Do Option Markets Undo Restrictions on Short-Sales: Evidence from the 2008 Short Sale Ban

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Abstract

We examine the effect of the September 2008 short sale ban on the trading behaviour in the options market. While theory suggests that long positions in put options are substitutes for short positions in the underlying stock, we find that the short sale ban has substantially driven up the cost of trading in options, to the extent that trading activity decreased for both put options and call options during the ban period. We further find that although violations of put-call parity are more frequent during the ban, the reduction in the transactional efficiency of the options market mitigates potential arbitrage profits.

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The effectiveness of any sanction depends on the costs of avoiding its restrictions. One rationale for the 2008 ban on short selling is a belief that a ban on short sales reduces the likelihood of a (further) collapse in prices associated with market manipulation. But although U.S. regulators banned short sales of specified U.S. financial stocks from the 19th of September through the 8th of October in 2008, they did not ban the trading in options. Manipulators can therefore still profit even when short sales are completely prohibited: those seeking to gain from a stock price collapse can profit by buying put options or writing call options.

This paper examines the relation between the 2008 short sale ban and the option market. We first focus on whether the ban on short sales increases option trading volumes. An investor who holds a stock at a time of increased uncertainty can reduce his exposure simply by selling it. It is investors who believe the stock is so overpriced that it should enter their portfolio with a negative weight who want to sell short.[1] The pessimistic group can still trade options when short sales in stock are banned. Given similar transactions costs for shorting stock and trading options, the substitution of option trades for short sales by pessimists might lead to an increase in option volumes for banned stock during the ban period. Consistent with this view, Blau and Wade (2009) provide evidence that options decrease the demand for short sales because of the substitutability of bearish options strategies and short selling. Similarly, Danielsen and Sorescu (2001) provide evidence consistent with the mitigation of short sale constraints resulting from the introduction of an option.

An expected increase in option volume during a ban on short sales also follows from other previous studies on short sale restrictions. Miller (1977) argues that a prohibition on short sales will increase both the stock price and the degree of

[1] This pessimistic group includes would-be manipulators. Manipulators need not believe that the current price is wrong per se, only that they can induce the price to become at least temporarily lower.

heterogeneity in investor beliefs, and Jones and Lamont (2001) present evidence that short sale constraints are consistent with overpricing of constrained stocks. Diamond and Verrecchia (1987) model a setting where constraints on short-selling do not bias prices upward, but do reduce the speed of price adjustment to private information, especially unfavourable private information, thereby increasing belief heterogeneity. One implication of an increase in belief heterogeneity is that, just as differences of opinion make a horse race, the Grundy and McNichols (1989) and Harris and Raviv (1993) models of trade in noisy rational expectations settings then predict that the volume of option trade will increase for banned stock during the ban period.

Note that the above models of trade are set in transaction cost free settings. Trading options in the real world however involves relatively large transactions costs. The second focus of this paper is to examine whether option bid-ask spreads increase when short sales of the underlying stock are prohibited. There are three reasons for this potential increase in spreads. First, any delayed reflection of negative private information in prices due to the ban creates a greater information asymmetry between those quoting prices and informed traders. This applies to both options and the underlying stock. Boehmer, Jones and Zhang (2009) investigate the effect of the 2008 ban on stocks and conclude that stocks subject to the ban suffered a severe degradation in market quality, as measured by the spreads on stock prices, price impacts, and intraday volatility. To the extent this was due to increased information asymmetry due to the ban, we would expect a diminution in the quality of the market for options. Second, during the ban period only option market makers were legally allowed to short banned stock and that exemption may have been limited to

"temporary" short positions.[2] Those who make a market in options on a banned stock may suddenly have some monopolistic pricing power and increase ask prices for puts and decrease bid prices for calls. A third potential reason for increased spreads during the ban follows from the fact that the ban followed an increase in uncertainty as measured by the VIX. A market maker's inventory cost of carrying a position in a written put until it can be hedged through a short sale or eliminated through a put purchase increases along with the increase in uncertainty. The ban itself may merely be contemporaneous rather causative, but option spreads will still be higher at the time of the ban.

The third focus of this paper is on market efficiency. An outright ban is the extreme of costly short-selling. Lamont and Thaler (2003), Ofek and Richardson (2003), and Ofek, Richardson and Whitelaw (2004) conclude that short sale restrictions are associated with violations of put–call parity that are asymmetric in the direction of short sales constraints, and that the magnitude of the violations is related to the cost of short selling.[3] Consistent with this, a ban designed to discourage downward price manipulation may actually have the effect of reducing the informational efficiency of the stock market and allowing stock prices to exceed the

[2] The SEC's emergency order prohibition on the short sale of the stock of financial institutions included an exception for market makers effecting short sales of restricted stocks. According to release no. 34-58611 the exemption applied for "bona fide market making and hedging activity related directly to bona fide market making in derivatives on" restricted stocks. It is not clear how market participants interpreted this exemption. If making a market requires the market maker to take a brief short position in a put, then it seems that the position could be hedged with a temporary short stock position. Unclear is however whether a market maker was allowed to maintain an ongoing short stock position to hedge an ongoing short put position. Interestingly, when the Dutch regulatory authorities (the AFM) banned short sales on 5 October 2008 and granted a similar exemption to their derivatives market makers their press release stated that "we [the AFM] would not expect Market Makers to hold significant short positions, other than for brief periods."

[3] Battalio and Schultz (2006) reach a quite different conclusion in their examination of options trades at the peak of the Internet bubble. They conclude that investors could have cheaply synthetically shorted using options and find no evidence that short-sale restrictions affected Internet stock prices.

values they would have in a setting of homogeneous information. In this paper we therefore also examine the effect that the ban has on violations of put-call parity.

The 2008 short sale ban was not introduced so that financial economists could run a controlled experiment on whether the trade in options can substitute for short sales in the stock market. The financial gods timed the ban to commence after a year-to-date 6.6% decline in the SPX and 42.9% increase in the VIX. And during the ban's brief life the SPX declined a further 18.4% and the VIX increased another 73.8%. Such changes in price levels and future price uncertainty can induce changes in option volumes, prices and spreads simply because the risks of the portfolios that investors seek to hedge will have changed and the diversity of investor beliefs may also have changed.[4] Thus we cannot ask the basic question: Does option volume increase when short sales are banned all else equal? But we can examine differences in option market behaviour before, during, and after the ban for financial stocks for which short sales were prohibited (restricted stocks) and for all other stock on which options were traded (unrestricted stocks).

Our findings are the following. We first show that the ban is associated with a decline in trade in put options on restricted stock. Controlling for changes in stock volume, stock returns, and the level of the VIX, we find that the average daily put option volume for restricted stock on average declines by 3,194 contracts during the ban. For unrestricted stock, the decrease during the ban is 490 contracts. After the ban is lifted, we find that put option volume increases again. When examining subsamples of in-the-money, at-the-money, and out-of-the-money put options, we conclude that the decrease in trading volume is present in each subsample, but strongest for at-the-money put options.

[4] See Bates (2000) for a study of the effect of the crash of 1987 on the market for index futures options.

We further find that trading volume in call options also decreases during the ban period, but the size of the decrease is much smaller than for put options. Furthermore, the difference is decline between call option volume for restricted and unrestricted stock is not statistically significant.

Hence, we find that a ban on short sales of stock is not circumvented by a trading in options. An explanation for this finding could be a change in spreads. That is, the increase in option volume expected as a result of both (a) the increase in investor belief heterogeneity occasioned by the ban and (b) the attempted substitution of legal option trades for prohibited short sales may not occur if option spreads increase at the time of the ban. In fact, the increase in transactions costs may lead to a net reduction in option volume. We indeed find an increase in spreads for put options on restricted stocks during the short sale ban, and find that this increase is significantly higher than the increase for unrestricted stock. After the ban is lifted, we find that spreads of put options decrease again.

Our results when viewed in the light of Blau and Wade (2009) and Danielsen and Sorescu (2001) suggest the following link between the stock and option markets. Investors who face high costs of short selling will prefer to buy puts. But someone must then be induced to write the put. The natural put writer is a party with low costs of shorting, e.g., an institution with the ability to borrow stock in house. The low-cost shorter will short and sell their exposure on to the high-cost would-be shorter via the options market. But when short sales are banned, a would-be short-seller who seeks a substitute long put position may find that there is no one who can use their usual ability to short at low-cost to hedge the necessary writing of the desired puts. Thus our results are consistent with those of Figlewski and Webb (1993) who present evidence of a significantly higher average level of short interest exhibited by optionable stocks

and argue (page 763) that "the put buyer's desire to sell the stock is transformed through the options market into an actual short sale by a market professional who faces the lowest cost and fewest constraints." When the transformation is precluded, so is the desired purchase of the put option.

According to Miller (1977), the short sale prohibition may lead stock prices to be upward biased. However, because option prices reflect potential payoffs at a future date (a date by which the bias may have been corrected), option prices are expected to be less biased. We therefore examine violations of put-call parity. More specifically, we examine whether for the at-the-money option pairs in our sample the package of the stock price and the put option is overpriced due to restrictions in short selling. We indeed find that the violations for restricted stock are significantly more frequent during the ban if we take the mid-point prices of the options to calculate violations. This indicates a decoupling of the stock and option market during the ban. However, implementing put-call parity arbitrage for overpriced stock will though involve selling the stock. During the short sale ban an apparent profit can then only be earned by those who already own the stock. Furthermore, attempting to capture the arbitrage profit requires selling at the bid price and buying at the ask price, which means that the increase in bid-ask spreads must be considered when examining whether arbitrage profits can be obtained. We find that spreads during the ban are so large that feasible trades based on sales at the best bid and purchases at the best ask may not allow even an owner of the stock to lock in an arbitrage.

Our study has implications for policy makers. For example, regulators in the U.S. did not explicitly restrict trading in the option markets during the short sale ban, while regulators in the Netherlands combined the short sale ban with a ban on trading in derivatives with negative deltas (i.e. buying a put option or writing a call option).

Our findings are also interesting for the ongoing debate on the uptick rule. The uptick rule precludes short selling if the last trade was either a down trade, or a flat trade following a flat or down trade. The uptick rule was introduced in 1938 following an enquiry into the effect of concentrated short selling during the 1937 Dow Jones Index collapse, a peak to trough decline from 194.4 to 98.95.[5] The rule was eliminated in 1997 after a series of empirical studies concluded the restriction had become ineffectual (see Alexander and Peterson, 1999). But the more recent market turmoil has brought forth calls for its reinstatement and the SEC is currently seeking comments on a proposed new variant of the uptick rule. The proposal involves, inter alia, a ban on short selling in a specific security for the remainder of the day if that security suffers a severe price decline. Understanding the effectiveness of the 2008 ban is important in evaluating the desirability of this proposed circuit breaker-style ban. Not only may short sale restrictions reduce the informational efficiency of the stock market, the evidence presented here suggests that short sale restrictions can decimate the transactional efficiency of options markets. A diminution of the value added by derivatives markets is a cost that should be recognized in the SEC's current deliberations on reintroducing an uptick rule.

The remainder of this paper is organized as follows. Section I provides the timeline of the imposed short sale ban and describes stock price returns at the time of the ban. Section II describes the data and presents summary statistics. Section III shows the empirical results regarding changes in option volume and Section IV examines bid-ask spreads. We report our results for violations of put-call parity in Section V, and Section VI provides robustness tests and examines the futures market. Section VII concludes.

[5] For an analysis of the effect of these early restrictions on short sales see Jones (2008).

I. Timeline and restrictions of the short sale ban

The first of the 2008 restrictions on short sales started July 15th, when the SEC issued an emergency order (release no. 58166) halting naked short selling in Freddie Mac, Fannie Mae, and 17 financial stocks. The stated goal was to limit so-called "rumourtrage", in which false rumours are spread by malicious traders seeking to profit on short positions. The order expired in mid-August. After the market closing on September 17th, a permanent ban (emergency order 34-58572) on naked short selling was issued for all U.S. firms, effective at midnight.

The next day, on September 18th, the FSA in the U.K. announced what would prove to be the first of a worldwide series of bans on short sales of specified financial stocks. The SEC followed suit with two emergency orders relating to short sales. The first (release no. 58591) required that institutional investors file any activity in their short positions in the previous week. The second (emergency order 34-58592), issued after the market close, halted all short selling on 797 financial stocks, effective immediately, with a limited exception for "certain bona fide market makers." Whether this exception would later include market makers in derivatives markets was, at the time, unclear, though the order did grant option market makers an immediate 24-hour delay given that September 19th marked the last trading day before the expiration of an array of index options, single equity options, and index futures. The order specified the ban would "terminate at 11:59 p.m. EDT on October 2nd, 2008, unless further extended by the Commission." Between September 19th and 22nd, nearly every major exchange worldwide followed suit, making provisions to restrict short selling of financial stocks.

Given the haste with which it had issued the original order, the SEC issued an amendment to the short-sales ban on September 21st in which it: 1) specified additional firms to be banned; 2) granted each exchange the authority to add firms to the list of banned stocks; 3) made allowances for short sales incurred in the expiration of certain options and futures contracts; and 4) exempted "any person that is a market maker that effects a short sale as part of bona fide market making and hedging activity related directly to bona fide market making in derivatives" unless "the market maker knows that the customer's or counterparty's transaction will result in the customer or counterparty establishing or increasing an economic net short position (i.e., through actual positions, derivatives, or otherwise) in the issued share capital of a firm covered by this Order." Boehmer, Jones, and Zhang (2008) speculate that the practical result of this last stipulation was simply to give market makers incentive to avoid learning a counterparty's net positions.

On October 2nd, the order was extended to terminate "at the earlier of (i) three business days from the President's signing of the Emergency Economic Stabilization Act of 2008 (H.R. 1424), or (ii) 11:59 p.m. E.D.T. on Friday, October 17, 2008." The following day, President Bush signed the act into law, and the SEC subsequently announced the ban would end at 11:59 p.m. E.D.T. on October 8th, 2008. Short selling would be allowed thereafter, though the naked short ban would remain in place.

II. Data and summary statistics

This section describes our data, shows stock returns during the ban and provides summary statistics for the options in our sample.

A. Data

We obtain the list of restricted stock from the original SEC emergency order (34-58592). Daily option prices, option volume, and stock prices are from the OptionMetrics IvyDB database. We use the Chicago Board Options Exchange Volatility Index (VIX) as a proxy for market-wide volatility. Our sample consists of stocks on the S&P 500. For a small number of firms, the ban was (un)installed on or after the 22nd. For the major investment banks and Freddie Mac and Fannie May naked shorts had already been banned before September. We remove both the firms added/deleted on or after the 22nd and the major financials subject to the earlier naked short sale ban from our main sample. We also exclude firms that have stock prices below five dollar at the start of the ban period, which leaves us with 467 firms. The short sale ban applies to 71 of these firms. We partition stocks into "restricted" and "unrestricted" categories. Appendix A lists the tickers of the firms in these categories. The sample period covers the interval between January 2nd, 2008, and January 28th, 2009.

B. Stock returns during the ban

Figure 1 shows the cumulative raw returns of equally-weighted portfolios constructed from restricted and unrestricted stocks for firms on the S&P 500.

[Insert Figure 1 about here]

The "restricted" line refers to S&P 500 stocks targeted by the ban, while the "unrestricted" line refers to the other S&P 500 firms in our sample. It can be seen that cumulative returns are negative for both restricted and unrestricted firms during the ban, which is also shown by Boehmer, Jones, and Zhang (2008). Note that the average

returns of restricted and unrestricted firms are relatively high on September 19th, 2008, the first day of the ban. Boehmer, Jones, and Zhang (2008) argue that these spikes are consistent with the constraints in short selling. However, an alternative explanation is that the positive returns are caused by the government's announcement on September 19th that it would bail out American Insurance Group (AIG).

Panel A of Table I shows the average stock returns and volumes for the firms in our sample over our complete sample period. The average return is negative for both restricted firms and unrestricted firms. Restricted firms have an average daily return of –0.19%, while unrestricted firms have an average daily return of –0.13% over our complete sample period. There on average 10.04 million shares traded on a given day for the firms in our restricted sample, and 6.68 million shares for the firms in our unrestricted sample.

[Insert Table I about here]

C. Summary statistics for put and call options

Panel A of Table I further reports that for the firms in our sample the average number of put-call options pairs for a firm on a given date is 64.7. A put-call option pair is a call and put option on a firm's stock on a given day with similar time to expiration and strike price. Panel B reports the average time to expiration and the moneyness of these option pairs. The average number of days to expiration is about 193 days. We use the natural log of the stock price divided by the strike price, $\ln(S/K)$, as our measurement of moneyness. The average moneyness in our sample is –0.11, which reflects the overall downward trajectory of prices during the sample period. Given

that we use a single metric for the moneyness of both put and call options, we note the following naming conventions:

	$\ln(S/K) < -0.1$	$-0.1 < \ln(S/K) < 0.1$	$\ln(S/K) > 0.1$
Put options	In-the-money	At-the-Money	Out-of-the-money
Call options	Out-of-the-money	At-the-Money	In-the-money

Panel C reports the daily total option volume per stock (OVS). The average daily put option volume per stock is 4,455. Each contract is written on 100 stocks, which means that these contracts correspond to 445,500 shares. The average daily call option volume is 5,441. Since we are mainly interested in measuring the change in trading activity across the aggregate number of options per stock in our sample (while distinguishing between call options and put options), we take the OVS measure as our primary volume measure.

We are also interested in the characteristics of the options that did trade on a day. For example, we want to examine whether trading shifted from at-the-money put options to in-the-money put options during the ban. Therefore, we also consider the total number of different options on different dates, henceforth referred to as an option-date. When we consider these option-dates, we have over 15 million observations in our sample. Panel D reports the trading volume of the option-dates. The average daily traded volume of a particular put option of a stock in our sample is 81.2 contracts. The standard deviation of both put and call option volumes is very high. This heterogeneity in volumes also shows in the percentage of options traded: 72% of the put options have a zero trading volume on a given date. A call option is slightly more likely to be traded, but again, the percentage of zero trade observations is high. Panel E reports trading volume of the options with a non-zero trading volume.

III. The effect of the short sale ban on option volume

In this section we investigate whether option volume for restricted stock increases during the short sale ban. Subsection A investigates overall option volume, while subsection B focuses on subsamples based on different ranges of moneyness.

A. Overall option volume

Figure 2 shows the average daily total option volume per stock over time.

[Insert Figure 2 about here]

It can be seen that OVS does not spike during the ban. In fact, both total put option volume and total call option volume are higher in the week before the ban, in which uncertainty about bankruptcies and bailouts was very high, than during the ban.[6]

In our regression analysis, we estimate the following OLS model:

$$\begin{aligned} OVS = {} & \alpha + \beta_1 Stock\ volume + \beta_2 Stock\ return + \beta_3 VIX + \beta_4 Restricted \\ & + \beta_5 Ban\ period + \beta_6 \left(Restricted \times Ban\ period \right) + \beta_7 Post\ Ban\ period \\ & + \beta_8 \left(Restricted \times Post\ Ban\ period \right) + \varepsilon \end{aligned}$$

where *OVS* is the daily total option volume per stock; *Stock volume* is the daily trading volume of the stock in millions; *Stock return* is the daily return on the stock, expressed as a decimal; *VIX* is the closing value of the CBOE Volatility Index on the observation date; *Restricted* is a dummy variable equal to one if the underlying stock is on the SEC list of restricted stocks, and zero otherwise; *Ban period* is a dummy variable equal to one if the observation date is between September 19th, 2008 and October 8th, 2008 (inclusive), and zero otherwise; and *Post Ban period* is a dummy variable equal to one if the date of the observation is after October 8th, 2008, and zero

[6] We find that the peak in option volume before the ban is mostly caused by high trading volume in options of AIG and GE.

otherwise. We expect higher volume in the option markets when stock trading volume and the VIX are higher. We further expect that positive stock returns relate to higher volume in call option trading, but lower volume in put option trading. Table II presents our regression results.

[Insert Table II about here]

We will first focus on put options. The results on the "Restricted" variable indicate that before the ban period, the firms in our restricted sample have higher put option volumes than the firms in our unrestricted sample. During the ban period, put option volume decreases. The negative coefficient of the interaction dummy between "Restricted" and "Ban period" in the put option regression indicates that restricted stock experience a significantly larger decrease in put option volumes during the ban period than unrestricted stocks experience. On average, the short sale ban decreases daily put option volume for unrestricted stock by 490 contracts per stock, while restricted stock have a daily put option decline of 3,194 contracts per stock (i.e. 490 + 2,704).

After the ban, average put option volume for restricted stock is 697 contracts lower than before the ban (587 – 1,284). Hence, after the ban is lifted, put option volume for restricted stock increases by 2,497 contracts (3,194 – 697) relative to volume during the ban period. Hence, we can conclude from Table II that overall volumes do not indicate that put option trades replaced short sales of stock during the 2008 short sale ban.

Table II also shows the results for call options. Before the ban, trading in call options is lower for restricted stock than for unrestricted stock. During the ban, call option volume decreases, but the difference in decrease between restricted and

unrestricted stock is not significant. After the ban, trading in call option increases again.

Stock volume has a positive and statistically significant effect on option volume. Regarding stock returns, we find that a negative stock return leads to an increase in put option volume but has no statistically significant effect on call option volume. Surprisingly, the level of the VIX is negatively related to both put and call volumes, though this may be the result of a contemporaneous increase in market-maker inventory costs and an increase in spreads.[7]

B. Subsample analysis

We next disaggregate the data by the options' moneyness. The rationale is simple. If would-be short sellers turn instead to the option market, they may be most attracted to long positions in deep-in-the-money puts if they are seeking to replicate the dollar price sensitivity of a short position in stock to a decline in the stock's price. If instead they want to maximize the percentage increase in the wealth associated with a stock price decline, they will be most attracted to deep out-of-the-money puts. Overall put option volume may have decreased, but a particular subsample might still show an increase in trading volume.

We partition our sample of daily option observations across ranges of moneyness. Thresholds are based on Ofek, Richardson and Whitelaw (2004). We examine options with moneyness between -0.3 and -0.1 (in-the-money for puts and out-of-the money for calls), for moneyness between -0.1 and 0.1 (at-the-money

[7] We have examined whether autocorrelation is a large issue in our sample. For example, we have tested whether Option Volume per Stock and Stock Volume are serially correlated per stock. To this end, for each stock we run augmented Dickey-Fuller tests on the option volume and stock volume time series. We find that even at the 99% confidence level, we can reject the null hypothesis of autocorrelation for 94.4% of the stocks in our sample. We also do not find strong indications of autocorrelation between the other variables in the regression specification.

options), and for moneyness between 0.1 and 0.3 (out-of-the-money for puts and in-the-money for calls). We again employ our daily total option volume per stock (OVS) measure, but now each observation is moneyness-dependent. For example, the OVS on at-the-money Citibank put options on August 18th would include all put options written on Citibank having an $\ln(S/K)$ between –0.1 and 0.1 on that date. Models (1)-(3) of Table III present the regression results for different subsamples of put options.

[Insert Table III about here]

It can be seen that the decrease in aggregated put volume for restricted stocks during the ban period is driven by a decrease in trading in at-the-money options. The coefficients for "Ban period" and the interaction term for "Restricted" and "Ban Period" are negative for all three subsamples, although not always statistically significant. We therefore do not find evidence that would-be short-sellers turn to a particular type of put option during the ban.[8]

Models (4)-(6) of Table III report the results for the subsamples of call options. We find that trading in at-the-money call options is less popular during the ban period for both restricted and unrestricted firms, while the results are insignificant for out-of-the-money calls. For in-the-money call options, we find that during the ban period trading volume increases for restricted firms, while this is not the case for unrestricted firms. This is interesting, since selling in-the-money call options is a strategy that would-be short sellers could follow. That is, instead of obtaining short positions in

[8] We have also examined a wide range of subsamples based on other segregations for moneyness, and subsamples based on a combination of ranges for moneyness and time to expiration. Again, trading volume during the ban decreases for the large majority of possible subsamples. The combination that gives the highest positive coefficient for the interaction term between "Restricted" and "Ban period" is for out-of-the-money puts with a time to maturity below 30 days (the coefficient on the interaction term is 624.2), indicating that some investors make the cheapest possible bet that stock prices will drop.

stock or buying put options, one could also sell call options if one believes stock prices will decline. The magnitude of the increase is however relatively limited. Compared to the period before the ban, the increase in total daily traded contracts of in-the-money call options for restricted stock is 367 contracts per firm.

IV. The effect of the short sale ban on option bid-ask spreads

One possible explanation for the finding that trading volume in the option market does not increase during the short sale ban is that the transactions costs of trading options increases during the ban. In this section we therefore examine option bid-ask spreads. We want to measure relative bid-ask spreads to examine how the short sale ban affects the spreads for both put and call options for restricted and unrestricted stock. A traditional measure for relative bid-ask spreads of securities like equities is

$$Relative\,Spread = \frac{Best\,Offer - Best\,Bid}{\left(Best\,Offer + Best\,Bid\right)/2} \times 100\%. \qquad (1)$$

This relative spread measure is not particularly appropriate for options. As a simple example, consider two call options on a stock XYZ. XYZ's price is currently $50. The options are identically specified except one has a strike price of $10 and the other has a strike price of $90. Given their respective deep in- and deep out-of-the-money qualities, they may likely have similar *absolute* bid-offer spreads, say 20 cents, but the option with a $10 strike price has a mid-point price of perhaps 30 cents, while the option with a $90 strike price has a mid-point price of perhaps $40.30. The relative spreads would then be 0.667 for the first option and 0.005 for the second option with the traditional measure.

With this in mind, rather than scaling the spread by the option's price, we argue for a measure of spreads relative to that component of the option value that is related to future uncertainty, namely the difference between an option's price and its intrinsic value. We calculate the *Adjusted Relative Spread (ARS)* for option *i* on date *t* as

$$ARS_{i,t} = \frac{Best\ Offer - Best\ Bid}{\frac{Best\ Offer + Best\ Bid}{2} - \text{intrinsic value}} \cdot 100 \qquad (2)$$

Best Offer refers to the lowest closing offer price and Best Bid refers to the highest closing bid price across all exchanges on which the option trades. The intrinsic value of a put option with an exercise price of K written on a stock worth S is max[0, K–S]. The intrinsic value of a call is max [0, S–K]. When option spreads are measured relative to the excess of an option's price over its intrinsic value, one obtains a better measure of just how high option transactions costs are. Figure 3 plots the typical pricing and intrinsic value for a put option, and illustrates further that our spread measure is more appropriate for comparing relative spreads for both in- and out-of-the-money options.

[Insert Figure 3 about here]

Our measure will be low for at-the-money options (relatively large denominator) and high for deep in- or out-of-the-money options (relatively small denominator).

We apply the following filters in obtaining our sample for the bid-ask spread analysis, in order to reduce the impact of price recording errors in very illiquid options: we eliminate observations when (1) the bid price is less than the intrinsic value of the option; (2) the closing offer is less than the closing bid; (3) the days to

expiration is smaller than 30 or higher than 365; (4) open interest is zero. We also delete observations when the mid-point price minus the intrinsic value is smaller than twice the difference between the offer and bid price. That is, as we scale the bid-offer spread by the distance between the mid-point price and the intrinsic value, we consider only those options for which the spread is sufficiently small relative to this distance.[9]

[Insert Figure 4 about here]

In Figure 4, we show smoothed scatter plots of adjusted relative spreads versus moneyness, where the darker the area, the higher the density of observations. As expected, the figures exhibit a U-shape pattern, as ARS is small for at-the-money options and large otherwise. To reduce the impact of the outliers that can be seen in Figure 4, we limit our sample in this section's further analyses to observations with a value for moneyness between -0.3 and 0.3. Panel A of Table IV reports summary statistics for our measure of relative spreads for this sample.

[Insert Table IV about here]

It can be seen that over our total sample period, adjusted relative spreads on call options are slightly higher than those on put options: the average ARS is 14.26% for calls and 13.87% for puts. To examine the relation between short sale restrictions and option bid-ask spreads, we estimate the following OLS regression:

$$ARS = \alpha + \beta_1 \left|\ln(S/K)\right| + \beta_2 Time\ to\ mat^{-1} + \beta_3 Restricted + \beta_4 Ban\ period + \beta_5 \left(Restricted \times Ban\ period\right) + \beta_6 Post\ Ban\ period + \beta_7 \left(Restricted \times Post\ Ban\ period\right) + \varepsilon.$$

[9] This implies that the maximum value for our ARS measure is 50.

where "|ln(S/K)|" is the absolute value of moneyness and "time to mat^{-1}" is the inverse of the time to maturity (expiration), expressed in years (i.e. 365/(days to maturity)). Results are presented in Panel B of Table IV.

Model (1) of Panel B shows the estimation results for put options. It can be seen that out-of-the-money put options have on average higher relative spreads than in-the-money put options, and the inverse of the time to maturity has a positive effect on our ARS measure. In the period before the ban, the financial firms in our sample did not have significantly different spreads than the non-financial firms. Although spreads increase for unrestricted stock during the ban, the spreads for restricted stock increase even more dramatically during the short sale ban. The interaction term between "Restricted" and "Ban period" is 3.23, which indicates that the relative spread for restricted stock increases by an absolute 3.23% during the ban taking the unrestricted firms as the benchmark, and an absolute 6.22% compared to before the ban. Given the average spread of 14.26% over the total sample period, this increase is quite substantial. The spread for restricted stock is lower after the ban than during the ban, which is also in line with our expectations. In fact, the spread after the ban is even lower than the spread before the ban. The R^2 of the model is 0.19.[10]

Model (2) in Panel B reports the results for call options. The results are very similar to those for put options. The only difference in significance is that for call options the restricted stock already had significantly higher spreads than unrestricted stock before the ban was introduced.

In unreported analyses, we have also examined subsamples for our adjusted relative spread measure, based on different ranges of moneyness, similar to the subsample analysis of volumes in Table III. We find positive coefficients in each

[10] We have re-estimated our regression with the traditional relative spread measure as the dependent variables, and although our main results are qualitatively similar, the R^2 drops substantially, to 10%.

subsample for the interaction term between the variables "Restricted" and "Ban period", and we further find that these coefficients are relatively similar over the subsamples and are always highly statistically significant.

Option spreads can increase during the short sale ban for a number of reasons. First, the short sale ban period could be characterized by higher information asymmetry when pessimists' views are less able to influence stock prices. Second, those willing to write options may have suddenly exercised pricing power when they did not have to compete with others who might normally have written puts while simultaneously hedging their short put position by shorting stock. Third, the risk component of a market-makers' inventory costs may be higher since the ban accompanies a general market wide increase in uncertainty as reflected in the higher level of the VIX. These reasons are not mutually exclusive.

V. Short sale restrictions and put-call parity

The short sale prohibition may lead stock prices to be upward biased (Miller, 1977), but because option prices reflect potential payoffs at a future date (a date by which the bias may have been corrected), option prices are expected to be less biased. Therefore, the short sale ban can lead to a decoupling of option and stock prices analogous to that previously documented in Ofek, Richardson and Whitelaw (2004) for stocks with high short sale costs.

Implementing put-call parity arbitrage for overpriced stock will though involve selling the stock. During the short sale ban an apparent profit can then only be earned by those who already own the stock. Furthermore, the increase in bid-ask spreads must be considered when examining whether arbitrage profits can be obtained. Attempting to capture the arbitrage profit requires selling at the bid price and buying

at the ask price. Based on bid-ask mid-point prices one might conclude that stock and option markets are decoupled. But spreads might be so large that feasible trades based on sales at the best bid and purchases at the best ask may not allow even an owner of the stock to lock in an arbitrage. In this section we examine whether stock and option mid-point prices become decoupled by the ban and separately ask whether any such decoupling is associated with an increase in the frequency of feasible arbitrage opportunities.

A. Put-call parity

Put-call parity for European options of non-dividend paying stock can be written as:

$$p(S,t,K) + S = c(S,t,K) + Ke^{-rt} \tag{3}$$

in which S is the stock price, K is the strike price, r is the continuously compounded zero-coupon interest rate, t is the time to expiration, and c and p are European call and put options, respectively, with similar maturity and strike price K. If we set the dividends with ex-dates prior to the option's maturity as *div*, put-call parity for European options is:

$$\begin{aligned} p(S,t,K) &= c(S,t,K) + Ke^{-rt} - \left[S - PV(div)\right] \\ &= c(S,t,K) + Ke^{-rt} - S + PV(div). \end{aligned} \tag{4}$$

For American options put-call parity is less straightforward. This follows because American options can be exercised early, which leads to an early exercise premium for put options. Although many previous papers have constructed analytical valuation formulas for American put options in which explicit values are given for the early exercise premium (see, e.g., Johnson, 1983; Geske and Johnson, 1984, Ho, Stapleton and Subrahmanyam, 1994), there is no widely accepted formula for calculating the early exercise premium for American put options. Also, for firms that

pay dividends, there would be an early exercise premium for call options, providing further complications for an equality of put-call parity.

Therefore, we do not focus on an equality function, but on a boundary. If the short sale prohibition leads stock prices to be upward biased, while option prices are less biased, then we are more likely to observe that the upper bound for put-call parity is violated than if all prices are unbiased. Hence, to examine whether the package of the stock price and the put options are overpriced due to restrictions in short selling, we have to look at the upper bound of this package. Without depending on a calculation of early exercise premiums, we can state this upper bound for put-call parity for American options as:

$$P(S,t,K) + S \leq C(S,t,K) + K + PV(div) \tag{5}$$

Appendix B presents the proof of this bound. We assume that during our estimation period the market was not anticipating any dividend growth in the immediate future. We therefore calculate the present value of the dividends (for a company whose regular quarterly cycle last involved a dividend of d and with a single dividend ex-date at time $t"$ during the remaining life of the option) as

$$PV(div) = de^{-rt"} \tag{6}$$

Note that when the market anticipated a decrease in dividends in 2009, we are likely to overestimate the present value of the dividends, which reduces the probability that we find a violation of Eq. (5).[11]

B. Put-call parity summary statistics

[11] We have examined whether the financial crisis had a strong effect on dividend payments in the last quarter of 2008. We examined dividend payments for stocks in the S&P 500 over 2008 as reported in CRSP, and found that a decrease in dividend payments for the last quarter of 2008 is rare. Typically, firms pay a similar dividend in the last quarter of 2008 as in the first quarter of 2008.

Since not all options are being traded frequently, we want to focus on the pairs that are expected to be relatively liquid. Our sample for this analysis is therefore a subset of our previous analyses. We limit our sample to one option pair per stock per day. We have several requirements of these option pairs to ensure that the pairs are relatively liquid and to reduce recording errors. These requirements are based on Ofek, Richardson and Whitelaw (2004). We require that: both the put and call options have positive open interest; ln(S/K) is between -0.3 and 0.3; the time to expiration is between 30 and 180 days; the call's bid-ask spread is smaller than 50% of the (call price – max[0, S-K]); the put's bid-ask spread is smaller than 50% of the (put price – max[0, K-S]); the call price is not smaller than S-K; and the call price is not smaller than S-PV(K)-PV(div).

In line with Ofek, Richardson and Whitelaw (2004), we select option pairs that are closest to having an ln(S/K) of zero, i.e. we select the option pairs that are closest to being at-the-money. If multiple option pairs of a firm on a day are closest to being at-the-money, then we select the option pair from these pairs that has a time to expiration closest to 105 days. We end up with 115,073 option pairs in our sample.

We construct the variable "violation mid-point" by using closing midpoint prices. The variable equals one if we observe that $P(S,t,K)+S > C(S,t,K)+K+de^{-rt}$", and is zero otherwise.[12] To trade on a potential violation of the upper bound, one needs to sell the relatively overpriced package of the put option and the stock and buy the relatively underpriced call option. When you

[12] We obtain the dividend payments (dates and amounts) in 2008 from CRSP. We predict that the dividend payments in 2009 occur on the same dates as in 2008, and set the amount expected in 2009 equal to the dividend payment of the stock in the last quarter in 2008 (or for firms that pay dividends annually: to the dividend payment in 2008). The interest rate that we use to calculate the present value is the daily continuously compounded zero-coupon interest rate, which we obtain from OptionMetrics. We use interpolation from a zero curve using LIBOR rates: for the present value of the dividends we match the maturities in the zero curve with the time to the dividend payments.

sell the put option and stock you receive the bid price. When you buy the call you pay the ask price. We therefore calculate the variable "violation arbitrage" by taking the lowest closing ask price for call options and the highest closing bid price for put options and shares. Table V shows the descriptive statistics of our put-call parity sample.

[insert Table V about here]

A violation of the upper bound of put-call parity for American options is not an extremely rare event. In our sample, 10.8% of the observations violate put-call parity based on mid-point prices. When we calculate violations by using bid and ask prices, we find that this percentage is only 1.8%. The highest stock price during our sample period ($685.33) is recorded by Google, while the lowest stock price ($1.86) is recorded by AMD. By construction, the average time to maturity and ln(S/K) of the options is close to 105 and zero, respectively.

C. Short sell restrictions and violations of put-call parity

We test for the effect of the short sale ban on violations of put-call parity in a multivariate analysis, in which we control for possible effects of stock volume, stock returns, and the VIX on put-call parity violations. We estimate the following binary probit regression: $Violation = \beta_0 + \beta_1 Restricted + \beta_2 Ban\ period + \beta_3 (Restricted * Ban\ period) + \beta_4 Post\ Ban\ period + \beta_5 (Restricted * Post\ Ban\ period) + \beta_6 ln(Stock\ Volume) + \beta_7 Stock\ Return + \beta_8 VIX + \varepsilon$. Table VI shows the results.

[insert Table VI about here]

Model (1) reports the results with the mid-point violation variable as the dependent variable, and Model (2) reports the results for the arbitrage violation variable. When we first consider violations based on mid-point prices, we find that restricted firms are more likely to violate put-call parity before the ban than unrestricted stock, all else equal, as indicated by the "Restricted" variable. During the ban, the violations increase (as indicated by the "Ban period" variable), and this increase is significantly higher for restricted stock than for unrestricted stock (as indicated by the interaction term "Restricted × Ban period"). After the ban, overall violations increase even further ("Post Ban period"), but this increase is especially caused by unrestricted stock. In fact, the interaction dummy between "Restricted × Post Ban period" is significantly negative.

The violations during the short sale ban do not necessarily point towards arbitrage opportunities. There are two reasons for this. First, if short selling is restricted, one needs to own a stock to profit from the violation. Second, for arbitrage profits, we have to focus on bid and ask prices instead of mid-prices. Even though that we established in Model 1 that during the ban the difference in violations between restricted stock and unrestricted stock increases for mid-point prices, Model 2 shows that this difference is not significant when we consider bid and ask prices. Thus, even though mid-prices indicate a decoupling of stock and option prices during the ban for restricted stock, the increase in bid-ask spreads seems to mitigate a large part of the profitable trading strategies for arbitrageurs, even if the arbitrageur owns the stock.

VI. Robustness tests and the futures market

In this section we provide various robustness tests. We also examine whether activity in the futures market increases during the short sale ban.

A. Matched sample

Throughout the paper, we have compared a sample of 71 restricted stocks (i.e. financial firms) to 396 unrestricted stocks. On average, these two samples are quite different in a range of firm characteristics. As an alternative we therefore compare our sample of restricted stock to a matched sample. To create this matched sample, we match unrestricted S&P 500 stocks to restricted stocks on implied volatility and market capitalisation, as these firm characteristics are potentially important for trading volume, bid-ask spreads, and violations of put-call parity. Implied volatilities and market capitalisation are measured on a single date – 2 September 2008 – which is both subsequent to the July/August naked short sale ban and prior to the September/October short sale ban. In fact, 2 September was a time of relative calm in a turbulent second half of 2008. For implied volatilities, we select the most at-the-money option possible with a time to expiration closest to 105 calendar days. Group E of Appendix A reports the tickers of our matched sample. The average market capitalization for our matched sample is 27 billion dollars, compared to 26 billion dollars for the firms in our restricted sample. The average implied volatility is 0.45 for our matched sample, and 0.49 for restricted stock.

We replicate Table II by employing our matched sample instead of our larger sample of unrestricted stock. Models (1) and (2) of Table VII show the results.

[insert Table VII about here]

It can be seen that the coefficient of our main variable of interest, the interaction term between “Restricted” and “Ban period” for put options, is with -3,174

relatively similar to the coefficient found in Table II (-2,704), and both are significant at the 1% level. For call options, we find that the effect of this interaction term is still insignificant when employing our matched sample, although the sign of the coefficient switched from negative to positive. The effects of the other variables are also relatively similar. In unreported analysis, we find that our results for bid-ask spreads and put-call parity violations are also unaffected by using our matched sample.

B. Delta volume and open interest

As another robustness check, we calculate Delta Volume per Stock (DVS), which is the sum of the volume times the delta of each option *i* written on stock *S* on date *t*:

$$DVS_{S,t} = \sum_{i}^{i \in S} vol_{i,t} * | delta_{i,t} | \qquad (7)$$

DVS is similar to Overall Volume per Stock (OVS), except that each option's volume is scaled by the absolute value of its delta. DVS is consequently proportional to the equivalent number of shares bought or sold implied by trades in the options market. We measure DVS only for option-dates with non-zero deltas, as calculated by OptionMetrics.[13] Models (3) and (4) of Table VII show the results of estimating the model:

$$\begin{aligned} DVS = {} & \alpha + \beta_1 Stock\ volume + \beta_2 Stock\ return + \beta_3 VIX + \beta_4 Restricted \\ & + \beta_5 Ban\ period + \beta_6 \left(Restricted \times Ban\ period \right) + \beta_7 Post\ Ban\ period \\ & + \beta_8 \left(Restricted \times Post\ Ban\ period \right) + \varepsilon \end{aligned}$$

When we compare the estimated coefficients for DVS with the corresponding coefficients for OVS found earlier in Table II, we observe little discrepancy in the

[13] According to the OptionMetrics Ivy DB reference manual, the implied volatility – and consequently the delta – will be undefined if any of the following conditions holds: 1. the option is a "special settlement"; 2. the midpoint of the bid/ask price is below intrinsic value; 3. the vega of the option is below 0.5; 4. the implied volatility calculation fails to converge; or 5. the underlying price is not available.

signs and significance. In particular, the coefficients on *Restricted*, *Ban Date*, and *Restricted x Ban Date* are all qualitatively similar for our DVS and OVS measures, both for put and call options.

We also examine open interest. We aggregate Open Interest per Stock (OIS) analogously to Option Volume per Stock: we sum up all open interest on all put (call) options written on stock *S* on date *t*. We then calculate the daily change in aggregate open interest per stock, discounting the mechanistic drop in open interest that occurs when options expire. That is, $\Delta OIS_{S,t} = OIS_{S,t} - OIS_{S,t-1} + \widehat{O}IS_{S,t-1}$, where $\widehat{O}IS_{S,t-1}$ is the sum of all open interest for options on *S* expiring on date *t*. $\widehat{O}IS_{S,t-1}$ is consequently zero for every date in a calendar month except the day prior to expiration (the third Friday of every month). In line with our results on trading volume, we do not find that the average changes in open interest during the ban period are larger than the average changes before or after the ban period (not reported for parsimony).

C. Firms affected by the July naked short sale ban

In order to make a fair comparison between restricted and unrestricted stock, we have excluded the firms in our analysis that were already affected by the naked short sale ban in July. In our original sample of S&P stocks, these firms are Bank of America, Citigroup, Goldman Sachs, JP Morgan, Merrill Lynch, and Morgan Stanley. However, these firms are potentially the most interesting ones to look at. We have therefore analysed these firms in isolation, and have re-estimated our regressions when these six firms are included. We find that the six stocks behave very similar to other financial stocks, and conclude that none of our main results are affected by excluding the stocks that were targeted by the July naked short sale ban. Arguably, the most

interesting result to report is on violations of put-call parity. Panel B of Table VII shows the percentage of violations over the six firms before, during, and after the ban. For violations with mid-point prices, it can be seen that the violations of put-call parity rise dramatically during the ban period: from about 3% before the ban to 34% during the ban. For violations on bid and ask prices, the increase during the ban is much less dramatic.

D. Stock futures

As a final test we consider the possibility that investors transferred some of their trading to the single stock futures market when the short-sales ban was in place. We use data from OneChicago (the U.S. futures market), which go back to April 7th, 2008. In Figure 5 we plot daily average futures volume for restricted and unrestricted stocks.

[Insert Figure 5 about here]

The volume is very low through the observation period. As the vast majority of single stock futures contracts are written on 100 shares, the graph implies a very low number of futures contracts traded on a given date. Given this result, we do not believe the single stock futures market played a significant role during the short sales ban.

VII. Conclusion

This paper examines the differential trading activity in options markets for financial stocks during the SEC ban on short sales between September 19th and October 8th, 2008. We investigate the differences in option volume between the periods before, during and after the ban and examine these time-period differences separately for

stocks that are restricted by the ban and those that are not restricted. We also examine differences at a point in time between option volumes for restricted and unrestricted stocks.

We find that option volume for both put options and call options decreases during the period of the ban for stock for which short sales are restricted. The effect is strongest for put options. We also find that relative spreads tend to increase for put options on restricted stocks during the ban period. After the removal of the ban, put option volume increases again, while spreads decrease compared to their levels during the ban. We further find that the short sale ban leads to a decoupling of stock and option prices, but the reduction in transactional efficiency mitigates the majority of these potential arbitrage profits.

On the face of it, the ban seems almost perfectly suited to test the substitutability of shorts sales and put options. The results suggests that while would-be short-sellers might wish to substitute long positions in puts for short positions in stock, the short side of the desired put trade is missing. One source of written puts is sales by those who simultaneously hedge by shorting stock. When such a hedge is precluded, put writers are not available to satisfy the would-be short-sellers desire to substitute into put options. The results suggest that options market-makers acted as if their exemption from the ban was limited and precluded significant short positions other than for brief periods.

The issue from a research standpoint is that the ban was enacted neither on a random set of stocks nor on a random interval of time, so simply examining volumes or returns with and without the ban on short sales does not tell a complete story. This type of endogeneity is an issue for all empirical studies on short sales restrictions, given that such restrictions are generally implemented (or relaxed) in response to

changes in market conditions. Still, the extreme nature of the market trends during our sample period underlines the caution with which researchers should proceed when approaching the topic.

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Appendix A: Restricted stocks, unrestricted stocks, and matched sample

We report Ticker codes.

Restricted Stocks

Group A: Restricted Stocks included in original sample

ACAS	BBT	CVH	HBAN	LNC	NDAQ	SCHW	UNH
AET	BEN	DFS	HCBK	LUK	NTRS	SHLD	UNM
AFL	BK	ESRX	HIG	MBI	NYX	SLM	USB
AIG	CB	FHN	HUM	MCO	PBCT	SOV	WB
AIZ	CI	FII	ICE	MET	PFG	STI	WFC
ALL	CIT	FITB	JNS	MHP	PGR	STT	WLP
AMP	CMA	GE	KEY	MI	PNC	TMK	XL
AOC	CME	GM	L	MTB	PRU	TROW	ZION
AXP	COF	GNW	LM	NCC	RF	TRV	

Group B: Restricted Stocks included in the July 2008 naked short sales ban

BAC	C	GS	JPM	MER	MS

Group C: Restricted Stocks excluded due to addition / deletion from the list during the ban

AIV	CBG	DDR	HRB	MHS	R
AN	CVS	GT	IBM	PLD	TXT

Group D: Restricted Stocks excluded due to no option data or stock price below $5

CINF	ETFC	F	IVZ

Unrestricted Stocks

Group E: Unrestricted Stocks matched by size and implied volatility to Group A Restricted Stocks

AA	AVP	CSX	GENZ	HOT	MA	RRC	TSO
ADSK	BBY	DHI	GME	HSY	MEE	RTN	VLO
AES	BTU	DRI	GWW	IGT	MON	SLB	VMC
AKS	CA	DVN	HAS	IP	NSC	SNDK	WFR
AMD	CEG	EBAY	HCP	IR	NUE	SYK	WMB
APA	CF	EMC	HD	JAVA	NVDA	SYMC	WMI
APC	CNP	EP	HES	LO	OMC	TGT	XOM
APOL	COG	EXPD	HOG	LSI	PCP	THC	YUM
ATI	CRM	FDX	HON	M	PNW	TIE	

Group F: Unrestricted stocks matched by size and implied volatility to Group B restricted stocks

AAPL	AMZN	FCX	GOOG	INTC	OXY

Group G: All other unrestricted stocks in our sample

A	BRL	DE	FRX	KO	NKE	RIG	TJX
ABC	BSX	DELL	FTR	KR	NOC	RL	TLAB
ABT	BXP	DF	GAS	KSS	NOV	ROH	TMO
ACS	CAG	DGX	GCI	LEG	NOVL	ROK	TSN
ADBE	CAH	DHR	GD	LEN	NSM	RRD	TSS
ADI	CAM	DIS	GILD	LH	NTAP	RSH	TWX
ADM	CAT	DOV	GIS	LIZ	NVLS	RX	TXN
ADP	CBE	DOW	GLW	LLL	NWL	S	TYC
AEE	CBS	DPS	GPC	LLTC	NYT	SBUX	UNP
AEP	CCE	DTE	GPS	LLY	ODP	SE	UPS
AGN	CCL	DTV	GR	LMT	ORCL	SEE	UST
AKAM	CELG	DUK	HAL	LOW	PAYX	SGP	UTX
ALTR	CEPH	DVA	HAR	LTD	PBG	SHW	VAR
AMAT	CHK	DYN	HNZ	LUV	PBI	SIAL	VFC
AMGN	CHRW	ECL	HPQ	LXK	PCAR	SII	VNO
AMT	CIEN	ED	HRS	MAR	PCG	SJM	VRSN
ANF	CL	EFX	HSP	MAS	PCL	SLE	VZ
APD	CLX	EIX	HST	MAT	PDCO	SNA	WAG
APH	CMCSA	EK	IFF	MCD	PEG	SO	WAT
AVB	CMI	EL	INTU	MCHP	PEP	SPG	WEC
AVY	CMS	EMN	IPG	MCK	PFE	SPLS	WFMI
AW	CNX	EMR	ISRG	MDT	PG	SRCL	WFT
AYE	COH	EOG	ITT	MIL	PGN	SRE	WHR
AZO	COL	EQ	ITW	MKC	PH	STJ	WIN
BA	COP	EQR	JBL	MMC	PHM	STR	WMT
BAX	COST	ERTS	JCI	MMM	PKI	STZ	WPI
BBBY	COV	ESV	JCP	MO	PLL	SUN	WU
BCR	CPB	ETN	JDSU	MOLX	PM	SVU	WY
BDK	CPWR	ETR	JEC	MOT	POM	SWK	WYE
BDX	CSC	EXC	JNJ	MRK	PPG	SWN	WYN
BHI	CSCO	EXPE	JNPR	MRO	PPL	SWY	WYNN
BIG	CTAS	FAST	JNY	MSFT	PSA	SYY	X
BIIB	CTL	FDO	JWN	MTW	PTV	T	XEL
BJS	CTSH	FE	K	MUR	PX	TAP	XLNX
BLL	CTX	FIS	KBH	MYL	PXD	TDC	XRAY
BMC	CTXS	FISV	KFT	NBL	QCOM	TE	XRX
BMS	CVG	FLR	KG	NBR	QLGC	TEG	XTO
BMY	CVX	FLS	KIM	NE	RAI	TEL	YHOO
BNI	D	FO	KLAC	NEM	RDC	TER	ZMH
BRCM	DD	FPL	KMB	NI	RHI	TIF	

Group H: Unrestricted stocks excluded due to no option data or stock price below $5

BF	MDP	MWV	NWS	SNI	WPO
LIFE	MU	MWW	Q	VIA	

Appendix B: The upper bound for put-call parity with American options and dividends

The upper bound for put-call parity for American options

is $P(S,t,K)+S \le C(S,t,K)+K+PV(div)$

Proof of bound: Suppose that in fact the inequality were violated and that

$P(S,t,K)+S > C(S,t,K)+K+PV(div).$

To realize an arbitrage profit, sell the relatively overpriced package of the American put and the stock and buy the relatively underpriced package of (i) the American call, (ii) an investment of K in bonds and (iii) the purchase of a security that guarantees to pay you an amount equal to any dividends on the stock paid between times 0 and t.[14] You gain initially by the difference between the values of the relatively overpriced package and the relatively underpriced package.

The set of scenarios you now face are:

I. The put is never exercised against you:

During the life of the option you use the proceeds of the dividend claim to honour your commitment to pay cash in lieu of the dividend to the party who lent you the stock to short-sell. Let S^* denote the stock price at the option's maturity. If the put is

[14] Such a security can always be constructed by going long in stock and selling a forward contract on that stock with a maturity date of time t and borrowing an amount equal to the present value of the forward price. During the life of the option you will receive the dividends. At time t you will deliver the stock given your commitment under your short forward position. You will use the forward price paid to you to payoff what you owe on your borrowings with interest. Let $F(S,t)$ denote this forward price. $F(S,t)=\left[S-PV\left(\text{Dividends with ex-dates prior to time } t\right)\right]e^{rt}$. The cost of acquiring the right to the dividend is then $PV\left(\text{Dividends with ex-dates prior to time } t\right)=S-F(S,t)e^{-rt}$.

never exercised against you, then $S^* > K$ and you owe one share at maturity. Exercise your call. Your bond-holdings are more than sufficient to cover the exercise price. Use the stock you acquire by exercising your call to close out your stock position. $Ke^{rt} > K$ and hence you gain by $K\left(e^{rt}-1\right)$ at the option maturity date.[15]

II. The put is exercised against you at some time t' with $0 \le t' \le t$:

Prior to the exercise of the put use the proceeds of the dividend claim to honour your commitment to pay cash in lieu of the dividend to the party who lent you the stock to short-sell. Let S^{**} denote the value of the stock on the date the put is exercised against you. If the put is exercised against you then $S^{**} < K$ and you owe one share.[16] Do not exercise your call. Use the stock delivered to you as a result of the put's exercise to close out your short stock position. You must pay the put-holder the agreed exercise price *K*. Your bond-holdings are at least enough to cover this exercise price: $Ke^{rt'} \ge K$. The inequality is a weak inequality because the put might be exercised against you as soon as you have sold it, i.e., at time $t' = 0$. Thus at time t' you have

(i) The American call worth $C\left(S^{**}, t', K\right) \ge 0$; plus

(ii) The interest earned to date on your bonds; i.e., $K\left(e^{rt'}-1\right) \ge 0$; plus

(iii) The right to any dividends that might be paid between times t' and t which is worth $S^{**} - F\left(S^{**}, t\right)e^{-r(t-t')} \ge 0$.

Thus whether or not the put is ever exercised against you, you gain

[15] If in fact the put is never exercised against you but $S^* < K$, then you gain from the put-holder's irrationality as well.

[16] If when the put is exercised against you $S^{**} > K$, you again gain from put-holder irrationality.

$P(S,t,K)-\left[C(S,t,K)+K-S+PV(div)\right]$ when the position is established and possibly more later.

Table I: Summary statistics

This table reports summary statistics. The sample period is 2-1-2008 to 28-1-2009. Our sample consists of firms in the S&P 500. Restricted firms are firms for which short sales are restricted during the ban. We exclude firms for which short sales were restricted before the September-ban, and firms for which the restricted status changed during the ban. Panel A reports the stock returns and volumes for the firms in our sample, and also reports the average number of put-call option pairs on a stock on a given date. Average daily volume is in millions of shares. A put-call option pair is a call and put option on a firm's stock on a given day with similar time to expiration and strike price. Panel B reports summary statistics for option pairs. ln(S/K) is the metric for moneyness, with negative values reflecting in-the-money put options and out-of-the-money calls. Panel C reports summary statistics on daily option volumes per stock, and Panel D reports summary statistics for daily option volume per option. Each unit of volume corresponds to a single contract written on 100 shares. Panel E is similar to Panel D, but only includes option-dates in which the option is actually traded.

Panel A: Stock returns, stock volume, and number of options per firm

	All	Restricted	Unrestricted
Number of firms	467	71	396
Average daily stock return	-0.14%	-0.19%	-0.13%
Average daily stock volume (mil. shares)	7.19	10.04	6.68
Average number of option pairs per day on one stock	64.7	73.3	63.1

Panel B: Time to expiration and moneyness for option pairs

	All	Restricted	Unrestricted
Number of option pairs	7,707,428	1,492,983	6,214,445
Average number of days to expiration	193.1	196.5	192.3
Average ln(S/K)	-0.111	-0.134	-0.106

Panel C: Daily total option volume per stock

	N	Average	St. dev	Min	Max
Put option volume	127,155	4,455.0	14,308.0	0	1,062,962
Call option volume	127,156	5,440.8	20,632.6	0	2,815,869

Panel D: Daily option volume per option

	N	Avg.	St. dev	Min	Max	% Zero volume
Put option volume	7,903,864	81.2	899.0	0	512,843	72%
Call option volume	7,707,428	95.3	1,282.9	0	1,515,319	66%

Panel E: Daily option volume per traded option

	N	Avg.	St. dev	Min	Max	% Zero volume
Put option volume	2,204,710	291.1	1,684.1	1	512,843	-
Call option volume	2,621,435	280.2	2,188.0	1	1,515,319	-

Table II: The effect of the short sale ban on option volume

This table reports the effects of the short sale ban on option volume. The sample period is 2-1-2008 to 28-1-2009. Our sample consists of firms in the S&P 500. Restricted firms are firms for which short sales are restricted during the ban. We exclude firms for which short sales were restricted before the September-ban, and firms for which the restricted status changed during the ban. We report the result of an OLS regression. The dependent variable is option volume per stock: the total put (call) option volume for a given stock on a given date. Each unit of volume corresponds to a single contract written on 100 shares. Stock volume is the daily trading volume of the stock in millions. Stock return is the daily return on the stock, expressed as a decimal. VIX is the closing value of the CBOE Volatility Index on the observation date. Ban period is a dummy variable equal to one if the observation date is between September 19th, 2008 and October 8th, 2008 (inclusive), and zero otherwise. Post Ban period is a dummy variable equal to one if the date of the observation is after October 8th, 2008, and zero otherwise. We report Huber-White heteroskedasticity-corrected standard errors in parentheses. * indicates significance at the 1% level.

	Put option volume	Call option volume
	(1)	(2)
Constant	856.1*	2,675.9*
	(151.3)	(189.0)
Stock Volume	659.8*	815.0*
	(35.6)	(37.5)
Stock Return	-108.0*	55.4
	(20.8)	(23.5)
VIX	-44.6*	-92.7*
	(7.0)	(8.6)
Restricted	1,786.9*	-1,519.3*
	(155.0)	(163.0)
Ban period	-489.6*	-530.4*
	(159.5)	(182.8)
Restricted × Ban period	-2,704.1*	-426.3
	(823.7)	(731.0)
Post Ban period	587.4*	1,091.7*
	(196.4)	(273.4)
	-1,283.7*	-578.3
Restricted × Post Ban period	(308.5)	(250.4)
N	127,155	127,156
R^2	0.38	0.28

Table III: Daily option volume per stock for subsamples

This table reports the effects of the short sale ban on option volume. The sample period is 2-1-2008 to 28-1-2009. Our sample consists of firms in the S&P 500. Restricted firms are firms for which short sales are restricted during the ban. We exclude firms for which short sales were restricted before the September-ban, and firms for which the restricted status changed during the ban. We report the result of an OLS regression. We partition in subsamples: one subsample consists of options with ln(S/K) between -0.3 and -0.1 (in-the-money for puts and out-of-the money for calls), one subsample with ln(S/K) between -0.1 and 0.1 (at-the-money), and one for ln(S/K) between 0.1 and 0.3 (out-of-the-money for puts and in-the-money for calls). The dependent variable is option volume per stock: the total put (call) option volume for a given stock on a given date. Each unit of volume corresponds to a single contract written on 100 shares. Stock volume is the daily trading volume of the stock in millions. Stock return is the daily return on the stock, expressed as a decimal. VIX is the closing value of the CBOE Volatility Index on the observation date. Ban period is a dummy variable equal to one if the observation date is between September 19th, 2008 and October 8th, 2008 (inclusive), and zero otherwise. Post Ban period is a dummy variable equal to one if the date of the observation is after October 8th, 2008, and zero otherwise. We report Huber-White heteroskedasticity-corrected standard errors in parentheses. * indicates significance at the 1% level.

	Put option volume			Call option volume		
	In-the-money	At-the-money	Out-of-the-money	In-the-money	At-the-money	Out-of-the-money
	(1)	(2)	(3)	(4)	(5)	(6)
Constant	-370.1*	2,040.0*	412.9*	425.5*	3,920.2*	412.1*
	(31.0)	(134.0)	(74.2)	(89.7)	(170.2)	(81.2)
Stock Volume	94.0*	469.7*	233.4*	69.8*	603.9*	375.3*
	(5.8)	(37.3)	(19.3)	(7.6)	(48.0)	(21.8)
Stock Return	-54.6*	-138.5*	10.8	47.2*	130.7*	-61.6*
	(3.6)	(16.5)	(9.0)	(6.4)	(23.0)	(11.3)
VIX	7.4*	-52.8*	-21.0*	-15.6*	-109.2*	-24.0*
	(1.4)	(6.6)	(3.7)	(3.9)	(8.3)	(5.0)
Restricted	432.1*	-16.7	786.0*	-49.1	-1,910.0*	-311.4*
	(49.5)	(104.6)	(66.0)	(60.0)	(117.4)	(83.1)
Ban period	-94.9*	-792.6*	-168.8*	-40.0	-1,123.4*	51.8
	(36.6)	(109.7)	(62.9)	(72.9)	(117.5)	(92.3)
Restricted × Ban period	-55.4	-1,893.6*	-634.2	407.2*	-629.7	-662.7
	(184.6)	(583.6)	(350.8)	(145.9)	(739.6)	(355.5)
Post Ban period	-217.5*	126.6	642.1*	311.7	811.1*	545.5*
	(41.2)	(177.4)	(102.4)	(161.6)	(218.0)	(133.2)
Restricted × Post Ban period	-120.5	-749.7*	-212.9	31.8	-152.8	-395.0*
	(75.6)	(206.0)	(150.8)	(79.7)	(198.6)	(126.3)
N	125,057	123,859	121,645	121,644	123,860	125,057
R^2	14%	35%	27%	2%	31%	31%

Table IV: The short sale ban and relative spreads on stock options

This table reports the effects of the short sale ban on option bid-ask spreads. The sample period is 2-1-2008 to 28-1-2009. Our sample consists of firms in the S&P 500. Restricted firms are firms for which short sales are restricted during the ban. We exclude firms for which short sales were restricted before the September-ban, and firms for which the restricted status changed during the ban. Panel A reports the relative spreads for a given option on a specific date. The relative spread measure is defined as $ARS_{i,t} = \frac{Best\ Offer - Best\ Bid}{\frac{Best\ Offer + Best\ Bid}{2} - \text{intrinsic value}} \cdot 100$. Panel B reports the results of an OLS regression, in which the relative spread is the dependent variable. |ln(S/K)| is the absolute value of moneyness. Time to maturity $^{-1}$ is the inverse of the time to maturity (expiration), expressed in years. Ban period is a dummy variable equal to one if the observation date is between September 19th, 2008 and October 8th, 2008 (inclusive), and zero otherwise. Post Ban period is a dummy variable equal to one if the date of the observation is after October 8th, 2008, and zero otherwise. We report Huber-White heteroskedasticity-corrected standard errors in parentheses. * indicates significance at the 1% level.

Panel A: summary statistics for relative spreads

	Average	St dev.	Min	Max
Relative spreads on put options	13.87	10.97	0.20	50
Relative spreads on call options	14.26	11.06	0.17	50

Panel B: the effect of the short sale ban on option spreads

	Spreads on put options (1)	Spreads on call options (2)
Constant	3.45*	2.83*
	(0.0)	(0.0)
$\lvert\ln(S/K)\rvert$	51.32*	53.72*
	(0.1)	(0.1)
Time to maturity $^{-1}$	379.13*	416.10*
	(1.1)	(1.1)
Restricted	-0.04	0.60*
	(0.0)	(0.0)
Ban period	2.99*	2.74*
	(0.0)	(0.0)
Restricted × Ban period	3.23*	4.23*
	(0.1)	(0.1)
Post Ban period	-0.85*	-0.42*
	(0.0)	(0.0)
Restricted × Post Ban period	-0.25*	-0.04
	(0.1)	(0.1)
N	1,938,298	1,975,279
R^2	0.19	0.21

Table V: Descriptive statistics of the put-call parity sample

This table shows descriptive statistics of the put-call parity sample. The sample period is 2-1-2008 to 28-01-2009. Our sample consists of one option pair per day for firms in the S&P 500. We exclude firms for which short sales were restricted before the September-ban, and firms for which the restricted status changed during the ban. Option pairs are a call and put option on a firm's stock on a given day that have similar time to expiration and strike prices. We select the option pair on a given day that is closest to being at-the-money. If multiple option pairs are closest to being at-the-money, we select the option pair from these pairs that has a time to expiration closest to 105 days. The violation variables equal one if we observe that $P(S,t,K)+S>C(S,t,K)+K+de^{-rt"}$, and are zero otherwise. Violation mid-point uses closing mid-point prices, while violation arbitrage uses the lowest closing ask price for call options and the highest closing bid price for put options and shares. Call and put prices are closing mid-prices. Present values are calculated with the daily continuously compounded zero-coupon interest rate. The maturities relating to the zero curve are matched with those of the dividend payments. Time to maturity is calculated as the difference between the option's expiration date and the date of the observation. Ln(S/K) is the natural logarithm of the ratio of the stock price and the strike price.

	Average	Median	St.dev	Minimum	Maximum
Violation mid-point	0.108	0.000	0.310		
Violation arbitrage	0.018	0.000	0.133		
Call price	4.032	3.150	4.036	0.075	67.550
Put price	4.019	3.150	3.890	0.100	66.300
Call volume	166	11	860	0	84,555
Put volume	164	10	859	0	57,180
Call open interest	2,963	864	6,771	0	170,781
Put open interest	3,465	1,036	8,373	0	242,095
Present value dividends	0.250	0.139	0.530	0.000	9.945
Stock price	44.134	37.520	39.445	1.860	685.330
Strike price	44.182	37.500	39.460	2.500	690.000
Time to maturity (days)	104	103	26	30	180
Ln(S/K)	-0.001	-0.001	0.039	-0.298	0.299

Table VI: Put-call parity violations

This table shows violations of the upper bound of put-call parity. The sample period is 2-1-2008 to 28-01-2009. Our sample consists of one option pair per day for firms in the S&P 500. We exclude firms for which short sales were restricted before the September-ban, and firms for which the restricted status changed during the ban. Option pairs are a call and put option on a firm's stock on a given day that have similar time to expiration and strike prices. We select the option pair on a given day that is closest to being at-the-money. If multiple option pairs are closest to being at-the-money, we select the option pair from these pairs that has a time to expiration closest to 105 days. The violation variables equal one if we observe that $P(S,t,K)+S>C(S,t,K)+K+de^{-rt"}$, and are zero otherwise. Model (1) reports the results of the estimation of a probit model, in which the dependent variable is the violation calculated with closing mid-point prices. Model (2) reports the results of a similar estimation, but with the lowest closing ask prices for call options and the highest closing bid prices for put options and shares. Ln(Stock volume) is the natural logarithm of the daily trading volume of the stock. Stock return is the daily return on the stock, expressed as a decimal. VIX is the closing value of the CBOE Volatility Index on the observation date. Ban period is a dummy variable equal to one if the observation date is between September 19th, 2008 and October 8th, 2008 (inclusive), and zero otherwise. Post Ban period is a dummy variable equal to one if the date of the observation is after October 8th, 2008, and zero otherwise. Huber-White standard errors are in parentheses. * indicates significance at the 1% level.

	Violation	
	Mid-point	Arbitrage
	(1)	(2)
Constant	-1.599*	-4.241*
	(0.080)	(0.141)
Ln(Stock Volume)	0.010	0.138*
	(0.005)	(0.009)
Stock Return	3.055*	0.098
	(0.130)	(0.174)
VIX	-0.013*	-0.013*
	(0.001)	(0.001)
Restricted	0.739*	0.812*
	(0.016)	(0.024)
Ban period	0.610*	0.269*
	(0.030)	(0.061)
Restricted × Ban period	0.193*	0.034
	(0.055)	(0.087)
Post Ban period	1.503*	0.920*
	(0.032)	(0.058)
Restricted × Post Ban period	-0.356*	-0.658*
	(0.028)	(0.047)
N	115,073	115,073
Pseudo R^2	0.14	0.09

Table VII: Robustness tests

This table reports robustness tests. The sample period is 2-1-2008 to 28-1-2009. Our sample consists of firms in the S&P 500. Restricted firms are firms for which short sales are restricted during the ban. We exclude firms for which short sales were restricted before the September-ban, and firms for which the restricted status changed during the ban. Panel A replicates the regression as shown in Table II. In Models (1) and (2) we use a matched sample (see Group E of Appendix A for the ticker codes of this matched sample). The dependent variable in Models (1) and (2) is option volume per stock: the total put option volume for a given stock on a given date. Each unit of volume corresponds to a single contract written on 100 shares. Models (3) and (4) differ from Table II in that the dependent variable is the Delta volume per stock, which is the sum of the volume times the delta of each option. We report Huber-White heteroskedasticity-corrected standard errors in parentheses. * indicates significance at the 1% level. Panel B reports the percentages of observations violating the upper bound of put-call parity for six firms: Bank of America, Citigroup, Goldman Sachs, JP Morgan, Merrill Lynch, and Morgan Stanley. Each observation in Panel B is the most at-the-money option pair for a stock on a given day. A violation of the upper bound occurs if $P(S,t,K)+S > C(S,t,K)+K+de^{-rt"}$.

Panel A: Matched sample and Delta volume

	Option volume per stock		Delta volume per stock	
	Put options	Call options	Put options	Call options
	(1)	(2)	(3)	(4)
Constant	2,196.3*	6,711.2*	278.8*	1,134.4*
	(394.3)	(383.9)	(59.5)	(75.6)
Stock Volume	748.5*	769.9*	203.1*	260.5*
	(39.5)	(30.1)	(15.9)	(19.1)
Stock Return	-208.9*	84.8	-57.2*	59.9*
	(48.3)	(40.0)	(8.2)	(10.9)
VIX	-30.7	-97.3*	-8.2*	-31.7*
	(16.7)	(14.3)	(3.0)	(3.4)
Restricted	1,905.8*	-3,486.7*	484.5*	-533.1*
	(247.5)	(269.3)	(63.6)	(50.6)
Ban period	-1,014.3	-791.3	-180.9*	-308.3*
	(660.2)	(641.7)	(56.9)	(52.7)
Restricted × Ban period	-3,174.1*	1,490	-1,249.7*	-468.9
	(1,141.7)	(978.3)	(304.9)	(332.8)
Post Ban period	-497.1	-311.1	-78.3	229.5*
	(545.1)	(503.9)	(78.2)	(88.7)
Restricted × Post Ban period	-3,211.7*	30.2	-574.2*	-273*
	(463.4)	(406.2)	(102.7)	(91.6)
N	41,934	41,935	127,036	127,087
R^2	46%	48%	25%	29%

Panel B: Violations for the S&P 500 firms targeted by the July naked short sale ban

	Overall	Before the Sept. short sale ban	During the Sept. short sale ban	After the Sept. short sale ban
Violation mid-point	7.39%	2.97%	34.15%	14.91%
Violation arbitrage	0.67%	0.46%	1.22%	1.17%

Figure 1: Cumulative raw returns for restricted and unrestricted stocks

The lines represent raw returns on equally-weighted portfolios of restricted and unrestricted stocks. Our sample consists of firms in the S&P 500. Restricted firms are firms for which short sales are restricted during the ban. We exclude firms for which short sales were restricted before the September-ban, and firms for which the restricted status changed during the ban. The ban period starts September 19th, and ends after October 8th, 2008.

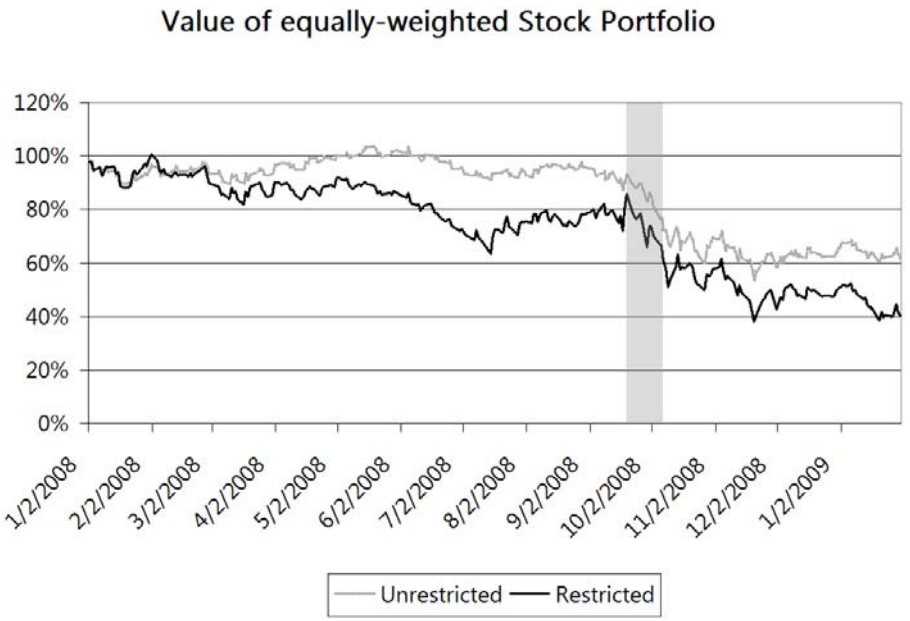


Figure 2: Average total option volume per stock

These figures show the average daily total put (call) option volumes per stock over time for restricted and unrestricted stock. Our sample consists of firms in the S&P 500. Restricted firms are firms for which short sales are restricted during the ban. We exclude firms for which short sales were restricted before the September-ban, and firms for which the restricted status changed during the ban. The ban period starts September 19th, and ends after October 8th, 2008. Each unit of volume corresponds to a single contract written on 100 shares.

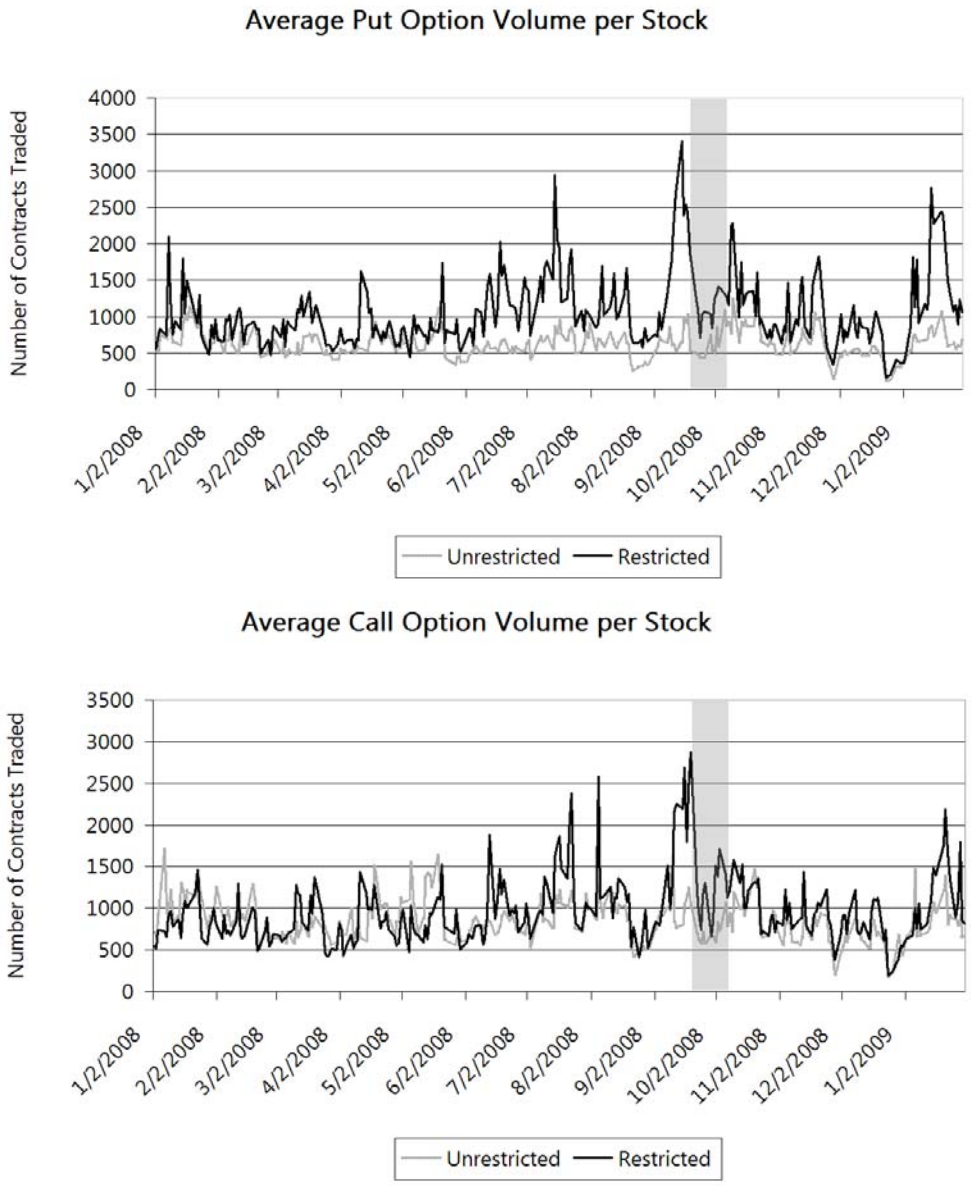


Figure 3: Option premium for a put option.

This figure shows the option premium for a put option. *K* is the strike price of the option and *S* is the price of the underlying stock.

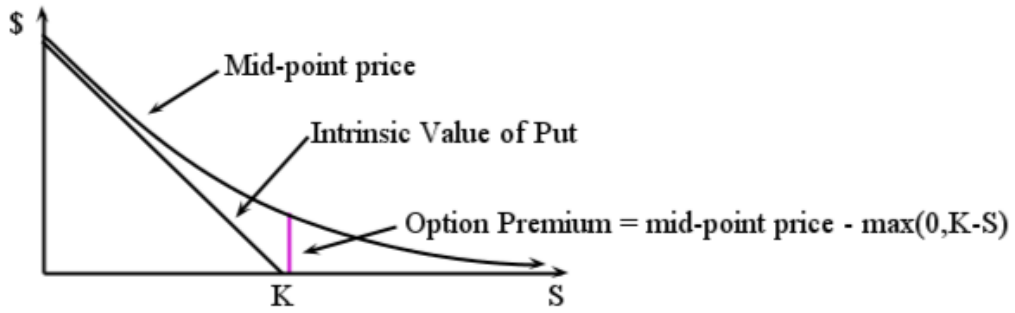
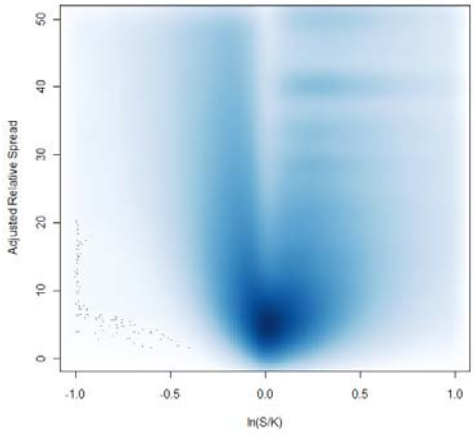


Figure 4: Smoothed scatter plot of Adjusted Relative Spreads for different levels of moneyness

These figures show the relation between the Adjusted Relative Spread, which is calculated as $ARS_{i,t} = \frac{Best\ Offer - Best\ Bid}{\frac{Best\ Offer + Best\ Bid}{2} - \text{intrinsic value}} \cdot 100$, and the moneyness of options, which is ln(S/K). S is the price of the underlying stock and K is the strike price of the option. Our sample consists of firms in the S&P 500, and the sample period is 2-1-2008 to 28-1-2009. We have deleted observations when (1) the bid price is less than the intrinsic value of the option; (2) the closing offer is less than the closing bid; (3) the days to expiration is smaller than 30 or higher than 365; (4) open interest is zero. We also deleted observations when the mid-point price minus the intrinsic value is smaller than twice the difference between the offer and bid price. The darker the area, the higher the density of observations.

Put Options:



Call Options:

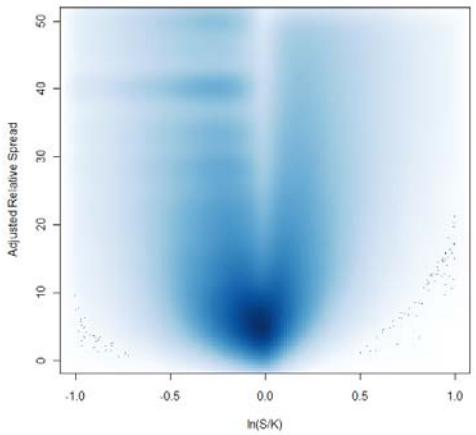


Figure 5: Daily average single-stock futures volume

This figure shows the daily average futures volume for unrestricted and restricted stocks on the OneChicago futures market. Our sample consists of firms in the S&P 500. Restricted firms are firms for which short sales are restricted during the ban. We exclude firms for which short sales were restricted before the September-ban, and firms for which the restricted status changed during the ban. The ban period starts September 19th, and ends after October 8th, 2008. Each unit of volume corresponds to a single contract written on 100 shares.