is denoted by * and **, respectively.

[8] Although not discussed in Xu (2007), there is the potential for autocorrelated returns, which is being used as an additional control variable. In a relatively efficient market, quarterly returns are not likely to be serially correlated. However, to further test this possibility, we take the average contemporaneous return (across stocks) and estimate an AR process with Durbin–Watson (DW) statistics to determine the degree of autocorrelation in returns. In the results from these unreported tests, we find that DW statistics are relatively low and that returns are neither positively nor negatively autocorrelated.

p value = 0.000). A one SD increase in RSI is associated with a reduction in skewness of approximately 0.05, which represents nearly 16% of mean idiosyncratic skewness.

The results from this set of tests have important implications. While prior research suggests that binding constraints on short selling can adversely affect the efficiency of stock prices (Miller 1977; Diamond and Verrecchia 1987; Bris, Goetzmann, and Zhu 2007; Chang, Cheng, and Yu 2007; Blau 2012), the results in our study also suggest that, without active short selling, stock return distributions become more right-skewed. Given our findings in the previous section that show that positively skewed stocks have the least informational efficiency, the results in Table 3 indicate that a possible mechanism by which short interest improves the efficiency of markets is by reducing skewness. This finding supports our second hypothesis.

Potential controls for endogeneity

We recognize that our results showing a negative relation between short interest and skewness are not necessarily indicative of causation. It is possible that short interest is simply higher for stocks that exhibit more negative skewness. To address these potential concerns, we re-estimate Equation (5) but instead of including contemporaneous RSI, we include RSI for a particular stock during the quarter $q-1$ as the independent variable of interest. Results replicating Table 3 using this new specification are reported in Table 4. As before, columns [1]–[3] show the results when total skewness is used as the dependent variable while columns [4]–[6] present the results when the dependent variable is idiosyncratic skewness.

The estimated coefficients on the control variables are, in general, similar in sign and magnitude to those in Table 3. Focusing our attention on the variable of interest, we find that the estimate for RSI_{q-1} is negative in each column in Table 3. We note, however, that the estimates in columns [3] and [6] are only marginally significant (p value = 0.090, 0.129). In terms of economic magnitude, the coefficients are less than half of the comparable estimates in Table 3. However, a one SD increase in lagged RSI in column [1] represents a decrease in total skewness of more than 0.025. This decrease in total skewness represents a nearly 7% decline. Similarly, a one SD increase in RSI reduces next quarter's idiosyncratic skewness by 0.028, which is nearly 9% of mean idiosyncratic skewness. These results support the conclusions that we were able to draw in Table 3.

In other unreported tests, we conduct Granger-like causality tests by including lagged dependent variables as additional control variables in our specifications in Table 4. We still find lagged short

Table 4. Panel regressions.

	Skewness			Idiosyncratic skewness		
	[1]	[2]	[3]	[4]	[5]	[6]
intercept	2.3064** (0.000)	2.2320** (0.000)	2.5859** (0.000)	2.6166** (0.000)	2.5348** (0.000)	2.8233** (0.000)
ret_q	1.4453** (0.000)	1.4349** (0.000)	1.4117** (0.000)	1.5206** (0.000)	1.5091** (0.000)	1.4903** (0.000)
ret_{q-1}	−0.1482** (0.000)	−0.1528** (0.000)	−0.1604** (0.000)	−0.1419** (0.000)	−0.1469** (0.000)	−0.1531** (0.000)
ret_{q-2}	−0.0815** (0.000)	−0.0840** (0.000)	−0.0871** (0.000)	−0.0942** (0.000)	−0.0969** (0.000)	−0.0994** (0.000)
ret_{q-3}	−0.0435* (0.049)	−0.0564* (0.011)	−0.0846** (0.000)	−0.0562* (0.015)	−0.0705** (0.002)	−0.0935** (0.000)
$turn_q$	0.1083 (0.229)	0.1167 (0.194)	0.1677 (0.063)	0.0601 (0.521)	0.0693 (0.459)	0.1109 (0.237)
r_volt_q	0.8271* (0.000)	0.8241** (0.000)	0.8521** (0.000)	0.8939** (0.000)	0.8907** (0.000)	0.9135** (0.000)
$size_q$	0.0195 (0.363)	0.0545* (0.014)	0.1458** (0.000)	0.0223 (0.316)	0.0608** (0.008)	0.1352** (0.000)
$instown_q$		−0.1341** (0.000)	−0.0528* (0.036)		−0.1473** (0.000)	−0.0810** (0.002)
$breadth_q$			−0.1539** (0.000)			−0.1255** (0.000)
RSI_{q-1}	−0.2535** (0.000)	−0.2104** (0.002)	−0.1187 (0.090)	−0.2329** (0.001)	−0.1856** (0.009)	−0.1108 (0.129)
Adj. R^2	0.2173	0.2183	0.2197	0.2215	0.2225	0.2234
Stock FE	Yes	Yes	Yes	Yes	Yes	Yes
Qtr FE	Yes	Yes	Yes	Yes	Yes	Yes

The table reports the results of estimating the following equation.

$$Skew_{i,q} \text{ or } Iskew_{i,q} = \beta_0 + \beta_1 ret_{i,q} + \beta_2 ret_{i,q-1} + \beta_3 ret_{i,q-2} + \beta_4 ret_{i,q-3} + \beta_5 turn_{i,q} + \beta_6 r\_volt_{i,q} + \beta_7 size_{i,q} + \beta_8 instown_{i,q} + \beta_9 breadth_{i,q} + \beta_{10} RSI_{i,q-1} + \varepsilon_{i,q}$$

The dependent variable is total skewness ($skew_{i,q}$) in columns [1]–[3] and idiosyncratic skewness ($Iskew_{i,q}$) in columns [4]–[6]. We include as independent variables contemporaneous ($ret_{i,q}$) and lagged ($ret_{i,q-1}$, $ret_{i,q-2}$ and $ret_{i,q-3}$) returns and contemporaneous turnover ($turn_{i,q}$), the natural log of market cap ($size_{i,q}$), the natural log of institutional ownership, ($instown_{i,q}$), the number of institutions holding the stock in hundreds ($breadth_{i,q}$) and the relative short interest during the previous quarter ($RSI_{i,q-1}$). A Hausman test reveals observed differences across stocks and quarters, so we report the two-way fixed effects estimates. Similar results are obtained using pooled OLS with Thompson (2006) SEs. p Values are reported in parentheses. Statistical significance at the 0.05 and 0.01 levels is denoted by * and **, respectively.

interest is negatively related to skewness and lottery classification while the lagged dependent variables produce estimates that are positive and significant. We also estimate equations where short interest is the dependent variable and lagged short interest and lagged skewness are the independent variables of interest. The results from these tests seem to indicate that causation is generally flowing from short interest to skewness and not the other way around.

Another test to mitigate endogeneity

While our results in Table 4 and the untabulated Granger-like causality tests seem to support our contention that short interest reduces return skewness, we still recognize the possibility that endogeneity might adversely affect our results. In this subsection, we conduct another set of tests that examine the effect of an exogenous relaxation of restrictions on short selling on both total skewness and idiosyncratic skewness. In May 2005, the SEC created a pilot program to repeal the uptick rule (Regulation SHO), which required short sales to execute on upticks. The uptick rule had been in effect since 1938 and was relaxed for a group of randomly selected stocks from May 2005 until August 2007. In the framework of our hypotheses, the relaxation of any type of short-sale constraints should reduce both total skewness and idiosyncratic skewness. After identifying stocks in our sample that were part of the randomly selected group of pilot stocks and restricting our sample time period to the Regulation SHO time period, we conduct two separate tests. First, we examine the skewness (and idiosyncratic skewness) of pilot stocks during the period before and after the Regulation SHO period. If the relaxation of any constraints on short selling influences the level of skewness, then we expect our measures of skewness to decrease during the period when the uptick rule was suspended. Second, we compare the total skewness and idiosyncratic skewness for the group of pilot stocks and the group of non-pilot stocks during the period when the rule was suspended. According to our second hypothesis, we expect that the skewness of pilot stocks will be markedly lower than the skewness of non-pilot stocks. Table 5 reports some univariate tests. Panel A shows the results for our first test while Panel B presents the results from our second test.

Table 5. Univariate tests.

	Total skewness	*Idiosyncratic skewness*
	[1]	[2]
Panel A. Skewness of pilot stocks surrounding Reg SHO		
Before	0.2640	0.2331
After	0.1223	0.1612
Difference	0.1418** (0.000)	0.0719 (0.051)
Panel B. Skewness of pilot versus non-pilot stocks during Reg SHO		
Pilot Stocks	0.1223	0.1612
Non-Pilot Stocks	0.3064	0.3214
Difference	−0.1841** (0.000)	−0.1602** (0.001)

The table reports simple *t*-tests examining the levels of total skewness and idiosyncratic skewness using an exogenous relaxation of short-sale constraints. In May 2005, the US Securities and Exchange Commission randomly selected approximately 1000 stocks as part of the Regulation SHO Pilot Program in which these pilot stocks no longer had to abide by the uptick rule. Panel A reports the mean skewness and the mean idiosyncratic skewness for pilot stocks before and after the period when the uptick rule suspension occurred. Panel B presents the mean skewness and idiosyncratic skewness for both pilot and non-pilot stocks during the period after the pilot programme was implemented. Differences between before and after and differences between pilot and non-pilot stocks are reported along with corresponding *p* values obtained from *t*-tests. Statistical significance at 0.01 level is denoted by **.

In column [1] of Panel A, we find that total skewness decreases by more than 50%. The before–after difference is statistically significant (p value = 0.000). We also find that idiosyncratic skewness for the average pilot stock decreases substantially during the Regulation SHO period. The before–after difference is again significant (p value = 0.051). In economic terms, idiosyncratic skewness decreased by nearly 31% during the Regulation SHO period. These univariate tests support the prediction of our second hypothesis and suggest that a relaxation of constraints on short selling will reduce the level of skewness in a particular stock.

Panel B shows that during the Regulation SHO period, the skewness of pilot stocks was markedly lower than the skewness of non-pilot stocks. For instance, the mean total skewness is 0.1223 for pilot stocks and 0.3064 for non-pilot stocks. The difference (−0.1841) is not only statistically significant but it is also economically meaningful as the difference is 1.5 times larger (in absolute value) than the mean for pilot stocks. Column [2] shows qualitatively similar results as mean idiosyncratic skewness is 0.1612 for pilot stocks and 0.3214 for non-pilot stocks. The difference in column [2] is −0.1602 and is nearly 100% the size of mean idiosyncratic skewness for pilot stocks. These results again support the idea that an exogenous relaxation of

Table 6. Panel regressions – pre- versus post-Reg SHO.

	Skewness			*Idiosyncratic skewness*		
	[1]	[2]	[3]	[4]	[5]	[6]
intercept	0.6883** (0.004)	−0.0279 (0.913)	0.2428 (0.344)	0.4326 (0.104)	−0.3442 (0.222)	−0.0712 (0.801)
ret_q	−0.0168 (0.727)	−0.0174 (0.717)	−0.0082 (0.863)	−0.0133 (0.802)	−0.0140 (0.792)	−0.0047 (0.929)
ret_{q-1}	0.0566 (0.259)	−0.0543 (0.277)	−0.0541 (0.277)	−0.0782 (0.158)	−0.0757 (0.169)	−0.0754 (0.169)
ret_{q-2}	−0.0563 (0.261)	−0.0479 (0.336)	−0.0456 (0.358)	−0.0238 (0.663)	−0.0147 (0.789)	−0.0123 (0.821)
ret_{q-3}	−0.0792 (0.156)	−0.1194* (0.032)	−0.2121** (0.000)	−0.0785 (0.202)	−0.220* (0.047)	−0.2155** (0.001)
$turn_q$	−1.4437** (0.001)	−10.572* (0.014)	−0.6231 (0.149)	−1.5774** (0.001)	−1.1583* (0.015)	−0.7206 (0.130)
$rvolt_q$	0.3820** (0.000)	0.2313* (0.019)	0.1828 (0.062)	0.2757* (0.010)	0.1122 (0.300)	0.0633 (0.558)
$size_q$	0.1866** (0.002)	0.4323** (0.000)	0.8668** (0.000)	0.2610** (0.000)	0.5274** (0.000)	0.9656** (0.000)
$instown_q$		0.7899** (0.000)	−0.3211** (0.004)		−0.8566** (0.000)	−0.3839** (0.002)
$breadth_q$			−0.5547** (0.000)			−0.5593** (0.000)
SHO	−0.1168** (0.003)	−0.0680 (0.082)	−0.0016 (0.969)	−0.0822 (0.055)	−0.0292 (0.497)	0.0377 (0.390)
Adj. R^2	0.0449	0.0556	0.0654	0.0421	0.0526	0.0608
Stock FE	Yes	Yes	Yes	Yes	Yes	Yes
Qtr FE	No	No	No	No	No	No

The table reports the results of estimating the following equation using pooled stock-quarter data for the sample of Pilot stocks that were part of the Reg SHO.

$$Skew_{i,q} \text{ or } Iskew_{i,q} = \beta_0 + \beta_1 ret_{i,q} + \beta_2 ret_{i,q-1} + \beta_3 ret_{i,q-2} + \beta_4 ret_{i,q-3} + \beta_5 turn_{i,q} + \beta_6 rvolt_{i,q} + \beta_7 size_{i,q} + \beta_8 instown_{i,q} + \beta_9 breadth_{i,q} + \beta_{10} SHO_i + \varepsilon_{i,q}$$

The dependent variable is total skewness ($skew_{i,q}$) in columns [1]–[3] and idiosyncratic skewness ($Iskew_{i,q}$) in columns [4]–[6]. We include as independent variables contemporaneous ($ret_{i,q}$) and lagged ($ret_{i,q-1}$, $ret_{i,q-2}$ and $ret_{i,q-3}$) returns and contemporaneous turnover ($turn_{i,q}$) and return volatility ($rvolt_{i,q}$), the natural log of market cap ($size_{i,q}$), the natural log of institutional ownership, ($instown_{i,q}$) and the number of institutions holding the stock in hundreds ($breadth_{i,q}$). The variable of interest is the indicator variable capturing the period when the uptick rule was suspended for pilot stocks (SHO), which was from May 2005 until 2007. We note that the number of stock-quarter observations is 6108. A Hausman test reveals observed differences across stocks and quarters, so we report the two-way fixed effects estimates. Similar results are obtained using pooled OLS with Thompson (2006) SEs. *p* Values are reported in parentheses. statistical significance at the 0.05 and 0.01 levels is denoted by * and **, respectively.

constraints on short selling can decrease the level of skewness in a particular stock. We recognize the need, however, to control for other factors that might influence skewness in a multivariate setting.

To examine the effects of the Regulation SHO period on pilot stocks, we estimate the following equation using pooled stock-quarter data and report the regression results in Table 6.

$$\begin{aligned} Skew_{i,q} \text{ or } Iskew_{i,q} = \beta_0 + \beta_1 ret_{i,q} + \beta_2 ret_{i,q-1} \\ + \beta_3 ret_{i,q-2} + \beta_4 ret_{i,q-3} \\ + \beta_5 turn_{i,q} + \beta_6 rvolt_{i,q} \\ + \beta_7 size_{i,q} + \beta_8 instown_{i,q} \\ + \beta_9 breadth_{i,q} + \beta_{10} SHO_t + \varepsilon_{i,q} \end{aligned} \quad (6)$$

The dependent variables and the independent variables are similar to those in Equation (5). However, instead of including relative short interest, which might be endogenously related to skewness, we include an indicator variable *SHO*, which equals unity during the period when the uptick rule was suspended – zero otherwise. We note that when we include SHO as an independent variable, we do not control for quarter fixed effects since doing so would violate the full rank condition required for consistent estimates. We do, however, control for stock fixed effects. Similar to the format of previous tables, we report the results when total skewness is the dependent variable in columns [1]–[3] and results when idiosyncratic skewness is the dependent variable in columns [4]–[6].

We find in column [1] that after controlling for most of the independent variables in column [1], the coefficient on *SHO* is negative and significant. In economic terms, the coefficient suggests that after holding constant other than a number of other variables, skewness is −0.1168 lower during the Regulation SHO period than during the period prior to Regulation SHO. This estimate is relatively close to the mean estimate discussed in Panel A of the previous table. Column [2] adds another variable that captures constraints (*instown*) and shows that the coefficient on SHO becomes less negative and less significant (estimate = – 0.0680, *p* value = 0.082). However, the result still provides some support for our second hypothesis. We note, however, that in column [3] when we include all three measures that proxy for short-sale constraints, the coefficient on *SHO* is not reliably different from zero. While the non-negative estimate on SHO seems to reject our third hypothesis, we are still able to argue that the effect of the Regulation SHO period on skewness is much weaker when hold constant all three proxies of short-sale constraints. A close examination of columns [4]–[6] provides a conclusion that is

Table 7. Panel regressions – pilot versus non-pilot stocks.

	Skewness			Idiosyncratic skewness		
	[1]	[2]	[3]	[4]	[5]	[6]
intercept	2.1015** (0.000)	1.9282** (0.000)	1.9882** (0.000)	2.4313** (0.000)	2.2592** (0.000)	2.3166** (0.000)
ret_q	0.1260 (0.152)	0.1190 (0.175)	0.1190 (0.174)	0.1265 (0.189)	0.1195 (0.213)	0.1195 (0.213)
ret_{q-1}	0.1241 (0.158)	0.1272 (0.147)	0.1276 (0.145)	0.1340 (0.164)	0.1370 (0.153)	0.1374 (0.152)
ret_{q-2}	−0.1034 (0.238)	−0.1059 (0.225)	−0.1053 (0.228)	−0.0860 (0.369)	−0.0885 (0.354)	−0.0878 (0.357)
ret_{q-3}	−0.1898* (0.031)	−0.2183* (0.013)	−0.2241* (0.011)	−0.2476* (0.010)	−0.2759** (0.004)	−0.2815** (0.003)
$turn_q$	0.7576* (0.011)	1.0125** (0.001)	1.0780** (0.000)	0.8842** (0.007)	1.1373** (0.001)	1.2000** (0.000)
$rvolt_q$	1.1733** (0.000)	1.1275** (0.000)	1.1308** (0.000)	1.2451** (0.000)	1.1996** (0.000)	1.2027** (0.000)
$size_q$	0.0133 (0.564)	0.1120** (0.000)	0.1111** (0.000)	0.0463 (0.066)	0.1443** (0.000)	0.1435** (0.000)
$instown_q$		−0.3033** (0.000)	−0.2960** (0.000)		−0.3012** (0.000)	−0.2942** (0.000)
$breadth_q$			−0.0350 (0.271)			−0.0335 (0.336)
Pilot	−0.1383** (0.001)	−0.1052* (0.013)	−0.1084* (0.010)	−0.1346** (0.003)	−0.1018* (0.027)	−0.1049* (0.023)
Adj. R^2	0.0413	0.0497	0.0499	0.0362	0.0431	0.0433
Stock FE	No	No	No	No	No	No
Qtr FE	Yes	Yes	Yes	Yes	Yes	Yes

The table reports the results of estimating the following equation using pooled stock-quarter data from the period during Reg SHO (Second quarter 2005–Second quarter 2007).

$$Skew_{i,q} \text{ or } Iskew_{i,q} = \beta_0 + \beta_1 ret_{i,q} + \beta_2 ret_{i,q-1} + \beta_3 ret_{i,q-2} + \beta_4 ret_{i,q-3} + \beta_5 turn_{i,q} + \beta_6 size_{i,q} + \beta_7 instown_{i,q} + \beta_8 breadth_{i,q} + \beta_9 Pilot_i + \varepsilon_{i,q}$$

The dependent variable is total skewness ($skew_{i,q}$) in columns [1]–[3] and idiosyncratic skewness ($Iskew_{i,q}$) in columns [4]–[6]. We include as independent variables contemporaneous ($ret_{i,q}$) and lagged ($ret_{i,q-1}$, $ret_{i,q-2}$ and $ret_{i,q-3}$) returns and contemporaneous turnover ($turn_{i,q}$) and return volatility ($rvolt_{i,q}$), the natural log of market cap ($size_{i,q}$), the natural log of institutional ownership, ($instown_{i,q}$) and the number of institutions holding the stock in hundreds ($breadth_{i,q}$). The variable of interest is the indicator variable capturing stocks that were randomly selected as part of the SEC pilot programme (*PILOT*). We note that the number of stock-quarter observations is 6506. A Hausman test reveals observed differences across stocks and quarters, so we report the two-way fixed effects estimates. Similar results are obtained using pooled OLS with Thompson (2006) SEs. *p* Values are reported in parentheses. Statistical significance at the 0.05 and 0.01 levels is denoted by * and **, respectively.

qualitatively similar to the conclusions we draw in columns [1]–[3]. That is, the coefficient on SHO, while significantly negative in column [4], decreases in both statistical and economic significance when we include all of the proxies for short-sale constraints. At a minimum, we are able to conclude that the multivariate tests provide only some support for our second hypothesis.

Next, we provide multivariate tests as a robustness to our findings in Panel B of Table 5, which show that pilot stocks had markedly lower skewness (and idiosyncratic skewness) than non-pilot stocks during the Regulation SHO period. In particular, we estimate the following equation.

$$\begin{aligned} Skew_{i,q} \text{ or } Iskew_{i,q} = \beta_0 &+ \beta_1 ret_{i,q} + \beta_2 ret_{i,q-1} \\ &+ \beta_3 ret_{i,q-2} + \beta_4 ret_{i,q-3} \\ &+ \beta_5 turn_{i,q} + \beta_6 rvolt_{i,q} \\ &+ \beta_7 size_{i,q} + \beta_8 instown_{i,q} \\ &+ \beta_9 breadth_{i,q} + \beta_{10} Pilot_i + \varepsilon_{i,q} \end{aligned} \quad (7)$$

The dependent variables and independent variables are similar to those in previous tables. However, the independent variable of interest is *Pilot*, which equals one for stocks that are classified as pilot stocks by the SEC. As before, we have to adjust our model by excluding stock fixed effects, given that including these effects along with the indicator variable *Pilot* would violate the full rank condition.

Table 7 reports the results from estimating Equation (7) and has a few noteworthy findings. First, the coefficients on the control variables are generally similar in sign as those in corresponding tables. However, we note that the coefficients on contemporaneous returns and the first two lagged returns are not reliably different from zero. Further, while the coefficient on breadth is negative, it is also statistically close to zero. Second, in each specification, we find that the estimate for *Pilot* is negative and significant at, at least, the 0.05 level. This result suggests that, after controlling for other factors that have been shown to influence the level of return skewness, pilot stocks had lower skewness than non-pilot stocks during the Regulation SHO period. This result further indicates that an exogenous relaxation of short-sale constraints adversely affected the level of both total skewness and idiosyncratic skewness.

Is the inverse relation between short interest and price delay driven by positive skewness?

In this final section, we test our third hypothesis by examining the interrelationship between short interest, skewness and price delay. Since Table 2 has already documented short interest is negatively related to price delay, which is consistent with findings in Blau (2012) and Boehmer and Wu (2013), we are ready to test whether skewness is a possible mechanism through which short interest reduces price inefficiency. To do so, we estimate the following variant of Equation (4).

$$Delay_{i,q} = \beta_0 + \beta_1 ret_{i,q-4,q-1} + \beta_2 Price_{i,q} + \beta_3 turn_{i,q} + \beta_4 r\_volt_{i,q} + \beta_5 B/M_{i,q} + \beta_6 size_{i,q} + \beta_7 instown_{i,q} + \beta_8 breadth_{i,q} + \beta_9 RSI_{i,q} + \beta_{10} skew_{i,q} + \beta_{11} RSI_{i,q} \times skew_{i,q} + \beta_{12} Iskew_{i,q} + \beta_{13} RSI_{i,q} \times Iskew_{i,q} + \varepsilon_{i,q} \quad (8)$$

As before, the dependent variable is the Hou and Moskowitz (2005) measure of price delay ($Delay_{i,q}$). The independent variables have been previously defined in earlier tables. However, we include two additional variables. The first is the interaction between relative short interest and total skewness ($RSI_{i,q} \times skew_{i,q}$) and the second is the interaction between relative short interest and idiosyncratic skewness ($RSI_{i,q} \times Iskew_{i,q}$). To the extent that the positive relation between skewness and price delay is driven by stocks with the least short interest, the interaction estimates are expected to be negative. Negative interaction estimates suggest that the marginal effect of skewness on delay, conditional on the level of skewness, is negative. As before, a Hausman test and *F*-tests reveal observed differences across stocks and quarters, so we report the two-way fixed effects estimates although we note that similar results are obtained using pooled OLS with Thompson (2006) SEs.

Table 8 reports the results from estimating Equation (8). Column [1] provides the results when we include the interaction between short interest and skewness. Consistent with the idea that the positive relation between skewness and price delay is reduced by short interest, we find a negative interaction estimate that is statistically different from zero (estimate = − 0.0141, *p* value = 0.002). In economic terms, this negative estimate suggests that a one SD in *RSI* reduces the direct relation between skewness and delay by approximately 30%.

Column [2] reports the results while including the interaction between short interest and idiosyncratic skewness. The interaction estimate is −0.0135 and is also reliably different from zero (*p* value = 0.001).

Table 8. Panel regressions – price delay.

	[1]	[2]
intercept	0.1750** (0.000)	0.1748** (0.000)
$ret_{q-4,q-1}$	0.0101** (0.000)	0.0101** (0.000)
$price_q$	−0.0170** (0.000)	−0.0168** (0.000)
$turn_q$	0.0345** (0.002)	0.0347** (0.002)
B/M_q	−0.0274** (0.000)	0.4589** (0.000)
r_volt_q	0.4507** (0.000)	−0.0273** (0.000)
$size_q$	−0.0704** (0.000)	−0.0704** (0.000)
$instown_q$	−0.0119 (0.113)	−0.0119 (0.112)
$breadth_q$	−0.0444** (0.000)	−0.0446** (0.000)
RSI_q	−0.0292** (0.003)	−0.0294** (0.003)
$skew_q$	0.0058** (0.000)	
$RSI_q \times skew_q$	−0.0141** (0.002)	
$Iskew_q$		0.0051** (0.000)
$RSI_q \times Iskew_q$		−0.0135** (0.001)
Adj. R^2	0.7829	0.7828
Stock FE	Yes	Yes
Qtr FE	Yes	Yes

The table reports the results of estimating the following equation.

$$Delay_{i,q} = \beta_0 + \beta_1 ret_{i,q-4,q-1} + \beta_2 Price_{i,q} + \beta_3 turn_{i,q} + \beta_4 r\_volt_{i,q} + \beta_5 B/M_{i,q} + \beta_6 Size_{i,q} + \beta_7 instown_{i,q} + \beta_8 breadth_{i,q} + \beta_9 RSI_{i,q} + \beta_{10} skew_{i,q} + \beta_{11} RSI_{i,q} \times skew_{i,q} + \beta_{12} Iskew_{i,q} + \beta_{13} RSI_{i,q} \times Iskew_{i,q} + \varepsilon_{i,q}$$

The dependent variable is the Hou and Moskowitz (2005) measure of Price Delay ($Delay_{i,q}$). We include as independent variables the prior year's return ($ret_{i,q-4,q-1}$), the natural log of price ($Price_{i,q}$), the contemporaneous share turnover ($turn_{i,q}$), the return volatility ($r\_volt_{i,q}$), the book-to-market ratio ($B/M_{i,q}$), the natural log of market cap ($size_{i,q}$), the natural log of institutional ownership, ($instown_{i,q}$), the number of institutions holding the stock in hundreds ($breadth_{i,q}$), the current relative short interest ($RSI_{i,q}$), the level of return skewness ($skew_{i,q}$), the interaction between relative short interest and skewness ($RSI_{i,q} \times skew_{i,q}$), the level of idiosyncratic skewness ($Iskew_{i,q}$) and the interaction between relative short interest and idiosyncratic skewness ($RSI_{i,q} \times Iskew_{i,q}$). A Hausman test and *F*-tests reveal observed differences across stocks and quarters, so we report the two-way fixed effects estimates. Similar results are obtained using pooled OLS with Thompson (2006) SEs. *p* Values are reported in parentheses. Statistical significance at 0.01 level is denoted by **.

The economic magnitude of the interaction estimate in column [2] is similar to the corresponding estimate in column [1]. Our findings in Table 8 support our third hypothesis that a possible mechanism by which short interest improves the efficiency of financial markets is through the channel of reducing return skewness.

IV. Conclusion

A growing body of research shows that some investors have preferences for stocks that resemble lotteries. Consistent with theory in Barberis and Huang (2008), this line of research shows that stocks with distributional characteristics that resemble lotteries exhibit price premiums and subsequently underperform other stocks (Zhang 2005; Mitton and Vorkink 2007; Kumar 2009; Boyer, Mitton, and Vorkink 2010; Bali, Cakici, and Whitelaw 2011; Kumar, Page, and Spalt 2011). These types of lotteries preferences might adversely affect the efficiency of stock prices. The first objective of this study is to test this assertion.

We find a positive and significant relationship between skewness and the Hou and Moskowitz (2005) measure of price delay, which captures the delay with which stocks incorporate market-wide information. These results are robust to both univariate and multivariate tests and indicate that indeed, stocks that are more positively skewed are less efficient. A natural extension to this finding might be to identify how skewness is reduced and subsequently how markets can be made more efficient. Motivated by theory in Xu (2007), which nicely develops the theoretical relation between short interest and skewness, our second objective of this study is to test whether or not short selling activity can meaningfully reduce positive skewness. Our multivariate tests provide strong evidence of a negative relation between short interest and skewness. After accounting for possible reverse causation and other potential endogeneity issues, we still find that short interest can meaningfully reduce both total and idiosyncratic skewness.

Observing a negative relation between short interest and skewness is not tantamount to determining that short interest can correct the inefficiencies associated with positive skewness. In our final set of tests, we attempt to determine whether the positive relation between skewness and price delay can be reduced by short interest. Consistent with our predictions, we find that when we condition on short interest, the positive relation between skewness and price delay substantially weakens. This is true whether we condition on total skewness or idiosyncratic skewness. In economic terms, our multivariate tests indicate that a one SD increase in short interest reduces the relation between skewness and price delay by approximately 30%. Given the results in our first set of tests that show that skewness is associated with less efficient stock prices, our combined results seem to imply that the ability of short interest to decrease return skewness is an important mechanism through which financial markets become more efficient.

Disclosure statement

No potential conflict of interest was reported by the authors.

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