Regulatory Uncertainty and Market Liquidity:
The 2008 Short Sale Ban’s Impact on Equity Option Markets

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Abstract. We examine how the confusion and regulatory uncertainty generated by the imposition of short sale restrictions in September 2008 impacted equity option markets. We uncover three primary findings. First, investors seeking short exposure in financial stocks did not migrate to the option market to avoid the short sale ban. Second, the short sale restrictions are associated with dramatically increased bid ask spreads for options on banned stocks that are not solely attributable to inflated bid ask spreads on the underlying stocks. We conservatively estimate that over the course of the ban, liquidity demanding investors trading options on banned stocks paid an additional $505 million in transactions costs due to inflated bid ask spreads. Third, synthetic share prices for banned stocks become significantly lower than actual share prices. Our results provide a reminder that regulations imposed in the middle of the night in response to political pressure are likely to have severe unintended consequences.

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“This ban is terrible for option market makers. It will kill options trading because you cannot price options fairly. You cannot buy a call or sell a put and hedge them.”

- Joe Kinahan, derivatives strategist at the Thinkorswim Group, September 19, 2008.

At the end of the summer of 2008, as prices of commercial and investment bank stocks plummeted, the SEC came under intense political pressure to curb short selling of financial stocks. Late in the day on September 17, 2008, the SEC moved to stop naked short selling by issuing Temporary Rule 204T, which imposed stringent penalties on short sellers who failed to deliver shares on time. This applied to all stocks. Then, in the early morning hours of September 19, 2008, the SEC announced a short selling ban for 797 ‘financial’ stocks. The ban was modified and clarified in several regulatory circulars in the next few days.

In this paper, we examine the impact of these short sale restrictions on equity options markets. Although these rules were directed at the market for underlying stocks, they could significantly affect options markets in several ways. First, they made it more difficult and costly for options market makers to hedge positions in the stock market. Even after the SEC clarified that options market makers could hedge by shorting stock, it appears to have been difficult and costly to short. Second, it is likely that prices of the underlying stock became less accurate or efficient when bearish investors were prevented from selling short. The implicit leverage in options positions means that the increase in informational asymmetries was likely to be an even bigger problem for options market makers than for market makers in the underlying stock. Third, there was a great deal of uncertainty about what was permitted under Rule 204T and under the short sale ban. The SEC issued a number of regulatory circulars in the days after these regulations, but in the meantime confusion reigned in both the equity and options markets. Fourth, these dramatic and unexpected SEC rulings increased regulatory uncertainty in the minds of many market participants. Additional SEC rulings could have been forthcoming and could have affected the options market in dramatic and unpredictable ways.

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1Doris Frankel (2008).
We examine three ways in which the restrictions could have affected options markets. First, we examine whether the options market was used to avoid the short selling restrictions. Short selling restrictions are ineffective if investors can circumvent them by selling short synthetically in the options market. Hence the SEC ban, as amended shortly after 12:00am on the morning of September 22\textsuperscript{nd}, only allowed market makers to sell short if they knew the customer or counterparty was not increasing a net economic short position.\textsuperscript{2} Harris, Namvar, and Phillips (2009) however, provide indirect evidence of a migration of shorting to the options market by showing that prices of stocks with options were affected less by the ban than other stocks.

We find no evidence that trading migrated to the options market after the ban. The ratio of option-to-stock volume is comparable for banned and control stocks throughout our sample period. In further tests, we examine whether investors trading on the ISE and on the CBOE opened more long put positions and more short call positions in options on stocks for which short selling was banned. Here too, we find little evidence that investors moved from the stock to the option market to gain short exposure.

The second issue we examine is whether short selling restrictions led to increased trading costs in the options market. Our analysis of intraday quotes reveals that spreads were unusually wide for options on both banned and control stocks on September 19\textsuperscript{th} and 22\textsuperscript{nd}. For example, during the first hour of trading on September 19\textsuperscript{th}, the intraday relative spread for puts on control stocks averages more than 20% as compared to 5% during early August. Our multivariate analysis reveals however, that spreads increase much more for banned stocks than others. On the first day of the ban, puts and calls on banned stocks with December 2008 expirations have quoted spreads that are more than $1.20 wider than the quoted spreads of options on our control stocks. From September 22\textsuperscript{nd} through October 8\textsuperscript{th}, the last day of the ban, we find the relative quoted spreads are an average of 10% higher for options on banned stocks than for options on control stocks. After the ban is removed, the difference in relative quoted spreads falls to around 4%. Order data provided by a retail

\textsuperscript{2}See “Options Market Makers get Relief from SEC Ban on Short-Selling,” published in Traders Magazine Online News on September 22, 2008.
options broker suggests that, on average, liquidity demanding investors paid more than the quoted spread during the short sale ban. If anything, our analysis of quoted spreads understates the impact of the short sale ban on trading costs in the option market.

The third question we address is whether biases in the relative prices of options and stocks emerge during the short sale ban. We measure bias as the difference between the price of a synthetic share of stock, created with a long position in a call and short position in a put, and the price of an actual share of stock. The price of a synthetic share of stock can fall relative to the price of an actual share for two reasons. First, since the short sale ban and the pre-borrow requirements made it difficult for options market makers to hedge long positions in puts and short positions in calls, option market makers may discourage the sale of puts and the writing of calls by raising their offer prices for puts and lowering their bid prices for calls. Together, this asymmetric adjustment of quotes for puts and calls decreases the price received by selling a share of stock synthetically. Second, the ban could inflate the prices of the actual shares of stock while leaving the prices of options unaffected. For October expiration options with a stock-to-strike price ratio between 80% and 120%, we find no difference in bid/ask spread midpoints for synthetic and actual shares of banned stocks prior to September 19th. On the day that the ban is instituted, the synthetic bid ask spread midpoint is an average of $0.18 per share lower than the actual bid ask spread midpoint. After the first few days of the ban, this difference falls to around $0.05 per share and when the short sale ban ends, the midpoints of the synthetic and actual bid ask spread converge. We also find that the prices of actual and synthetic shares of stock diverge in a similar way when the actual shares of stock become hard to borrow, suggesting that it is the inability to sell short that is responsible for the bias.

It is difficult to identify the mechanism through which the short sale restrictions affect the options market. Nevertheless, the abrupt decline in spreads and the narrowing of price biases following the SEC’s

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3 We obtain similar results for December expiration options.
clarification that options market makers could hedge suggests that the short sale rules impact on hedging was critical for the options market. The gradual narrowing of spreads and convergence of synthetic and actual stock prices during the remainder of the ban suggests that uncertainty about what was permitted under the short sale ban and concerns about the possibility of future regulation also weighed on the options market. When we separately examine options on financial and non-financial stocks (e.g. Ford, General Electric) that fell under the short sale ban, we find that the impact of the ban on spreads and price biases was much greater for financial stocks. This could indicate that information asymmetries, which were aggravated by the short sale ban, were particularly large for financial stocks. Alternatively, the stronger impact on financial stocks could reflect uncertainty about new SEC rulings, which presumably would be greater for financial stocks than others.

The remainder of this paper is organized as follows. In Section I we discuss how events around the shorting ban impacted the equity options market. Section II provides a brief description of related literature. In Section III we describe our data. In Section IV we examine whether investors seeking short interest migrated to the equity options market after the imposition of the short sale ban. In Section V we investigate the impact of the short sale ban on liquidity in the options market. Section VI investigates the impact of the short sale ban on the linkage between the equity and equity options markets. Section VII concludes.

I. The Shorting Ban

Stock prices for banks and other financial institutions declined steeply during the summer of 2008. Some regulators feared a potential death spiral in which short sales drove down stock prices, leading depositors and creditors to withdraw funds from banks, driving prices down further and attracting more short selling. The SEC first attempted to limit short selling in 19 financial stocks with a July 21st directive banning “naked shorting,” or shorting without actually borrowing the shares. This ban remained in effect until August 12th. The ban’s effectiveness was limited. The two stocks that had served as catalysts for the SEC’s directive, Fannie Mae and Freddie Mac, continued their declines, falling 40% and 41% over the life of the naked shorting ban.
In September 2008, as prices of financial stocks plunged, the SEC came under additional pressure to limit short sales. New York State Attorney General Andrew Cuomo announced an investigation into short selling. Senators Hillary Clinton and Chuck Schumer pressured SEC commissioner Christopher Cox to ban short sales. Meanwhile, the U.K.’s Financial Services Authority instituted a ban on short selling in financial stocks through January 2009.

On September 18th, the SEC adopted Temporary Rule 204T, which imposed “enhanced delivery requirements on the sales of all equities securities” in the United States. If a broker dealer fails to deliver shares by 9:30 on the morning after the settlement date (three days after the trade date), its clearing firm and any broker dealer for which it clears (including option market makers) is prohibited from executing additional short sales for itself or its customers without pre-borrowing the shares. This penalty would remain in effect until the trade was settled. Historically, the SEC had been tolerant of failures to deliver. In contrast, the new rule imposed a stiff penalty. In a December 19, 2008 letter to the SEC, the seven options exchanges and the OCC expressed concern that complying with Temporary Rule 204T “has caused, and will continue to cause, market volatility, increased borrowing costs, and wider bid ask spreads.”

On the evening of September 18th, SEC commissioners met to discuss short selling and other issues. Shortly after midnight on September 19th, the SEC issued a ban, effective immediately, on short selling for 797 ‘financial’ stocks. The ban was set to expire in 10 days, but could be extended to 30 days at the SEC’s discretion. “Registered market makers, block positioners, or other market makers obligated to quote in the over-the-counter market” were exempted from the ban for short sales that occurred as part of their market making activity. An exception was also granted for “...automatic exercise or assignment of an equity option held prior to effectiveness of this Order due to expiration of the options.” This was interpreted by some to mean that

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4See SEC Release 34-58572, September 18, 2008.
options could not be exercised early. Finally, to facilitate the expiration of options on September 20th, a triple witching day, the SEC granted an exception to option market makers “when selling short as part of bona fide market making and hedging activities related directly to bona fide market making in derivatives” on the 797 stocks until 11:59 p.m. on September 19th. To many option market makers, this implied that they would be unable to sell short for any reason during the remainder of the short sale ban.

By midday on September 19th, several options market makers threatened to stop trading if they were not allowed to hedge by shorting stock. Bill Easley, vice chairman of the Boston Options Exchange, “explained to the SEC [on Friday] that the ban meant the options market makers wouldn’t function come Monday.” Nina Mehta, a reporter for Traders Magazine, noted that “by mid-afternoon Friday, the SEC’s Division of Trading and Markets had issued a statement noting that Commission staff would recommend modifying the short-selling ban to extend the exception to options market makers’ hedging activities.”

In the early hours of Monday, September 22nd, the SEC confirmed that the exception for market makers for options and other derivatives would remain in place. The SEC did not, however, want investors to use the options market to circumvent short selling restrictions. So, they added a provision that market makers could not short if they knew a customer or counterparty was increasing an “economic net short position in the shares of that stock.” The vague prohibition against shorting if the market maker knew the trade would create an economic net short position seemed to give market makers an incentive to avoid knowing what their customers were doing.

The SEC’s original list of 797 banned stocks did not include all financial stocks. This is hardly surprising as the list was drawn up overnight and without industry comment. On Monday September 22nd, the SEC announced that decisions on which companies to add to the short sale ban would be left to the exchanges. The New York Stock Exchange added an additional 71 stocks after the market close on Monday, September 22nd. Over the next few days, the list of banned stocks increased to about 1,000. Some of the stocks, like CVS Caremark and IBM are financial stocks only when the financial sector is defined very broadly. Other financial
companies like Diamond Hill Investment and JMP group asked to be dropped from the list because they did not agree with the idea that short sales should be banned.

The emergency actions taken on September 18th and 19th were both sudden and not well understood by industry participants. In a May 2009 report, the Government Accountability Office (GAO) notes that, “industry officials stated that due to the rushed nature of the September emergency order and the temporary rule, there was a lot of uncertainty and confusion related to the scope and application of the new requirements.” The seven options exchanges and the OCC argue in a December 19, 2008 letter to the SEC that “with respect to the emergency actions overall, imposing significant requirements without advance warning or input from the exchanges and market participants, but which must be complied with immediately, was and still is extremely disconcerting to all market participants. Adjustments to trading strategies and compliance systems that would be difficult, but possible, with reasonable advance notice become, in some situations, nearly impossible.”

Confusion over the emergency actions is evidenced by a series of regulatory circulars put out by the CBOE during the week of September 22nd. CBOE Regulatory Circular RG08-117, issued on September 24th, notes that “yesterday evening, the SEC Staff issued guidance in the form of an FAQ on the emergency order that adopted Temporary Rule 204T, which pertains to the delivery of securities.” The FAQ attempted to answer three questions. First, the FAQ suggested that a clearing firm can allocate responsibility for Temporary Rule 204T’s close-out requirement to the broker-dealer that is responsible for the fail position, rather than to the clearing firm and all of its customers. Second, there was confusion about whether firms had to close out their short positions on the settlement date or whether they could close them out earlier. The FAQ suggested that “a broker-dealer may receive credit for purchasing securities prior to the beginning of regular trading hours on

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6See GAO-09-483.

7See December 19, 2008 letter from option exchanges to the SEC.
the settlement day...” Finally, the FAQ suggested that “any Market Maker to which a fail to deliver position at a registered clearing agency is attributable must attest in writing to the market on which it is registered that the fail to deliver position at issue was established solely for the purpose of meeting its bona fide market making obligations.”

On September 25th, the CBOE issued another regulatory circular conveying the SEC Staff’s guidance on close-out and pre-borrow requirements under Temporary Rule 204T. This circular states that option market makers must now close out their short positions by the beginning of regular trading hours on the morning of the sixth trading day following the transaction. The circular also confirmed that the option market makers could short shares of a security even when a customer of its clearing agency has a fail to deliver in that security as long as “the Market Maker can show that it does not have an open fail to deliver position at the time of any additional short sales.”

The shorting ban was set to expire on October 2nd if it was not extended. The SEC did extend the ban until the earlier of October 17th, or three business days after the $700 billion financial rescue legislation was passed into law. Shorting resumed on October 9th, but as noted in the December 19, 2008 letter from the seven options exchanges and the OCC to the SEC, “even when an emergency action ends, its impact lingers.” Table 1 characterizes the various regulatory events and clarifications.

To summarize, there were several ways in which SEC actions limited the ability of option market makers to hedge. Beginning on September 18th, Temporary Rule 204T limited market makers ability to hedge by penalizing failure to deliver. This rule affected options on all stocks. On September 19th, short sales of financial stocks were banned. An exemption was granted for options market makers that day, but it was not clear if options market makers would be able to hedge by shorting banned stocks after that day. This issue was resolved on September 22, as it was made clear that options market makers would be able to sell short for hedging purposes. There were still, however, special obstacles for market makers that want to hedge by shorting banned stocks. Market makers were not allowed to sell banned stocks short if the net result was to
create an economic short position in the stock for a customer. In addition, unusually wide spreads on banned stocks made it costly for market makers to hedge using underlying shares. Finally, borrowing banned stocks became more difficult as a number of institutions, like CalPERS, stopped lending them.

II. Literature Review

For the most part, financial economists view short selling restrictions as counterproductive. Miller (1977) argues that short sale restrictions keep pessimistic opinions from being impounded in stock prices, thereby leading to overpriced shares. Consistent with Miller’s hypothesis, Figlewski (1981), Figlewski and Webb (1993), and Dechow et al. (2001) find stocks with high short interest have low subsequent returns and Jones and Lamont (2002) find evidence that stocks that are expensive to short have high valuations and low subsequent returns. Ofek and Richardson (2003) suggest that the inability to short led to high prices for internet stocks in 1999 and 2000, and the relaxation of constraints on borrowing shares for shorting led to the eventual collapse of prices for these stocks.

Diamond and Verrecchia (1987) conclude that short sale restrictions need not lead to overpriced assets. In their model, investors are aware that short sale restrictions prevent selling by pessimistic investors and will adjust their valuations accordingly. Even if prices are unbiased though, they will be less accurate than if short selling was unconstrained. Investors may take into account that pessimistic traders are shut out of the market, but that is not the same as knowing when pessimistic traders are selling. Bris, Goetzmann, and Zhu (2007) provide some empirical support for the idea that markets with short selling restrictions are less efficient. Using a number of markets around the world, they show that short sale restrictions lead to slower impounding of negative information.

Jones (2008) uses a series of regulatory changes that made shorting more difficult in the U.S. to explore the impact of short sale restrictions on liquidity and asset prices. During the 1930's, short sales were banned for two days, versions of the uptick rule were introduced, and brokers were required to get authorization
before using their customers’ shares for shorting. Jones finds evidence suggesting that each of these events made shorting more costly. He also finds the affected stocks have significantly positive average returns around these events. Jones interprets these results as being “consistent with the limits-to-arbitrage notion that when there are restrictions on shorting, optimists have more influence on pricing.” Finally, Jones (2008) shows that bid ask spreads tighten when versions of the uptick rule are introduced. This may be because the uptick rule requires short sellers to supply liquidity to get their orders executed. Diether, Lee, and Werner (2009) find the opposite result when the uptick rule is removed.

Recent studies document several ways in which the September 2008 short sale ban affected equity markets. First, the short-sale ban dramatically reduced short selling. Boehmer, Jones, and Zhang (2009) found that on average, short sales made up 21.75% of trading volume for banned stocks in the six weeks leading up to the ban but only 7.72% during the ban itself. Presumably, these remaining short sales were made by market makers. Over the same period, the proportion of trading volume from short sales declined from 20.38% to 19.32% for control stocks. Gurliacci, Jeria, and Sofianos (2008) use proprietary Goldman Sachs electronic order flow (algorithmic and direct market access) to examine short-seller activity in S&P 500 stocks initially included in the short sale ban. In May 2008, they find short selling in the banned stocks was 23% of executed value, while buying was 51% of value. On October 8th, the last day of the ban, they find short selling is 4% of value, which they attribute to exempt market making activity, and buying is 48% of value. Finally, on October 9th, Gurliacci et al. find shorting activity returns to 23% of value and buying activity remains at 48% of value. Gagnon and Witmer (2008) report a substantial migration of trading volume to Canada for banned stocks that also traded there.

The ban appears to have increased the cost of trading the affected stocks. Boehmer, Jones, and Zhang (2009) report that median effective spreads for banned stocks increased from 42 basis points in the six weeks before the ban to 145 basis points while the ban was in effect. Over the same period, the increase in the median effective bid-ask spreads for control stocks was much smaller: from 35 basis points to 57 basis points. Other
measures of market quality, like price impact and volatility also deteriorated during the short sale ban. Kolasinksi, Reed, and Thornock (2009) find market quality, as measured by $R^2$, falls during the ban.

There is also evidence that stock prices were artificially inflated during the ban. Boehmer, Jones, and Zhang (2009) document large gains in prices of banned stocks when the ban was announced that were gradually surrendered over the ban period. Of course, other factors, like the status of the TARP bill before Congress could explain the returns of banned stocks. Harris, Namvar, and Phillips (2009) refute this by estimating a factor analytic model of stock price changes around the ban. Among the factors are the returns on a value-weighted index of the banned stocks and a TARP index. After adjusting for common factors, Harris et al. report that banned stocks earned positive abnormal returns of about 10.5% during the ban period and find that these returns were concentrated in stocks without listed options. The abnormal returns, however, do not disappear after the short sale ban is lifted. Harris et al. conjecture that returns could be less for banned stocks with listed options because investors may have been able to construct synthetic short positions in the options market in these stocks.\footnote{Kolasinksi, Reed, and Thornock (June 2009) find short sales become more informative following each of these actions, especially for stocks with listed options. They interpret this as evidence that informed investors move to the options market to obtain short exposure when the cost of short selling becomes more expensive.}

III. Data

We use option market data collected under the Options Price Reporting Authority (OPRA) Plan for Reporting of Consolidated Last Sale Reports and Quotation Information. We obtain OPRA data from a large options market maker. These data are also available from the International Securities Exchange (ISE) and the Chicago Board Options Exchange (CBOE). See Battalio and Schultz (2006) for a more detailed discussion of the characteristics of the OPRA data.
The SEC’s initial list of 797 banned securities includes ADRs, warrants, and other securities. We examine the 330 U.S. listed common stocks with exchange traded options. Our dataset contains all quotes and trades for all equity options traded each day from August 1, 2008 through October 21, 2008 with two exceptions. Our daily OPRA files containing data for August 14th and August 26th are corrupt. We narrow our analysis down to options on stocks for which shorting is banned in the original SEC order and to options on a sample of control stocks. The control stock sample is chosen by matching each banned stock with the non-banned stock with the smallest sum, at the beginning of the sample period, of the squared percentage difference in price and the squared percentage difference in capitalization.

The OPRA quote records contain the date, the to-the-millisecond time, the option and underlying stock symbols, the exchange on which the record is generated, bid and ask prices, and bid and ask messages. The quote messages indicate whether the quotes are regular way quotes, non-firm, part of the opening rotation, eligible for automatic execution, or whether they contain customer trading interest. The OPRA trade records contain the date, the to-the-second time, the option class and series symbols, the exchange on which the trade is reported, the trade price, and the trade message. Among other things, the trade message indicates whether the trade was a regular transaction, whether it was cancelled, whether it was executed electronically, and whether it was reported with delay.

Even with a short sample period, the size of the data set makes it difficult to use. A single stock will have puts and calls with perhaps ten exercise prices and five expiration dates, for a total of 100 options per stock. For some stocks on some days, the number of options is much larger. Each of these options may be quoted on as many as seven options exchanges. Files containing these data average 100 gigabytes per day in 2008 and are as large as 450 gigabytes per day in the last two weeks of September 2008. To reduce the data set to a manageable size, we create a NBBO quote for each option at the end of each minute by taking the

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9Boehmer, Jones and Zhang (2009) find that of the 797 stocks initially subject to the short sale ban, only 404 were common stocks. Their 404 stocks include small firms without options.
highest firm bid and the lowest firm offer price across the exchanges. For the underlying equity market, we obtain end-of-minute NBBO quote records from the New York Stock Exchange’s (NYSE) Daily Trade and Quote (TAQ) database. The file that contains all of the equity option transactions that occur during our 55-day sample period is only 1.33 gigabytes and is therefore much more manageable.

To explore the relationship between quoted prices and actual trade prices, we obtain a file of all marketable orders in our sample option classes that are executed via a large retail broker in September 2008. Among other things, for each order these data indicate whether the order is a market or a marketable limit order, a limit price if the order is a marketable limit order, a buy/sell indicator, the order submission date and time, the execution date and time, the order size, the trade size, the trade price, and the order-receipt-time NBBO.

Our initial dataset consists of 58,590 trades. We eliminate 8,141 trades from orders received prior to 9:45 a.m. since we are not interested in trades that occur in the opening rotation. We eliminate 509 trades resulting from orders received after 3:51 p.m. to avoid trades executed in closing rotations. We eliminate one order as a data error because the order receipt date is different from the execution date. Our analysis requires a valid order receipt time (ORT) quote. We eliminate 352 trades with a NBBO of zero and 42 trades with an ORT National Best Bid that is greater than its ORT National Best offer. Finally, we eliminate 21 trades with relative bid ask spreads that exceed 5% as data errors. Our final sample contains 49,524 trades, or 84.5% of our original sample.

Finally, we obtain data sets indicating the number of contracts contained in trades that open and close buy positions and open and close sell positions from the ISE and the CBOE. These exchanges, which account for more than 57% of the average daily trading volume of all options in 2008, are the only ones that make these data available for purchase. These data include the number of trades and the volume of contracts involved in transactions in which customers and market professionals opened and closed buy and sell positions on each of these exchanges for each series, for each day during August and September 2008.
Table 2 provides a description of the sample. Panel A summarizes the distribution of price and market capitalization for banned and control stocks as of July 31, 2008 - the date when matching stocks are determined. 330 of the 404 U.S. common stocks subject to the initial short sale ban have options that trade at that time. Each is matched with a control stock drawn from all NYSE, AMEX, and Nasdaq stocks. Following Davies and Kim (2009), our match is the non-banned stock that minimizes the sum of the squared percentage difference between the banned stock and control stock prices and the squared percentage difference between the banned stock and control stock market capitalizations. No control stock is used twice. If the control stock does not have options quoted for any day of the sample period, the second best match (or third best if needed) is used.

As intended, the price and market capitalization of banned and control stocks are similar. The mean capitalization of both bank and control stocks is $8.7 billion and the mean stock price is $30.76. The medians and quartiles of the prices are also very similar for banned and control stocks.

Panel B reports the distribution, across days, of the number of options quoted on each stock. The banned stocks have a mean of 29,678 options quoted per day with a range of 27,434 to 34,088. For the control stocks, the mean number of options quoted on a day is 32,619. The number of options on control stocks quoted on any specific day ranges from 30,540 to 38,072. For each expiration month from August through December 2008, there are at least 1,500 options quoted on control stocks and at least 1,000 options quoted on banned stocks. The last three rows of Panel B report the number of options for which the stock price is 20% below the exercise price, the number with a stock price within 20% of the exercise price, and the number with a stock price at least 20% greater than the exercise price. For both the banned stocks and the control stocks, there are more options quoted with a stock price at least 20% less than the exercise price than with a stock price at least 20% greater than the exercise price. This is symptomatic of falling stock prices over the prior months. In some of the tests to follow, we use only options with exercise prices within 20% of the stock price, so it is more significant that there are always at least 7,000 options trading in the in-the-money category.
We explore the ratio of option-to-stock trading volume in Figure 1, which plots the ratio of option-to-stock volume in banned and control stocks for each of the days in our sample period. Each day, we first multiply the volume of put and call contracts traded on banned stocks by 100 since each contract contains options on 100 shares of stock. We then divide this product by the number of shares traded in the underlying banned stocks on that day. The ratio of option-to-stock volume for control stocks is computed analogously. Figure 1 suggests that the ratio of option-to-stock volume averages around 15% per day for banned and control stocks. This ratio does not appear to be affected at all by the ban, thus providing no support for the idea that short sellers migrated to the options market. In untabulated results, similar patterns emerge when this ratio is computed separately for puts and for calls and when we use multivariate regressions to analyze the data. The evidence in Figure 1 suggests that investors did not move to the option market when short selling was banned in the equity market. In the next section, we use an alternative dataset to investigate this issue more fully.

IV. Did Investors Seeking Short Exposure Move to the Options Market?

In this section we more fully examine whether investors seeking short exposure migrated to the option market during the short sale ban. On September 19, 2008 investors were prohibited from shorting shares of banned stocks but they could buy puts and write calls on these stocks in the option market. For the remainder of the ban, options market makers were prohibited from providing liquidity to investors seeking a synthetic short position in stocks for which short selling was banned.

Figure 1 shows that there is little evidence in the OPRA data that investors seeking short exposure in stocks for which short sales were banned moved to the options market. In this section we use the Open/Close Trade Profile obtained from the CBOE and the ISE to investigate how customers and firms used options to change their exposure to underlying stocks. Unlike OPRA trade data, these data allow us to track the actual opening and closing of positions. However, they only cover positions initiated and/or closed on the CBOE and the ISE.
We obtain daily records of trading activity for all options traded on the CBOE and on the ISE for August and September 2008. These records are similar to those used by Pan and Poteshman (2006). They decompose volume into four trade types. “Open-buys” (“open-sells”) are trades that are initiated by buyers (sellers) to open a position and “close-buys” (“close-sells”) are trades that are initiated by buyers (sellers) to close a position. The OCC assigns one of three origin codes to each option trade: public customer, firm proprietary trader, or market maker. Our data contains the positions of two investor classes: customers and firm proprietary traders. Pan and Poteshman (2006) note that customer trades include clients of brokers such as E-Trade and Merrill Lynch. The ISE’s website also indicates that they include trades placed by institutions and hedge funds. Firm proprietary trades include trades executed on the behalf of an exchange member’s own account and on the behalf of another broker dealer that is not a member of the exchange. For our purposes, the primary advantages of these data over the OPRA trade records are that we know whether the initiator of observed volume is opening a new position or closing one that was already outstanding and whether the initiator was a customer or a firm.

Each day, for each customer type, we compute the *Initiation of Short Exposure* on these two exchanges separately for options on banned and control stocks as follows:

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\text{Initiation of Short Exposure} = (\text{Put Open-Buy} + \text{Call Open-Sell}) - (\text{Put Close-Buy} + \text{Call Close-Sell}).
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We compute the *Initiation of Short Exposure* separately for October, November, and December expiration options and for customers and firm proprietary traders. Figure 2 plots the time series of short exposure by customer type and expiration month. The top two plots contain the *Initiation of Short Exposure* in October expiration options, the middle two plots contain the *Initiation of Short Exposure* in November expiration options, and the bottom two plots contain the *Initiation of Short Exposure* in December expiration options. In each of these plots, there appears to be little difference between the aggregate short exposure accumulated by customers trading put options on banned stocks versus put options on control stocks. We obtain similar results when we examine Net Put Buys and Net Put Sells separately (not shown). These results are consistent with the
We also examine put exercise as a proportion of open interest. We examine exercise of puts that sell for less than their intrinsic value and find that the short sale ban did not have a differential impact on the ability of investors to exercise puts on stocks that were subject to the ban early. However, these results also suggest that investors were able to use option markets to gain short exposure in banned stocks during the short sale ban.

One explanation for why bearish investors did not migrate to the options market is that the cost of trading options increased relative to the cost of trading shares during the ban. To demonstrate this, we first calculate average daily spreads from minute-by-minute quotes for each December put option on banned stocks with an exercise price within 20% of the mean stock price for the day. We then average daily put spreads across all of the put options for each underlying stock. Next, we calculate daily average put spreads across all underlying stocks. These averages, along with the daily average spreads of the underlying stocks are shown in Figure 3.

The top plot in Figure 3 shows the stock and put spreads together plotted against the same vertical axis and the bottom plot depicts the stock and put spreads against different vertical axes (puts spreads on the left and stock spreads on the right). The top plot clearly demonstrates that bid-ask spreads are much higher for puts than their underlying stocks prior to the short sale ban. As seen in the bottom plot, spreads for both rise sharply when the ban is instituted, but the increase is much, much larger for puts. Puts spreads are about $2.00 wider on the first day of the ban and remain at least $0.50 wider over the remainder of the short-sale ban. Stock spreads generally increase by $0.06 to $0.08. Stock prices are typically much greater than the prices of (roughly) at-the-money puts. Hence the difference in relative or percentage spreads (not shown) is much greater. The huge increase in the spreads of options relative to the spreads of stocks may be one reason why

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10We also examine put exercise as a proportion of open interest. We examine exercise of puts that sell for less than their intrinsic value and find that the short sale ban did not have a differential impact on the ability of investors to exercise puts on stocks that were subject to the ban early.

11Similar results are obtained with call options and with different expiration dates.
volume did not migrate from the stock market to the options market during the ban. We now examine the impact of the ban on option trading costs in greater detail.

V. The Impact of the Short Sale Regulation on Bid-Ask Spreads in the Options Market

A. The impact of short sale regulation on the levels of daily quoted and effective spreads.

We compute relative quoted spreads for October expiration puts with implied volatilities between 0.7 and 1.0 and with a stock-to-strike price ratio between 80% and 120% by dividing the difference between the National Best Offer and the National Best Bid by the midpoint of the NBBO at the end of each minute. Next, we compute the average of the relative spreads at the end of each minute separately for put options on banned and control stocks and plot them for different days or sets of days. These plots are presented in Figure 4.

Intraday relative spreads for puts on banned and control stocks for the first full week of August 2008 provide a useful benchmark to evaluate spreads during the short sale ban. On average, relative spreads are around 5% of the NBBO midpoint for puts on banned stocks and around 4% for puts during the first week of August. While there is little difference in the relative spreads of puts on banned and control stocks on September 17th, the evening on which SEC Regulation 204T was announced, intraday relative spreads are elevated to nearly 10% of the option value, about twice their value during the first week of August. This implies that a put with a NBBO midpoint of $1.00 had a bid ask spread of $0.10. Intraday spreads for puts on banned and control stocks begin to diverge around 1pm on September 18th, the day that Temporary Rule 204T was enacted. During the last hour of trading on September 18th, relative spread for put options on both banned and control stocks rose by around 500 basis points.

The confusion associated with the announcement of the short sale ban in the early morning of September 19th is clearly evidenced in the plots of intraday relative spreads on that day. Spreads for options on banned stocks increase sharply, but the spreads of options on control stocks also jumped. This could be due
to regulatory uncertainty. Conversations with industry participants suggest that spreads of options on stocks that were not subject to the ban increased because of the uncertainty as to whether more emergency orders were yet to come. Relative spreads for puts on banned stocks averaged around 20% throughout the afternoon of September 19th, likely reflecting the uncertainty as to whether option market makers would be allowed to short shares of banned stocks during the remainder of the ban.

The SEC announced at 12:01am on Monday, September 22nd that option market makers would continue to be allowed to short shares of stock in order to hedge positions resulting from normal market making. It is likely, however, that many option market makers were unable to recalibrate their option pricing models to reflect the ability to short shares of banned stocks. This conjecture is consistent with the plots of relative spreads for puts on banned and control stocks on the September 22nd. At the start of trading on September 22nd, relative spreads for puts on banned stocks are around 60% higher than relative spreads for puts on control stocks. By 11am, average relative spreads for puts on banned and control stocks converge, and for the remainder of the trading day relative spreads on banned and control stocks are comparable.

Figure 4 also plots intraday average relative spreads each day from September 22nd through September 26th and the across day average intraday relative spreads for September 29th through October 8th, the last day of the short sale ban. Relative spreads for puts on banned stocks are inflated relative to relative spreads for puts on control stocks in the first half hour of trading each day during the week of September 26th, which is consistent with the argument that option market makers were confused during this period. With the exception of the first hour of trading, average intraday relative spreads for puts on control stocks average around 10% for the remainder of the ban, which is equal to the average intraday relative spreads on control stocks on the day prior to the SEC’s implementation of Temporary Rule 204T on September 18th. This suggests that the measures taken by the SEC to soften Rule 204T during the week of September 26th effectively relaxed the constraints that Rule 204T had placed on market makers trading options on control stocks. That intraday relative spreads for puts on banned stocks remain elevated throughout the short sale ban suggests either that
Rule 204T was binding for market makers trading put options in the harder-to-borrow financial stocks or that the wider relative spreads for puts on financial stocks reflected compensation for bearing increased levels of regulatory risk.

To determine whether the high spreads documented in the OPRA quote data translate into higher effective spreads for investors, we obtain order data from a large options broker. This order data indicates whether the order is a buy or a sell, if it is a market or a marketable limit order, and perhaps most importantly, when the order was received. This allows us to use the order receipt time (ORT) quotes to compute effective spreads. As a result, we do not have to worry about delays associated with trade reporting during periods of high trading activity.

For buy orders, effective spreads are twice the difference between the trade price and the midpoint of the ORT bid ask spread. For sell orders, effective spreads are twice the difference between the midpoint of the ORT bid ask spread and the trade price. Relative effective spreads are computed by dividing the effective spread by the midpoint of the ORT bid ask spread. Relative quoted spreads are computed by dividing the ORT bid ask spread by the midpoint of the ORT bid ask spread. We compute the contract-weighted ratio of effective-to-quoted spread for each option each day. We then compute the across-stock average of these spreads separately for options on stocks in which short sales are banned on September 19, 2008 and for options on our set of control stocks. We present these averages in Figure 5.

Over the first two weeks of September, the average ratio of relative effective to relative quoted spread for options on banned stocks is around 100%, indicating the average liquidity demanding round-trip trade executed via our broker paid 100% of the quoted bid ask spread. Liquidity demanding investors seeking to trade options on our control stocks paid 98.4% of the quoted relative bid ask spread on a round-trip trade over this same interval. On September 18th, the day on which the SEC adopted Temporary Rule 204T, the ratio of effective-to-quoted relative bid ask spreads grew to 109% for options on banned stocks. On September 19th, this ratio rises to 137% for options on stocks for which short sales were restricted. The ratio remains elevated
for options on banned stocks on September 22nd, and then returns to an average of 99.8% for the remainder of the month. Excluding September 19th, the ratio of effective-to-quoted spreads for options on control stocks averaged 97.8%. Overall, Figure 5 suggests that if anything, our analysis of quoted spreads understates the impact of the short sale ban on trading costs.

B. Marginal impact of the short sale ban on daily spreads.

We have been making comparisons of the trading costs for options on banned stocks and options on control stocks. We are cautious about drawing strong conclusions from these comparisons, however, as the differences in spreads may be due to differences in the volatility or moneyness of the two option samples. The financial stocks that fell under the short sale ban were very volatile at the time. In addition, prices of these stocks had fallen dramatically, leaving many put options deep in the money and many call options deep out of the money. To account for these potentially confounding differences, we estimate the impact of the ban using daily cross-sectional regressions.

For each option, we compute the National Best Bid and Offer (NBBO) at the end of each minute between 9:30am and 4:00pm. Next, we calculate an average percentage spread, $Pct\ Spread$, each day by taking the average of the NBBO (divided by the midpoint) at the end of each of the 390 minutes of the trading day. We examine how bid ask spreads were affected by the short sale ban by running the following cross-sectional regression each day from August 1, 2008 through October 21, 2008, with standard errors clustered by underlying stock:

$$Pct\ Spread_i = \alpha_0 + \alpha_1 \text{Banned}_i + \alpha_2 \left( \frac{S}{X}_i \right) + \alpha_3 \left( \frac{S}{X}_i \right)^2 + \alpha_4 \left( \frac{S}{X}_i \right)^{-1} + \alpha_5 ISD_i + \alpha_6 ISD_i^{-1} + \alpha_7 \left( \frac{S}{X}_i \right) ISD_i + \alpha_8 \text{Penny}_i + \varepsilon_i$$ (1)

where $\text{Banned}_i$ takes a value of one if option $i$ is on a stock with banned short selling and zero otherwise, $(S/X)_i$ is the average ratio of the stock price to the exercise price computed using the 390 end-of-minute observations.
During our sample period, 63 stocks were part of the SEC’s Penny Pilot. The tick size for options on these stocks is $0.01 if the option is worth less than $3.00 and is $0.05 if the option has a value of $3.00 or more. Options on stocks that are not part of the Penny Pilot have a tick size of $0.01 if the option is worth less than $3.00 and a tick size of $0.10 if the option is worth more than $3.00. Ten of our banned stocks and thirteen of our control stocks are in the Penny Pilot.

on day \( t \), \((S/X)\); and \((S/X)^{-1}\) are the square and inverse of the average value of \((S/X)\) for day \( t \), \( ISD \), is the mean implied standard deviation for option \( i \) on day \( t \) calculated from calls with the same exercise price and expiration date, \( ISD^{-1} \) and \( ISD^{1/2} \) are square and inverse of the average implied standard deviation for day \( t \), and \textit{Penny} is one if the option is part of the SEC’s Penny Pilot and zero otherwise.\(^{12}\) To calculate standard errors, we cluster on the underlying stock. Inverses and squares of the implied standard deviation and moneyness are included to capture non-linear relations between these variables and trading costs. They make the regressions difficult to interpret though, so we report only the coefficient on the banned variable, and we report it graphically. Other coefficient estimates are available from the authors.

Figure 6 plots the daily estimates of the coefficient on Banned from cross-sectional regressions using December expiration put options. The coefficient is not significantly different from zero for August and the first part of September, but jumps to 9% on September 18\(^{th}\) when Temporary Rule 204T is put into place. This may be because it was more difficult to borrow shares of financial stocks and hence failure to deliver was a bigger danger for options market makers who hedged by shorting these stocks. When the short sale ban is enacted on September 19\(^{th}\), the coefficient estimate jumps to 25%. So, if the bid ask spread on a control stock put was 5%, the bid-ask spread on a similar put on a banned stock would be 30% of the price. The short sale ban is in effect until October 8\(^{th}\). The coefficient on the banned dummy variable decreases slowly while the ban is in effect, but remains significantly positive, suggesting that either the short sale ban, Temporary Rule 204T, or both had lingering impacts on the cost of providing liquidity in puts on banned stocks.

Figure 7 plots the daily coefficient estimates for Banned from regressions using all December expiration call options. As in the put regressions, standard errors are clustered on the underlying stock. Figure 7 reveals that, after adjustment for moneyness and volatility, the percentage spread for calls on banned stocks

\(^{12}\) During our sample period, 63 stocks were part of the SEC’s Penny Pilot. The tick size for options on these stocks is $0.01 if the option is worth less than $3.00 and is $0.05 if the option has a value of $3.00 or more. Options on stocks that are not part of the Penny Pilot have a tick size of $0.01 if the option is worth less than $3.00 and a tick size of $0.10 if the option is worth more than $3.00. Ten of our banned stocks and thirteen of our control stocks are in the Penny Pilot.
is about five percent higher than the percentage spread for calls on control stocks between August 1st and September 15th. As is the case with puts, this difference in percentage spreads increases by around 9% on the day that Temporary Rule 204T is put into place. When the short sale ban is instituted on September 19th, the difference in percentage spreads for calls on banned and control stocks is around 28%, about 23% higher than it was between August 1st and September 15th. After the short sale ban is lifted on October 8th, the difference in percentage spreads decreases but remains higher than it was prior to September 15th. Together, Figures 6 and 7 suggest the short sale ban had similar effects on the relative spreads of puts and calls on banned stocks.

The regressions discussed so far use the percentage spread, that is bid-ask spread divided by the average of the bid and ask prices, as the dependent variable. To insure that the changes in spreads are not due to changes in the options’ prices, we reestimate (1) each day using the dollar bid-ask spread rather than the percentage spread as the dependent variable. Standard errors are clustered by stock. Daily coefficient estimates for the banned variable are plotted in Figure 8 for put and call options with December expirations.

The difference between quoted spreads of options on banned and control stocks is similar for puts and calls. This suggests that option market makers made similar adjustments to put and call bid ask spreads when the short sale ban was instituted. The impact of the short sale ban on quoted spreads is striking. In the six weeks prior to the ban, the coefficient on the banned variable was between $0.10 and $0.20. Dollar spreads were a little wider for banned stocks, but not much wider. On September 19th, the first day of the ban, the spread differences jumped to over $1.20. The spread differences remain over $0.40 for the duration of the ban and then slowly decline toward pre-ban levels.

Regressions using options with other expiration months yield very similar results. It is clear that it became much more expensive to trade both puts and calls when the ban on shorting the underlying stock was implemented. Options market makers routinely hedge their positions by trading the underlying stock. When the ban was announced in the early morning hours of September 19th, shorting by options market makers was to be banned along with other short selling. Industry participants successfully lobbied the SEC to allow market
makers to short for hedging purposes at least for September 19th, but it was uncertain if they would be able to short in succeeding days. On the morning of that day, there was still some confusion though as to whether the market makers would need to pre-borrow the stock before shorting it. These factors may explain why spreads became so large on September 19th.

Other factors are likely to explain the difference in banned and control stocks after September 19th. First, market makers were still prohibited from transactions that would create an economic short position for an investor. Also, even if options market makers were allowed to hedge with short sales, the market for the underlying stocks was less liquid. A number of institutions like CalPERS, who had been active participants in the equity lending market, stopped lending shares. In addition, Boehmer, Jones, and Zhang (2009) report a sharp increase in bid-ask spreads for banned stocks during the banned period. Our Figure 2 shows however, that the change in option spreads under the short selling ban was much, much greater that the change in stock spreads. It seems unlikely that wider stock spreads had a big impact on option market makers’ hedging costs.

C. The Ban’s Effect on Spreads of Financial and Non-Financial Stocks

Some of the stocks covered by the short-sale ban are not what we would usually regard as financial firms. To see if the ban affected financial firms differently from others, we designate banned firms with CRSP primary SIC codes between 6000 and 6999 as financial firms. All others we designate as non-financial firms. These include General Electric, Ford, IBM, and McGraw Hill. Out of our sample of 330 banned stocks, 300 are financial stocks and 30 are non-financial firms.

To compare the impact of the ban on spreads of options on financial and non-financial stocks, we run the following cross-sectional regression each day:

\[ \text{Spread}_i = \alpha_0 + \alpha_1 \text{Banned}_i + \alpha_2 \text{FinBanned}_i + \alpha_3 \left( \frac{S}{X} \right)_i^2 + \alpha_4 \left( \frac{S}{X} \right)_i^{12} + \alpha_5 \left( \frac{S}{X} \right)_i^{1/4} + \alpha_6 \text{ISD}_i + \alpha_7 \text{ISD}_i^2 + \alpha_8 \text{ISD}_i^{12} + \alpha_9 \left( \frac{S}{X} \right)_i \text{ISD}_i + \alpha_{10} \ln \text{Vol} + \alpha_{11} \text{Putprice} + \varepsilon_i \]  

This regression is similar to regression (1) which we has provided our estimates of the impact of the short sale ban on spreads. In (2) we include both a dummy variable that takes a value of one if short sales are banned on
the stock and FinBanned, a dummy variable that takes a value of one if the stock is a financial stock and short sales are banned. To attract the attention of regulators, it is likely that non-financial banned stocks are both actively traded and financially distressed. To insure that are results were not caused by differences between financial and non-financial banned stocks, we also include LnVol, the logarithm of the average daily dollar volume of the stock over the previous 20 days and PutPrice, the average price of the put in the regression.

Results are shown in Table 3. The coefficients for the banned and financial banned dummy variables are reported for September 2, 2008 through October 21, 2009 for October and December puts. The coefficient on the banned dummy can be interpreted as the extra spread of non-financial banned stocks over control stocks. For the October puts, this coefficient is always statistically insignificant and often negative. In part, this can be due to the small number of banned non-financial stocks. The coefficient on the financial banned dummy is positive and significant throughout the period but is much larger during the ban. This demonstrates that banned financial stocks have significantly wider spreads than non-financial stocks that are also subject to the ban.

Results for the December puts are shown in the bottom three rows of the table. For these puts, coefficients are positive and often significant during the ban. It appears that spreads did widen for December puts on non-financial banned stocks. The coefficient on the financial banned dummy is positive and highly significant during the ban, so spreads of puts on financial banned stocks increased much more than spreads of puts on other stocks.

It is not clear why the effect of the short sale ban was so much greater for financial stocks than other stocks. One possibility is that the ban itself had no impact on spreads, and that bid-ask spreads for options on financial stocks increased for other reasons. We find this to be implausible. After weeks of turmoil for financial stocks, option spreads increased dramatically when the ban was announced. Anecdotes from market participants indicate that the short sale rule itself was a problem for options market makers, and options exchanges threatened the SEC that they would not open on September 22nd unless market makers were given an exemption from the ban.

Another reason the impact of the ban on spreads of options on non-financial stocks was so weak could be that information asymmetries were much greater in the financial sector, and that these asymmetries were exacerbated
when the shorting ban kept bearish investors out of the market. Finally, it is possible that uncertainty about potential future SEC actions was much greater for financial stocks.

D. Summary.

The SEC’s restrictions on short selling had a dramatic impact on quoted spreads in the options market. Relative spreads on options on stocks that did not come under the short sale ban increased following the imposition of Rule 204T. This reflects the extra cost to options market makers of hedging when the failure to deliver shares is heavily penalized. The ban on short sales led to an additional dramatic increase in spreads for options on banned stocks. Spreads for options on banned stocks narrowed sharply when options market makers were given explicit permission to short for hedging purposes. Nevertheless, spreads on puts and calls on banned stocks remained wide during the remainder of the ban period, likely reflecting regulatory uncertainty, high costs of hedging, and information asymmetries exacerbated by the ban. A simple back of the envelope calculation that assumes investors traded at the posted quotes suggests that liquidity demanding investors trading options on banned stocks during the short sale ban paid an extra $505 million in liquidity costs because of the inflated spreads.13 Data obtained from a retail broker shows that investors were lucky if they paid the quoted spread on September 19th, suggesting that our analysis understates the cost of the short sale ban on liquidity demanding investors.

VI. Biases in Prices Arising from the Short Sale Ban

A. Differences between synthetic and actual share prices

We next examine the impact of the ban on the difference between prices of synthetic shares created from options and the prices of the underlying shares. There are two reasons why the price of synthetic shares

13Each day of the short sale ban we take the difference between the marginal cost of trading options on banned stocks obtained from our daily regressions of the dollar bid ask spreads of Option expiration options without the underlying stock’s bid ask spread as an explanatory variable and the marginal cost of trading options on banned stocks on September 17, 2008. We then multiply this difference by the number of contracts traded on banned stocks on that day. Finally, since liquidity demanders only pay ½ of the spread, we multiply this estimate by 0.5.
may fall relative to the price of actual shares. First, the stock may be overpriced if the short sale ban holds stock prices at artificially high levels. Harris, Namvar, and Phillips (2009) provide evidence that suggests prices were held artificially high for stocks that were included in the short sale ban. Second, synthetic share prices may have fallen as the result of option market makers’ inability to hedge. A synthetic short position in a stock involves writing a call and buying a put. If market makers were unable to hedge investors’ sales of calls by shorting stock, they may decrease the price they pay for calls to reflect the risks that they are taking. Similarly, if market makers were unable to hedge investors’ purchases of puts by shorting stock, they might increase the price of puts to reflect these risks. Either or both of an increase in put prices or a decrease in call prices would mean a fall in synthetic share prices.

We calculate synthetic buy and sell prices at the end of each minute of each day during the sample period using all pairs of call and put options with the same exercise price and expiration date. The cost to buy a share of stock synthetically is

\[
Synthetic \ Stock_{Ask} = C_{Ask} + e^{-rT} X - P_{Bid} + EEP + \sum_{j=1}^{J} e^{-rT_j} D_j
\]

where \( C_{Ask} \) is the ask price of a call, \( r \) is the riskless rate, \( T \) is the time to expiration for the call and put, \( X \) is the exercise price, \( P_{Bid} \) is the bid price of a put with the same exercise price and expiration date as the call, \( EEP \) is the early exercise premium in the put price, \( t_j \) is the time until the stock pays its \( j \)th dividend before the option expires, and \( D_j \) is the amount of the \( j \)th dividend. We approximate the dividends expected to be paid over the life of the option with the actual dividends from CRSP for 2008, and with the previous quarter’s dividend for 2009. The early exercise premium for the put is calculated as in Barone-Adesi and Whaley (1987). Similarly, the proceeds to be received from selling a share synthetically are given by

\[
Synthetic \ Stock_{Bid} = C_{Bid} + e^{-rT} X - P_{Ask} + EEP + \sum_{j=1}^{J} e^{-rT_j} D_j
\]

To examine biases in option prices we compare the bid-ask midpoint of the underlying stock with the synthetic midpoint, calculated as the average of the synthetic bid and ask. For every day from August 1, 2008 through October 17, 2008, we calculate the mean difference between the synthetic bid-ask midpoint and the
actual stock bid-ask midpoint using all options expiring in October 2008, clustering standard errors by the underlying stock. In order to minimize the impact of data errors, we discard all instances when the difference between synthetic and actual bid ask midpoints is $2 or more in absolute value. The daily mean differences for banned stocks are plotted in Panel A of Figure 9 while the daily mean differences for control stocks are plotted in Panel B of Figure 9. Prior to the introduction of Temporary Rule 204T and the short sale ban, the mean difference between the synthetic bid-ask midpoint and the actual midpoint is close to zero for banned and control stocks. When Temporary Rule 204T is enacted on September 18th, the synthetically implied midpoint is, on average, $0.05 per share lower than the actual midpoint. With the advent of the short sale ban on September 19th, the difference falls sharply to -$0.37 for options on banned stocks. That is, synthetic shares of stock were priced an average of $0.37 lower than the shares themselves. For control stocks, the difference only falls to -$0.08. For banned stocks, the discrepancy between the synthetic and actual stock bid-ask midpoints declines steadily but remains statistically negative until the short sale ban ends. The relationship between the synthetic and actual stock bid-ask midpoint of control stocks returns to parity on September 22nd, where it more or less remains for the remainder of the short sale ban.

Figure 10 is similar to Figure 9, but presents average differences between the prices of synthetic and actual shares using options that expire in December. Here again, the price of synthetic shares is very close to the price of actual shares before the short sale ban for control and banned stocks. When the ban is initiated, prices of synthetic shares of banned stock fall sharply relative to actual share prices. On September 19th, synthetic prices average about $0.36 less than actual prices. This difference is narrowed, but remains significantly negative for the duration of the short selling ban.

Given the potential differences in the characteristics of banned and control stocks, we run the following cross-sectional regression each day of our sample period using October and December expiration options to create synthetically implied stock midpoints:
where \( \text{Bias}_i \) is the average difference in the midpoints of the synthetically implied and the underlying stock’s actual bid ask spread computed using the 390 end-of-minute observations on day \( t \) that are not greater than $2.00 in absolute value and the remaining explanatory variables are identical to those used in the daily spread regressions. Standard errors are clustered by stock.

Table 4 contains both the results for the regressions that use October 2008 expiration options to create synthetic bid ask spread midpoints and the results for the regressions that use December 2008 expiration options. To control for possible non-linearities, we include the inverse and square of the implied standard deviations and moneyness in the regressions. This makes the coefficients very difficult to interpret, so we report only the regression intercept and the coefficient on the banned short sales dummy in the table.

Results suggest that the differences in bias for banned and control stocks are not statistically different from one another at the 1% level on most days prior to September 18\textsuperscript{th}. On September 18\textsuperscript{th}, the bias for banned stocks computed using October 2008 expiration options becomes about $0.077 lower than the bias for control stocks. On September 19\textsuperscript{th}, the coefficient indicates that the bias is $0.269 less for the synthetic shares derived from October banned stocks than the bias for synthetic shares derived from control stocks. For synthetic shares derived from December options, the difference is $0.258. Consistent with the evidence presented in Figures 9 and 10, the difference between the bias for banned and control stocks is statistically different at the 1% level for the entire short sale ban. After the ban ends, there are few days on which the bias for banned and control stocks are statistically different from one another at the 1% level.

\( \text{Bias}_i = \alpha_0 + \alpha_1 \text{Banned}_i + \alpha_2 \left( \frac{S_{X_i}}{\text{X}_i} \right) + \alpha_3 \left( \frac{S_{X_i}}{\text{X}_i} \right)^2 + \alpha_4 \left( \frac{S_{X_i}}{\text{X}_i} \right)^{-1}
+ \alpha_5 \text{ISD}_i + \alpha_6 \text{ISD}_i^2 + \alpha_7 \text{ISD}_i^{-1} + \alpha_8 \left( \frac{S_{X_i}}{\text{X}_i} \right) \text{ISD}_i + \alpha_9 \text{Penny}_i + \epsilon_i \) (5)

\( B. \quad \text{Biases in Bid and Ask Prices} \)

There is no reason why synthetic bid and synthetic ask prices must fall symmetrically relative to actual prices. Indeed, if market makers are attempting to prevent synthetic short selling because they cannot hedge these trades, we might expect the decline in synthetic bid prices relative to actual bid prices to be especially
steep. To examine this, we separately calculate the difference between synthetic and actual bid prices and between synthetic and actual ask prices for all pairs of December options each day during our sample period. Figure 11 plots the average differences each day.

The solid line in Figure 11 depicts the mean difference between the synthetic stock ask and actual stock ask for banned stocks. Prior to the ban, the difference is consistently positive and averages around $0.05. Buying a stock synthetically is usually a little more expensive than buying the shares themselves - perhaps because two securities, both a put and a call, are traded. It is interesting that after the ban takes effect, the synthetic ask does not fall relative to the actual ask, and in fact rises at the start of the ban.

The dashed line in Figure 11 is the stock bid minus the synthetic bid price. Note that the line is flipped - we are subtracting the synthetic bid from the actual bid rather than subtracting the actual price from the synthetic price as we have done before. Doing this allows us to compare the magnitude of the change in the bid and ask prices. Here we see that the synthetic bid price fell an average of about $0.50 relative to the actual bid price when the ban took effect, while the average synthetic ask price actually rose about $0.20 relative to the actual ask price. The change in synthetic stock prices relative to actual stock prices is asymmetric, exactly as we might expect if market makers were attempting to discourage short selling.

C. Biases in financial and non-financial banned stocks

We next compare the differences between synthetic and actual shares separately for financial and non-financial stocks. As before, we define financial stocks as those with CRSP primary SIC codes between 6000 and 6999 and non-financial stocks as all others. For options on each underlying stock, we create a dummy variable that equals one if the stock is included in the short-sale ban and another that takes a value of one if the stock is a financial stock and is included in the ban. We then estimate the following cross-sectional regression each day, with standard errors clustered at the firm level.
where $\text{Bias}_i$ is the daily difference between the synthetic stock price midpoint and actual stock price midpoint, obtained by averaging differences over all minutes of the day.

Figure 12 shows daily estimates of the coefficients on the sum of the constant and the banned stock dummy, and on the sum of the constant and the banned and financial banned stock dummies. Panel A contains these estimates for October expiration options. The sum of the constant and the banned and financial banned stock dummies is close to zero throughout the pre-ban period, while the sum of constant and the banned dummy is between -$0.10 and -$0.18 for several days in September prior to the ban. This suggests that options market makers did not quote options on banned stocks differently than options on financially banned stocks prior to the short sale ban. During the ban, however, on most days actual share prices were only lower than synthetic prices for banned stocks with SIC codes between 6000 and 6999. This suggests that option market makers more actively discouraged the purchase of October expiration puts and the sale of October expiration calls on financial stocks subject to the short sale ban than they did for similar options on nonfinancial banned stocks.

Panel B presents similar data for December expiration options. Prior to the short sale ban, there appears to be little difference between the synthetic and actual prices for financial or nonfinancial, banned stocks. However, when the short sale ban is put into place on September 19th, the synthetic prices of both financial and nonfinancial banned stocks become lower than the actual prices of the stocks, with the difference being more severe for financial banned stocks. Throughout the ban, the synthetic prices of financial and nonfinancial banned stocks are lower than the actual stock prices and the difference in prices remains greater for financial banned stocks.

D. Short sale constraints and differences in synthetic and actual stock prices.

If it is the case that the difference in actual and synthetic stock prices is due to short sale constraints, we might expect to observe similar biases when the underlying stock is hard to borrow. To test this, we obtain the daily list of hard-to-borrow securities for September 2008 from a major investment bank. The proportion
of banned stocks and control stocks that are hard to borrow each day of September is shown in Figure 13. The proportion of stocks that are hard-to-borrow is between 20% and 30% most days for both control stocks and banned stocks. These proportions soar to over 80% for three days: September 15th, September 18th, and September 25th. There are at least anecdotal explanations for each of these events. September 15th corresponds to the collapse of Lehman Brothers, September 18th is the day when Regulation 204T becomes effective, and September 25th is the day of the TARP testimony.

Each day, for each pair of options with a December expiration date, we calculate the average bias, or difference between the synthetic and actual stock price midpoints. We then estimate daily cross-sectional regressions of these average differences on a dummy variable for a banned stock and a dummy variable that takes a value of one if the stock was on the hard to borrow list.\textsuperscript{14}

Daily coefficients on the banned and hard-to-borrow dummies are depicted in Figure 14. Here again we see that when the ban on short selling is initiated, the price of synthetic share of a banned stock falls by about $0.30 relative to the price of an actual share. We also see that the price of synthetic share of a hard-to-borrow stock is less that the price of an actual share both before and during the ban, and that the difference is similar in magnitude to the difference of banned stocks after the ban. This gives us some additional confidence that the higher prices for actual shares of the banned stocks than synthetic shares is due to short sale constraints. For hard-to-borrow stocks, like banned stocks, actual shares could have a higher price than synthetic ones either because the actual shares are overpriced, or because options market makers keep prices of synthetic shorts low because they are hard to hedge. In the case of hard-to-borrow stocks there is a third alternative though. Actual shares may sell for more than synthetic shares because the actual ones can be lent out to provide income.

\textsuperscript{14}The graphical results are obtained by throwing out observations where the difference between the synthetic and actual stock price exceeded $2 in absolute value. Similar results are obtained when outliers are not discarded. We also ran the regressions with an interaction between banned and hard-to-borrow. The interaction term was generally insignificant and had little impact on the coefficients of the other variables.
Differences between synthetic and actual stock prices during the shorting ban should not be interpreted as arbitrage opportunities. Inability to short makes it impossible to directly arbitrage between stock and option markets. In addition, even if shares could be shorted, recall that bid-ask spreads were wide for both stocks and options during the ban. Finally, misestimating the early exercise premia or failing to properly account for the cost of shorting stock may create the appearance of arbitrage opportunities where none actually exist.

VII. Conclusions.

Confusion generated by the directive banning short selling in 797 ‘financial’ stocks announced in the early hours of September 19th and over the requirements of Temporary Rule 204T had severe ramifications for equity option markets. First, trading costs for options increased sharply when the ban was initiated. This made options trading less attractive to investors who were attempting to lay off risk or to speculate on a rebound in bank stock prices. Indeed, ignoring welfare effects associated with investors who found it too costly to use option markets to hedge during the short sale ban, we conservatively estimate that liquidity demanding investors trading options on banned stocks paid an extra $505 million in liquidity costs. Second, a bias in relative prices of options and stock appeared with the ban. Synthetic shares of stock became cheap relative to the actual shares. This could be because stock prices were to high, or because it was more difficult for market makers to hedge customers’ long positions in puts or short positions in calls and they therefore increased ask prices of puts and lowered bid prices of calls. Our results suggest the second explanation is more likely.

We draw two larger lessons from our study of the short sale ban. First, options market makers need to be able to hedge. If they cannot hedge easily and cheaply, trading costs in options markets increase and option and stock prices decouple. Second, financial regulators need to be shielded from political pressures. The SEC came under tremendous pressure from politicians to ban short selling in September 2008. The result was a hastily-crafted, ill-conceived rule that sowed chaos in the options and equity markets and injected regulatory uncertainty that still lingers in these markets.
References


CBOE Regulatory Circular RG08-117, September 24, 2008.


Comment letter from Options Exchanges to Florence E. Harmon, Acting Secretary, SEC, December 19, 2008.


References (continued)


Gurliacci, Mark, David Jeria, and George Sofianos, October 14, 2008, The Short-Sell Ban and Quoted Spreads, Street Smart 34.

Harris, Lawrence, Ethan Namvar, and Blake Phillips, 2009, Price Inflation and Wealth Transfer During the 2008 SEC Short-Sale Ban, Working paper, University of Southern California.


Kolasinksi, Adam, Adam Reed, and Jacob Thornock, 2009, Prohibitions versus Constraints: The 2008 Short Sales Regulations, University of North Carolina working paper.


Mehta, Nina, September 22, 2008, Options Market Makers get Relief from SEC Ban on Short-Selling, Traders Magazine Online News.


SEC, October 17, 2008, Amendments to Regulation SHO, Release 34-58773.
Table 1. Relevant regulatory events and clarifications.

<table>
<thead>
<tr>
<th>Date</th>
<th>Event</th>
<th>How action impacted option market participants</th>
</tr>
</thead>
<tbody>
<tr>
<td>September 18(^{th})</td>
<td>Adopted temporary Rule 204T</td>
<td>• If a broker dealer fails to deliver shares within three days of a trade, its clearing firm and any broker dealer and/or option market maker for which it clears must pre-borrow shares before entering into a short sale. This penalty remains in effect until trade is settled. Temporary Rule 204T was made permanent on October 17, 2008 (see SEC Release 34-58773).</td>
</tr>
<tr>
<td>September 19(^{th})</td>
<td>Short sale ban</td>
<td>• Option market makers only allowed to sell short pursuant to bona fide market making and hedging activities until 11:59pm on September 19(^{th}).</td>
</tr>
<tr>
<td>September 22(^{nd})</td>
<td>Extension of option market maker exemption</td>
<td>• Option market makers allowed to sell short pursuant to bona fide market making and hedging for the remainder of the short sale ban.</td>
</tr>
</tbody>
</table>
| September 23\(^{rd}\) | SEC clarification of Rule 204T     | • Only the firm that fails to deliver shares must pre-borrow shares if it fails to deliver shorted shares within three days of a trade.  
• Firms do not have to cover their short position exactly three days after a transaction – they can do this anytime during the three days after the transaction.  
• Market makers failing to deliver must provide a document attesting that the failure to deliver position was established while performing bona fide market making obligations. |
| September 24\(^{th}\) | SEC clarification of Rule 204T     | • Option market makers must now close out their short positions within five days of a trade.  
• Confirmation that option market makers could short shares even when another member of its clearing agency had failed to deliver.                                                                                                                                       |
| October 8\(^{th}\) | Short sale ban ends                |                                                                                                                                                                                                                                            |
Table 2. Summary statistics.

Panel A. Distribution of the price and market capitalization for the 330 stocks with exchange traded options that came under the initial short sale ban banned stocks on July 31, 2008 and their matching control stocks.

<table>
<thead>
<tr>
<th></th>
<th>330 Banned Stocks</th>
<th>330 Control Stocks</th>
<th>330 Banned Stocks</th>
<th>330 Control Stocks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Price</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean</td>
<td>$30.76</td>
<td>$30.76</td>
<td>8,727</td>
<td>8,716</td>
</tr>
<tr>
<td>25&lt;sup&gt;th&lt;/sup&gt; Percentile</td>
<td>$12.69</td>
<td>$12.77</td>
<td>818</td>
<td>1,177</td>
</tr>
<tr>
<td>Median</td>
<td>$23.75</td>
<td>$22.00</td>
<td>2,314</td>
<td>2,948</td>
</tr>
<tr>
<td>75&lt;sup&gt;th&lt;/sup&gt; Percentile</td>
<td>$39.38</td>
<td>$38.28</td>
<td>5,763</td>
<td>6,721</td>
</tr>
</tbody>
</table>

Panel B. The distribution across days from August 1, 2008 through October 21, 2008 of the number of options quoted on banned and control stocks.

<table>
<thead>
<tr>
<th></th>
<th>Banned Stocks</th>
<th>Control Stocks</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>Minimum</td>
</tr>
<tr>
<td>All Options</td>
<td>29,678</td>
<td>27,434</td>
</tr>
<tr>
<td>August Exp.</td>
<td>4,875</td>
<td>4,600</td>
</tr>
<tr>
<td>September Exp.</td>
<td>5,194</td>
<td>4,776</td>
</tr>
<tr>
<td>October Exp.</td>
<td>4,653</td>
<td>2,368</td>
</tr>
<tr>
<td>November Exp.</td>
<td>2,651</td>
<td>1,036</td>
</tr>
<tr>
<td>December Exp.</td>
<td>2,622</td>
<td>2,248</td>
</tr>
<tr>
<td>Expire After 2008</td>
<td>15,919</td>
<td>12,422</td>
</tr>
<tr>
<td>S/X &lt; 0.8</td>
<td>11,572</td>
<td>8,107</td>
</tr>
<tr>
<td>0.8 &lt; S/X &lt; 1.2</td>
<td>9,663</td>
<td>7,084</td>
</tr>
<tr>
<td>1.2 &lt; S/X</td>
<td>8,443</td>
<td>4,660</td>
</tr>
</tbody>
</table>
Table 3
Marginal impact of the short sale ban on quoted bid ask spreads of puts on all banned stocks and on banned financial stocks

Panel A.

<table>
<thead>
<tr>
<th>October Exp.</th>
<th>902</th>
<th>903</th>
<th>904</th>
<th>905</th>
<th>908</th>
<th>909</th>
<th>910</th>
<th>911</th>
<th>912</th>
<th>915</th>
</tr>
</thead>
<tbody>
<tr>
<td>Banned</td>
<td>-$0.009</td>
<td>-$0.018</td>
<td>-$0.014</td>
<td>-$0.018</td>
<td>-$0.042</td>
<td>-$0.028</td>
<td>-$0.029</td>
<td>-$0.029</td>
<td>-$0.023</td>
<td>-$0.044</td>
</tr>
<tr>
<td>Financial banned</td>
<td>$0.108***</td>
<td>$0.136***</td>
<td>$0.138***</td>
<td>$0.121***</td>
<td>$0.169***</td>
<td>$0.137***</td>
<td>$0.129***</td>
<td>$0.180***</td>
<td>$0.191***</td>
<td>$0.224***</td>
</tr>
<tr>
<td># of stocks</td>
<td>610</td>
<td>608</td>
<td>608</td>
<td>611</td>
<td>608</td>
<td>606</td>
<td>603</td>
<td>608</td>
<td>605</td>
<td>601</td>
</tr>
</tbody>
</table>

December Exp.

| Banned       | $0.064    | $0.006    | $0.005    | $0.009    | -$0.002   | $0.031    | $0.010    | -$0.023   | $0.039    | -$0.001   |
| Financial banned | $0.044    | $0.136**  | $0.130**  | $0.081    | $0.142**  | $0.103    | $0.072    | $0.140*** | $0.107**  | $0.151**  |
| # of stocks | 249       | 249       | 249       | 249       | 248       | 246       | 246       | 246       | 245       | 240       |

Panel B.

<table>
<thead>
<tr>
<th>October Exp.</th>
<th>916</th>
<th>917</th>
<th>918</th>
<th>919</th>
<th>922</th>
<th>923</th>
<th>924</th>
<th>925</th>
<th>926</th>
<th>929</th>
</tr>
</thead>
<tbody>
<tr>
<td>Banned</td>
<td>-$0.039</td>
<td>-$0.035</td>
<td>-$0.074</td>
<td>-$0.006</td>
<td>$0.021</td>
<td>-$0.000</td>
<td>-$0.067</td>
<td>-$0.005</td>
<td>$0.044</td>
<td>$0.061</td>
</tr>
<tr>
<td>Financial banned</td>
<td>$0.280***</td>
<td>$0.282***</td>
<td>$0.473***</td>
<td>$1.186***</td>
<td>$0.709***</td>
<td>$0.570***</td>
<td>$0.474***</td>
<td>$0.448***</td>
<td>$0.406***</td>
<td>$0.590***</td>
</tr>
<tr>
<td># of stocks</td>
<td>604</td>
<td>594</td>
<td>596</td>
<td>567</td>
<td>596</td>
<td>593</td>
<td>593</td>
<td>586</td>
<td>582</td>
<td></td>
</tr>
</tbody>
</table>

December Exp.

| Banned       | $0.101    | $0.216**  | $0.122    | $0.200    | $0.117    | $0.230**  | $0.113    | $0.159**  | $0.265**  | $0.297**  |
| Financial banned | $0.154**  | $0.001    | $0.261*** | $1.153*** | $0.532*** | $0.416*** | $0.276*** | $0.289*** | $0.240**  | $0.356*** |
| # of stocks | 244       | 242       | 243       | 237       | 244       | 247       | 245       | 245       | 242       | 240       |
Table 3 (continued)

Panel C.

<table>
<thead>
<tr>
<th>October Exp.</th>
<th>930</th>
<th>1001</th>
<th>1002</th>
<th>1003</th>
<th>1006</th>
<th>1007</th>
<th>1008</th>
<th>1009</th>
<th>1010</th>
<th>1013</th>
</tr>
</thead>
<tbody>
<tr>
<td>Banned</td>
<td>$0.032</td>
<td>$0.039</td>
<td>$0.084</td>
<td>$0.026</td>
<td>$0.030</td>
<td>$0.002</td>
<td>$0.032</td>
<td>$0.0189</td>
<td>-$0.111</td>
<td>-$0.030</td>
</tr>
<tr>
<td>Financial banned</td>
<td>$0.454***</td>
<td>$0.406***</td>
<td>$0.350***</td>
<td>$0.404***</td>
<td>$0.480***</td>
<td>$0.402***</td>
<td>$0.444***</td>
<td>$0.354***</td>
<td>$0.730***</td>
<td>$0.294***</td>
</tr>
<tr>
<td># of stocks</td>
<td>569</td>
<td>579</td>
<td>584</td>
<td>591</td>
<td>579</td>
<td>572</td>
<td>570</td>
<td>565</td>
<td>536</td>
<td>531</td>
</tr>
</tbody>
</table>

| December Exp. |           |       |       |       |       |       |       |       |       |
| Banned        | $0.192* | $0.242*** | $0.335*** | $0.253** | $0.267** | $0.307*** | $0.184 | $0.174** | $0.070 | $0.184** |
| Financial banned | $0.287*** | $0.211** | $0.130 | $0.232** | $0.172 | $0.221** | $0.274** | $0.268*** | $0.260* | $0.142 |
| # of stocks    | 238 | 240 | 239 | 239 | 235 | 235 | 231 | 233 | 225 | 230 |

Panel D.

<table>
<thead>
<tr>
<th>October Exp.</th>
<th>1014</th>
<th>1015</th>
<th>1016</th>
<th>1017</th>
<th>1020</th>
<th>1021</th>
</tr>
</thead>
<tbody>
<tr>
<td>Banned</td>
<td>-$0.073</td>
<td>-$0.023</td>
<td>-$0.064</td>
<td>-$0.075</td>
<td>n.a.</td>
<td>n.a.</td>
</tr>
<tr>
<td>Financial banned</td>
<td>$0.301***</td>
<td>$0.284***</td>
<td>$0.250***</td>
<td>$0.233***</td>
<td>n.a.</td>
<td>n.a.</td>
</tr>
<tr>
<td># of stocks</td>
<td>537</td>
<td>517</td>
<td>475</td>
<td>355</td>
<td>n.a.</td>
<td>n.a.</td>
</tr>
</tbody>
</table>

| December Exp. |       |       |       |       |       |       |
| Banned        | $0.288** | $0.164 | $0.178 | $0.248** | $0.004 | $0.015 |
| Financial banned | $0.069 | $0.143 | $0.083 | $0.029 | $0.261*** | $0.186** |
| # of stocks    | 234 | 235 | 233 | 231 | 578 | 587 |
Table 3 continued)

Notes: We run the following cross-sectional regression each day of our sample period using October and December expiration options to create synthetically implied stock midpoints:

\[
\text{Spread}_t = \alpha_0 + \alpha_1 \text{Banned}_t + \alpha_2 \text{FinBanned}_t + \alpha_3 \left( \frac{S}{X} \right)_t + \alpha_4 \left( \frac{S}{X} \right)^2_t + \alpha_5 \left( \frac{S}{X} \right)^{1/2}_t \\
+ \alpha_6 \text{ISD}_t + \alpha_7 \text{ISD}^2_t + \alpha_8 \text{ISD}^3_t + \alpha_9 \left( \frac{S}{X} \right)_t^{1/2} \text{ISD}_t + \alpha_{10} \text{Penny}_t + \alpha_{11} \text{LnVol}_t + \alpha_{12} \text{Putprice}_t + \epsilon_t
\]

where \(\text{Spread}_t\) is the average bid ask spread computed using the 390 end-of-minute observations on day \(t\), \(\text{Banned}_t\) takes a value of one if option \(i\) is on a stock with banned short selling and zero otherwise, \(\text{FinBanned}_t\) takes a value of one if option \(i\) is on a financial stock with banned short selling, \(\frac{S}{X}_t\) is the ratio of the stock price to the exercise price over the 390 end-of-minute observations on day \(t\), \(\left(\frac{S}{X}\right)_t^2\) and \(\left(\frac{S}{X}\right)^{1/2}_t\) are the square and square root of the average value of \(\frac{S}{X}\) for day \(t\), \(\text{ISD}_t\) is the mean implied standard deviation for option \(i\) on day \(t\) calculated from calls with the same exercise price and expiration date, \(\text{ISD}^2_t\) and \(\text{ISD}^{1/2}_t\) are square and square root of the average implied standard deviation for day \(t\), \(\text{Penny}_t\) is one if the option is part of the SEC’s Penny Pilot and zero otherwise, \(\text{LnVol}_t\) is the average daily dollar volume of the underlying stock over the prior 20 days and \(\text{Putprice}_t\) is the average price of the put on that day. The regressions examine the spreads of options on the 330 optionable stocks for which short selling is banned on September 19th, 2008 and options on a set of stocks not subject to the short sale ban that we match to the set of banned stocks. Our daily OPRA files containing data for August 14th and August 26th are corrupt so we have no data for these days. *Different from zero at the 10% level, **Different from zero at the 5% level, ***Different from zero at the 1% level.
Table 4
Difference in the midpoint of the bid ask spread synthetically created from pairs of puts and calls
and the midpoint of the underlying stock’s bid ask spread midpoint

Panel A. August 1, 2008 through September 19, 2008.

<table>
<thead>
<tr>
<th></th>
<th>Min</th>
<th>Median</th>
<th>Max</th>
<th>Days p&lt;0.01</th>
<th>915</th>
<th>916</th>
<th>917</th>
<th>918</th>
<th>919</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>20080801 - 20080912</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>October 2008 Options</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ban Dummy</td>
<td>-$0.0632</td>
<td>-$0.0328</td>
<td>$0.0027</td>
<td>3</td>
<td>-$0.0336</td>
<td>-$0.0415</td>
<td>-$0.0280</td>
<td>-$0.0773</td>
<td>-$0.2688</td>
</tr>
<tr>
<td>Constant</td>
<td>-$0.0944</td>
<td>$0.0346</td>
<td>$0.2771</td>
<td>4</td>
<td>$0.1588</td>
<td>$0.1865</td>
<td>$0.2026</td>
<td>$0.0862</td>
<td>-$0.3090</td>
</tr>
<tr>
<td>Pseudo R²</td>
<td>2.69%</td>
<td>6.32%</td>
<td>12.60%</td>
<td></td>
<td>4.64%</td>
<td>4.09%</td>
<td>3.22%</td>
<td>7.38%</td>
<td>14.96%</td>
</tr>
<tr>
<td>N</td>
<td>1,529</td>
<td>3,331</td>
<td>3,424</td>
<td></td>
<td>3,312</td>
<td>3,328</td>
<td>3,237</td>
<td>3,348</td>
<td>3,413</td>
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</tbody>
</table>

December 2008 Options

<table>
<thead>
<tr>
<th></th>
<th>Min</th>
<th>Median</th>
<th>Max</th>
<th>Days p&lt;0.01</th>
<th>915</th>
<th>916</th>
<th>917</th>
<th>918</th>
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</tr>
</thead>
<tbody>
<tr>
<td>Ban Dummy</td>
<td>$0.0074</td>
<td>$0.0397</td>
<td>$0.1081</td>
<td>0</td>
<td>$0.0733</td>
<td>$0.0601</td>
<td>$0.0415</td>
<td>-$0.0142</td>
<td>-$0.2580</td>
</tr>
<tr>
<td>Constant</td>
<td>-$0.2315</td>
<td>$0.0361</td>
<td>$0.3357</td>
<td>0</td>
<td>$0.0369</td>
<td>$0.2386</td>
<td>$0.5452</td>
<td>$0.4462</td>
<td>-$0.4462</td>
</tr>
<tr>
<td>Pseudo R²</td>
<td>4.13%</td>
<td>8.36%</td>
<td>12.57%</td>
<td></td>
<td>8.20%</td>
<td>7.62%</td>
<td>6.57%</td>
<td>8.82%</td>
<td>18.86%</td>
</tr>
<tr>
<td>N</td>
<td>1,731</td>
<td>1,804</td>
<td>1,840</td>
<td></td>
<td>1,746</td>
<td>1,754</td>
<td>1,712</td>
<td>1,744</td>
<td>1,737</td>
</tr>
</tbody>
</table>

Note: Shading indicates p<0.01.
Table 4 (continued)


<table>
<thead>
<tr>
<th></th>
<th>922</th>
<th>923</th>
<th>924</th>
<th>925</th>
<th>926</th>
<th>929</th>
<th>930</th>
<th>1001</th>
<th>1002</th>
<th>1003</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>October 2008 Options</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ban Dummy</td>
<td>-$0.2280</td>
<td>-$0.1922</td>
<td>-$0.1736</td>
<td>-$0.1417</td>
<td>-$0.1392</td>
<td>-$0.1252</td>
<td>-$0.1386</td>
<td>-$0.1357</td>
<td>-$0.1479</td>
<td>-$0.1329</td>
</tr>
<tr>
<td>Constant</td>
<td>-$0.0159</td>
<td>-$0.0778</td>
<td>-$0.1002</td>
<td>-$0.1624</td>
<td>-$0.0851</td>
<td>$0.1480</td>
<td>-$0.1037</td>
<td>-$0.0606</td>
<td>$0.0972</td>
<td>-$0.1253</td>
</tr>
<tr>
<td>Psuedo R²</td>
<td>12.25%</td>
<td>12.01%</td>
<td>14.17%</td>
<td>11.61%</td>
<td>13.00%</td>
<td>10.51%</td>
<td>10.26%</td>
<td>10.61%</td>
<td>12.15%</td>
<td>12.30%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>922</th>
<th>923</th>
<th>924</th>
<th>925</th>
<th>926</th>
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<th>930</th>
<th>1001</th>
<th>1002</th>
<th>1003</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>December 2008 Options</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ban Dummy</td>
<td>-$0.2232</td>
<td>-$0.2310</td>
<td>-$0.2517</td>
<td>-$0.2401</td>
<td>-$0.1763</td>
<td>-$0.1646</td>
<td>-$0.1398</td>
<td>-$0.1827</td>
<td>-$0.1667</td>
<td>-$0.1420</td>
</tr>
<tr>
<td>Constant</td>
<td>-$0.0199</td>
<td>-$0.2630</td>
<td>-$0.0488</td>
<td>-$0.1192</td>
<td>-$0.0023</td>
<td>$0.2638</td>
<td>-$0.0485</td>
<td>-$0.0230</td>
<td>-$0.0747</td>
<td>-$0.1858</td>
</tr>
<tr>
<td>Psuedo R²</td>
<td>9.61%</td>
<td>12.47%</td>
<td>13.67%</td>
<td>13.26%</td>
<td>10.22%</td>
<td>11.50%</td>
<td>10.71%</td>
<td>12.86%</td>
<td>11.69%</td>
<td>13.06%</td>
</tr>
<tr>
<td>N</td>
<td>1,777</td>
<td>1,758</td>
<td>1,770</td>
<td>1,786</td>
<td>1,689</td>
<td>1,702</td>
<td>1,658</td>
<td>1,687</td>
<td>1,687</td>
<td>1,691</td>
</tr>
</tbody>
</table>

Note: Shading indicates p<0.01.
Table 4 (continued)

Panel C. October 6, 2008 through October 17, 2008.

<table>
<thead>
<tr>
<th>20081009 - 20081017</th>
<th>1006</th>
<th>1007</th>
<th>1008</th>
<th>Min</th>
<th>Median</th>
<th>Max</th>
<th>Days p&lt;0.01</th>
</tr>
</thead>
<tbody>
<tr>
<td>October 2008 Options</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ban Dummy</td>
<td>-$0.1138</td>
<td>-$0.0961</td>
<td>-$0.0619</td>
<td>-$0.0779</td>
<td>-$0.0394</td>
<td>-$0.0200</td>
<td>2</td>
</tr>
<tr>
<td>Constant</td>
<td>$0.0266</td>
<td>$0.0061</td>
<td>$0.1943</td>
<td>-$0.1040</td>
<td>$0.1126</td>
<td>$1.3023</td>
<td>1</td>
</tr>
<tr>
<td>Psuedo R²</td>
<td>7.31%</td>
<td>10.15%</td>
<td>8.37%</td>
<td>7.20%</td>
<td>9.35%</td>
<td>15.36%</td>
<td></td>
</tr>
<tr>
<td>N</td>
<td>2,894</td>
<td>2,845</td>
<td>2,792</td>
<td>1,636</td>
<td>1,631</td>
<td>2,687</td>
<td></td>
</tr>
</tbody>
</table>

| December 2008 Options |      |      |      |     |        |     |             |
| Ban Dummy            | -$0.0941 | -$0.0597 | -$0.0237 | -$0.0728 | -$0.0338 | $0.0246 | 0 |
| Constant             | $0.2466 | $0.0396 | $0.1126 | $0.0061 | $0.1637 | $0.5009 | 1 |
| Psuedo R²            | 9.72% | 7.69% | 8.43% | 2.42% | 6.12% | 8.41% | |
| N                   | 1,630 | 1,658 | 1,616 | 1,565 | 1,745 | 3,550 | |

Note: We run the following cross-sectional regression each day of our sample period using October and December expiration options to create synthetically implied stock midpoints:

\[
\text{Bias}_i = \alpha_0 + \alpha_1 \text{Banned}_i + \alpha_2 \left(\frac{S}{X}\right)_i + \alpha_3 \left(\frac{S}{X}\right)_i^2 + \alpha_4 \left(\frac{S}{X}\right)_i^{1/2} + \alpha_5 \text{ISD}_i + \alpha_6 \text{ISD}_i^2 + \alpha_7 \text{ISD}_i^{1/2} + \alpha_8 \left(\frac{S}{X}\right)_i \text{ISD}_i + \alpha_9 \text{Penny}_i + \epsilon_i
\]

where Bias is the average difference in the midpoints of the synthetically implied and the underlying stock’s actual bid ask spread computed using the 390 end-of-minute observations on day t that are not greater than $2.00 in absolute value, Banned, takes a value of one if option i is on a stock with banned short selling and zero otherwise, \((S/X)_i\) is the ratio of the stock price to the exercise price over the 390 end-of-minute observations on day t, \((S/X)_i^2\) and \((S/X)_i^{1/2}\) are the square and square root of the average value of \((S/X)_i\) for day t, ISD is the mean implied standard deviation for option i on day t calculated from calls with the same exercise price and expiration date, \text{ISD}_i^2\) and \text{ISD}_i^{1/2}\) are square and square root of the average implied standard deviation for day t, and Penny is one if the option is part of the SEC’s Penny Pilot and zero otherwise. The regressions examine the spreads of options on the 330 optionable stocks for which short selling is banned on September 19th, 2008 and options on a set of stocks not subject to the short sale ban that we match to the set of banned stocks. Our daily OPRA files containing data for August 14th and August 26th are corrupt so we have no data for these days. Shading indicates variable has a p-value that is less than 0.01.
Table 5
Difference in the midpoint of the bid ask spread synthetically created from pairs of puts and calls and the midpoint of the underlying stock’s bid ask spread midpoint for all stocks and for financial stocks subject to the short sale ban

<table>
<thead>
<tr>
<th>Expiration</th>
<th>915</th>
<th>916</th>
<th>917</th>
<th>918</th>
<th>919</th>
<th>922</th>
<th>923</th>
<th>924</th>
<th>925</th>
<th>926</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>October 2008</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>banned</td>
<td>-$0.164</td>
<td>-$0.153</td>
<td>-$0.087</td>
<td>-$0.045</td>
<td>-$0.008</td>
<td>-$0.058</td>
<td>-$0.036</td>
<td>-$0.034</td>
<td>-$0.055</td>
<td>-$0.019</td>
</tr>
<tr>
<td>financial banned</td>
<td>$0.164</td>
<td>$0.121</td>
<td>$0.073</td>
<td>-$0.009</td>
<td>-$0.360</td>
<td>-$0.188</td>
<td>-$0.160</td>
<td>-$0.139</td>
<td>-$0.090</td>
<td>-$0.106</td>
</tr>
<tr>
<td>N</td>
<td>1,605</td>
<td>1,593</td>
<td>1,561</td>
<td>1,528</td>
<td>1,189</td>
<td>1,421</td>
<td>1,449</td>
<td>1,442</td>
<td>1,441</td>
<td>1,410</td>
</tr>
<tr>
<td># of stocks</td>
<td>584</td>
<td>581</td>
<td>576</td>
<td>576</td>
<td>477</td>
<td>539</td>
<td>557</td>
<td>551</td>
<td>564</td>
<td>552</td>
</tr>
<tr>
<td><strong>November 2008</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>banned</td>
<td>-$0.022</td>
<td>$0.021</td>
<td>-$0.041</td>
<td>-$0.029</td>
<td>$0.099</td>
<td>-$0.106</td>
<td>-$0.060</td>
<td>-$0.078</td>
<td>-$0.062</td>
<td>-$0.051</td>
</tr>
<tr>
<td>financial banned</td>
<td>$0.013</td>
<td>-$0.066</td>
<td>-$0.009</td>
<td>-$0.066</td>
<td>-$0.475</td>
<td>-$0.169</td>
<td>-$0.178</td>
<td>-$0.165</td>
<td>-$0.131</td>
<td>-$0.139</td>
</tr>
<tr>
<td>N</td>
<td>474</td>
<td>467</td>
<td>450</td>
<td>447</td>
<td>400</td>
<td>1,592</td>
<td>1,700</td>
<td>1,712</td>
<td>1,776</td>
<td>1,742</td>
</tr>
<tr>
<td># of stocks</td>
<td>132</td>
<td>131</td>
<td>130</td>
<td>132</td>
<td>120</td>
<td>537</td>
<td>564</td>
<td>563</td>
<td>577</td>
<td>552</td>
</tr>
<tr>
<td><strong>December 2008</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>banned</td>
<td>-$0.028</td>
<td>-$0.026</td>
<td>-$0.105</td>
<td>-$0.079</td>
<td>-$0.147</td>
<td>-$0.148</td>
<td>$0.090</td>
<td>-$0.155</td>
<td>-$0.113</td>
<td>-$0.038</td>
</tr>
<tr>
<td>financial banned</td>
<td>$0.097</td>
<td>$0.064</td>
<td>$0.114</td>
<td>$0.059</td>
<td>-$0.214</td>
<td>-$0.098</td>
<td>-$0.141</td>
<td>-$0.146</td>
<td>-$0.162</td>
<td>-$0.134</td>
</tr>
<tr>
<td>N</td>
<td>744</td>
<td>743</td>
<td>703</td>
<td>695</td>
<td>625</td>
<td>698</td>
<td>707</td>
<td>729</td>
<td>740</td>
<td>703</td>
</tr>
<tr>
<td># of stocks</td>
<td>234</td>
<td>233</td>
<td>232</td>
<td>229</td>
<td>206</td>
<td>227</td>
<td>226</td>
<td>227</td>
<td>231</td>
<td>225</td>
</tr>
</tbody>
</table>
Table 5 (continued)

Notes: We run the following cross-sectional regression each day of our sample period using October and December expiration options to create synthetically implied stock midpoints:

\[
Bias_i = \alpha_0 + \alpha_1 \text{Banned}_i + \alpha_2 \text{FinBanned} + \alpha_3 \left(\frac{S}{X}\right)_i + \alpha_4 \left(\frac{S}{X}\right)^2_i + \alpha_5 \left(\frac{S}{X}\right)^{1/2}_i \\
+ \alpha_6 \text{ISD}_i + \alpha_7 \text{ISD}^2_i + \alpha_8 \text{ISD}^{1/2}_i + \alpha_9 \left(\frac{S}{X}\right)_i \text{ISD}_i + \alpha_{10} \text{Penny}_i + \alpha_{11} \text{LnVol} + \alpha_{12} \text{Putprice} + \epsilon_i
\]

where \(Bias_i\) is the average difference in the midpoints of the synthetically implied and the underlying stock’s actual bid ask spread computed using the 390 end-of-minute observations on day \(t\) that are not greater than $2.00 in absolute value, \(\text{Banned}_i\) takes a value of one if option \(i\) is on a stock with banned short selling and zero otherwise, \(\text{FinBanned}\) takes a value of one if option \(i\) is on a financial stock with banned short selling, \(\left(\frac{S}{X}\right)_i\) is the ratio of the stock price to the exercise price over the 390 end-of-minute observations on day \(t\), \(\left(\frac{S}{X}\right)^2_i\) and \(\left(\frac{S}{X}\right)^{1/2}_i\) are the square and square root of the average value of \(\left(\frac{S}{X}\right)\) for day \(t\), \(\text{ISD}_i\) is the mean implied standard deviation for option \(i\) on day \(t\) calculated from calls with the same exercise price and expiration date, \(\text{ISD}^2_i\) and \(\text{ISD}^{1/2}_i\) are square and square root of the average implied standard deviation for day \(t\), \(\text{Penny}_i\) is one if the option is part of the SEC’s Penny Pilot and zero otherwise, \(\text{LnVol}\) is the average daily dollar volume of the underlying stock over the prior 20 days and \(\text{PutPrice}\) is the average price of the put on that day. The regressions examine the spreads of options on the 330 optionable stocks for which short selling is banned on September 19, 2008 and options on a set of stocks not subject to the short sale ban that we match to the set of banned stocks. Our daily OPRA files containing data for August 14th and August 26th are corrupt so we have no data for these days. *Different from zero at the 10% level, **Different from zero at the 5% level, ***Different from zero at the 1% level.
Figure 1. Daily ratio of option-to-stock trading volume in August, September, and October 2008.

Notes. Each day, we first multiply the volume of put and call contracts traded on banned stocks by 100 since each contract contains options on 100 shares of stock. We then divide this product by the number of shares traded in the underlying banned stocks on that day. The ratio of option-to-stock volume for control stocks is computed analogously. Banned includes the 330 optionable stocks for which short selling is banned on September 19th, 2008. Control refers to the set of optionable stocks not subject to the short sale ban that we match to the set of banned stocks. Our daily OPRA files containing data for August 14th and August 26th are corrupt so we have no data for these days. Our sample period ends on October 21, 2008.
Figure 2. Daily initiations of short exposure on the CBOE and ISE in August and September 2008.

Notes: Banned includes the 330 optionable stocks for which short selling is banned on September 19th, 2008. Control refers to the set of optionable stocks not subject to the short sale ban that we match to the set of banned stocks. Each day, the CBOE and the ISE identify the number of contracts involved in trades by customers and firm proprietary traders that either “open-buys”, “open-sells”, “close-buys”, or “close-sells”. Each day, for each customer type, we compute the short exposure on these two exchanges separately for options on banned and control stocks as follows:

Initiation of Short Exposure, t = (Put Open-Buy + Call Open-Sell) - (Put Close-Buy + Call Close-Sell).
Notes: We first calculate average daily spreads for puts from minute-by-minute quotes for each December put option on banned stocks with an exercise price within 20% of the mean stock price for the day. We then average daily put spreads across all of the put options for each underlying stock. We then calculate daily average put spreads across all underlying stocks. We compute average daily spreads for the underlying stocks from minute-by-minute quotes for each underlying stock. We then compute daily average stock spreads across all underlying stocks.
Figure 4. Average minute-by-minute relative spreads for puts on banned and control stocks
Notes. Figures are constructed using October expiration puts with implied volatilities between 0.7 and 1.0 and with a stock-to-strike price ratio between 80% and 120%. We compute the National Best Bid and Offer (NBBO) by taking the highest valid bid and the lowest valid offer posted at one of the seven venues currently trading equity options in the United States. Next, for each put option we compute a relative spread by dividing the difference between the National Best Offer and the National Best Bid by the midpoint of the NBBO at the end of each minute. We compute the arithmetic average of these relative spreads at the end of each minute separately for put options on banned and control stocks and plot them for different days or sets of days. Banned includes the 330 optionable stocks for which short selling is banned on September 19th, 2008. Control refers to the set of optionable stocks not subject to the short sale ban that we match to the set of banned stocks.
Figure 5. Ratio of the relative effective-to-relative quoted bid ask spread for marketable orders placed with a major retail broker in September 2008

Notes. We obtain 58,590 trades initiated by marketable orders for puts and calls on stocks for which short sales are banned on September 19, 2008 and on a set of control stocks from a retail broker during the month of September 2008. After imposing several data screens, we are left with 49,524 trades. For buy orders, effective spreads are twice the difference between the trade price and the midpoint of the order-receipt time (ORT) bid ask spread. For sell orders, effective spreads are twice the difference between the midpoint of the ORT bid ask spread and the trade price. Relative effective spreads are computed by dividing the effective spread by the midpoint of the ORT bid ask spread and the trade price. Relative quoted spreads are computed by dividing the ORT bid ask spread by the midpoint of the ORT bid ask spread. We compute the contract-weighted ratio of effective-to-realized spread for each option class each day. We then compute the across-class average of these spreads separately for option classes on stocks in which short sales are banned on September 19, 2008 and for option classes on our set of control stocks and present these averages.
Figure 6. Marginal impact of the short sale ban on the relative bid-ask spreads of December 2008 expiration puts on banned stocks.

Notes. For each put option \( i \) expiring on December 20, 2008, we compute the National Best Bid and Offer (NBBO) by taking the highest valid bid and the lowest valid offer posted at one of the seven venues currently trading equity options in the United States. Next, we calculate an average percentage spread, \( \text{Pct Spread} \), each day by taking the average of the NBBO (divided by the midpoint) at the end of each of the 390 minutes of the trading day. We run the following cross-sectional regression each day from August 1, 2008 through October 21, 2008, with standard errors clustered by underlying stock:

\[
\text{Pct Spread} = \alpha + \alpha_{\text{Banned}} + \alpha \left( \frac{S}{X} \right) + \alpha \left( \frac{S}{X} \right)^2 + \alpha \left( \frac{S}{X} \right)^{1/2} + \alpha_{\text{ISD}} + \alpha, \text{ISD}^2 + \alpha_{\text{ISD}}, \text{ISD} + \alpha_{\text{Penny}}, \text{Penny} + \epsilon,
\]

where \( \text{Banned} \) takes a value of one if option \( i \) is on a stock with banned short selling and zero otherwise, \( \frac{S}{X} \) is the ratio of the stock price to the exercise price over the 390 end-of-minute observations on day \( t \), \( \frac{S}{X} \) and \( \frac{S}{X}^{1/2} \) are the square and square root of the average value of \( \frac{S}{X} \) for day \( t \), \( \text{ISD} \) is the mean implied standard deviation for option \( i \) on day \( t \) calculated from calls with the same exercise price and expiration date, \( \text{ISD}^2 \) and \( \text{ISD}^{1/2} \) are square and square root of the average implied standard deviation for day \( t \), and \( \text{Penny} \) is one if the option is part of the SEC’s Penny Pilot and zero otherwise. The regressions examine the spreads of options on the 330 optionable stocks for which short selling is banned on September 19, 2008 and options on a set of stocks not subject to the short sale ban that we match to the set of banned stocks. Our daily OPRA files containing data for August 14th and August 26th are corrupt so we have no data for these days.
Figure 7. Marginal impact of the short sale ban on the relative bid ask spreads of December 2008 expiration calls on banned stocks.

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Notes. For each call option $i$ expiring on December 20, 2008, we compute the National Best Bid and Offer (NBBO) by taking the highest valid bid and the lowest valid offer posted at one of the seven venues currently trading equity options in the United States. Next, we calculate an average percentage spread, $Pct\ Spread$, each day by taking the average of the NBBO (divided by the midpoint) at the end of each minute of the day. We run the following cross-sectional regression each day from August 1, 2008 through October 21, 2008, with standard errors clustered by underlying stock:

$$Pct\ Spread = \alpha_0 + \alpha_{Banned} + \alpha_1 (S/X) + \alpha_2 (S/X)^2 + \alpha_3 (\sqrt{S/X})^{1/2} + \alpha_4 ISD + \alpha_5 ISD^{1/2} + \alpha_6 ISD^{3/2} + \alpha_7 (\sqrt{S/X})^{1} ISD + \alpha_8 Penny + \varepsilon,$$

where $Banned$ takes a value of one if option $i$ is on a stock with banned short selling and zero otherwise, $(S/X)_t$ is the ratio of the stock price to the exercise price over the 390 end-of-minute observations on day $t$, $(S/X)_t^2$ and $(S/X)_t^{1/2}$ are the square and square root of the average value of $(S/X)$ for day $t$, $ISD$ is the mean implied standard deviation for option $i$ on day $t$ for the call, $ISD^{1/2}$ and $ISD^{3/2}$ are square and square root of the average implied standard deviation for day $t$, and $Penny$ is one if the option is part of the SEC’s Penny Pilot and zero otherwise. The regressions examine the spreads of options on the 330 optionable stocks for which short selling is banned on September 19th, 2008 and options on a set of stocks not subject to the short sale ban that we match to the set of banned stocks. Our daily OPRA files containing data for August 14th and August 26th are corrupt so we have no data for these days.
Figure 8. Marginal impact of the short sale ban on the quoted bid ask spreads of December 2008 expiration puts and calls on banned stocks.

\[ \text{Qte Spread} = \alpha_0 + \alpha_1 \text{Banned} + \alpha_2 \left( \frac{S}{X} \right) + \alpha_3 \left( \frac{S}{X} \right)^2 + \alpha_4 \left( \frac{S}{X} \right)^{1/2} + \alpha_5 ISD + \alpha_6 ISD^2 + \alpha_7 ISD^{1/2} + \alpha_8 \left( \frac{S}{X} \right) ISD + \alpha_9 Penny + \epsilon. \]

where \( \text{Banned} \) takes a value of one if option i is on a stock with banned short selling, \( \frac{S}{X} \) is the ratio of the stock price to the exercise price, \( ISD \) is the implied standard deviation for option i (for puts, the ISD is calculated from calls with the same exercise price and expiration date), and \( Penny \) is one if the option is part of the SEC’s Penny Pilot. We plot the daily estimate of \( \alpha \) for puts (black) and calls (grey). The regressions examine the spreads of options on the 330 optionable stocks for which short selling is banned on September 19th, 2008 and options on a set of stocks not subject to the short sale ban that we match to the set of banned stocks. Our daily OPRA files containing data for August 14th and August 26th are corrupt so we have no data for these days. Plots with the 95% confidence are available from the authors upon request.

Notes. For each option i expiring on December 20, 2008, we compute the National Best Bid and Offer (NBBO) by taking the highest valid bid and the lowest valid offer posted at one of the seven venues currently trading equity options in the United States. Next, we calculate an average quoted spread, \( Qte \text{ Spread} \), each day by taking the average of the NBBO at the end of each of the 390 minutes of the trading day. We run the following cross-sectional regression each day from August 1, 2008 through October 21, 2008 separately for puts and calls, with standard errors clustered by underlying stock:
Figure 9. Average daily differences between synthetic spread midpoints implied by October 2008 expiration options and actual stock spread midpoints.

Panel A. Average daily difference for banned stocks.

Panel B. Average daily difference for control stocks.
Notes. Banned includes the 330 optionable stocks for which short selling is banned on September 19th, 2008. Control refers to the set of optionable stocks not subject to the short sale ban that we match to the set of banned stocks. We calculate synthetic buy and sell prices at the end of each minute of each day during the sample period using all pairs of call and put options with the same exercise price and expiration date. The cost to buy a share of stock synthetically is

$$\text{Synthetic Stock}_{\text{Ask}} = C_{\text{Ask}} + e^{-rT} X - P_{\text{Bid}} + EEP + \sum_{j=1}^{J} e^{-rT} D_j$$

where $C_{\text{Ask}}$ is the ask price of a call, $r$ is the riskless rate, $T$ is the time to expiration for the call and put, $X$ is the exercise price, $P_{\text{Bid}}$ is the bid price of a put with the same exercise price and expiration date as the call, $EEP$ is the early exercise premium in the put price, $t$ is the time until the stock pays its jth dividend before the option expires, and $D_j$ is the amount of the jth dividend. We approximate the dividends expected to be paid over the life of the option with the actual dividends from CRSP for 2008, and the previous quarter's dividend for 2009. The early exercise price for the put is calculated using the method of Barone-Adesi and Whaley (1987). Similarly, the proceeds generated by selling a share of stock synthetically is

$$\text{Synthetic Stock}_{\text{Bid}} = C_{\text{Bid}} + e^{-rT} X - P_{\text{Ask}} + EEP + \sum_{j=1}^{J} e^{-rT} D_j$$

For every day from August 1, 2008 through October 17, 2008, we calculate the mean difference between the synthetic bid-ask midpoint and the actual stock bid-ask midpoint using all options expiring in October 2008 with a bias that is no greater than $2.00 in absolute value. Averages are computed with clustered standard errors.
Figure 10. Average daily differences between synthetic spread midpoints implied by December 2008 expiration options and actual stock spread midpoints.

Panel A. Average daily difference for banned stocks.

Panel B. Average daily difference for control stocks.
Notes. Banned includes the 330 optionable stocks for which short selling is banned on September 19th, 2008. Control refers to the set of optionable stocks not subject to the short sale ban that we match to the set of banned stocks. We calculate synthetic buy and sell prices at the end of each minute of each day during the sample period using all pairs of call and put options with the same exercise price and expiration date. The cost to buy a share of stock synthetically is

\[ \text{Synthetic Stock Buy} = C_{\text{Ask}} + e^{-rT} X - p_{\text{Bid}} + EEP + \sum_{j=1}^{J} e^{-rT} D_j \]

where \( C_{\text{Ask}} \) is the ask price of a call, \( r \) is the riskless rate, \( T \) is the time to expiration for the call and put, \( X \) is the exercise price, \( p_{\text{Bid}} \) is the bid price of a put with the same exercise price and expiration date as the call, \( EEP \) is the early exercise premium in the put price, \( t \) is the time until the stock pays its jth dividend before the option expires, and \( D_j \) is the amount of the jth dividend. We approximate the dividends expected to be paid over the life of the option with the actual dividends from CRSP for 2008, and the previous quarter's dividend for 2009. The early exercise price for the put is calculated using the method of Barone-Adesi and Whaley (1987). Similarly, the proceeds generated by selling a share of stock synthetically is

\[ \text{Synthetic Stock Sell} = C_{\text{Bid}} + e^{-rT} X - p_{\text{Ask}} + EEP + \sum_{j=1}^{J} e^{-rT} D_j \]

For every day from August 1, 2008 through October 21, 2008, we calculate the mean difference between the synthetic bid-ask midpoint and the actual stock bid-ask midpoint using all options expiring in December 2008 with a bias that is no greater than $2.00 in absolute value. Averages are computed with clustered standard errors.
Figure 11. Average daily differences between synthetic bid and ask prices implied by December 2008 expiration options and actual stock bid and ask prices for banned stocks.

Notes. Banned includes the 330 optionable stocks for which short selling is banned on September 19, 2008. Control refers to the set of optionable stocks not subject to the short sale ban that we match to the set of banned stocks. We calculate synthetic buy and sell prices at the end of each minute of each day during the sample period using all pairs of call and put options with the same exercise price and expiration date. The cost to buy a share of stock synthetically is

\[ \text{Synthetic Stock } \text{Ask} = C_{\text{Ask}} + e^{-rT} X - p_{\text{Bid}} + EEP + \sum_{j=1}^{J} e^{-rT_j} D_j. \]

where \( C_{\text{Ask}} \) is the ask price of a call, \( r \) is the riskless rate, \( T \) is the time to expiration for the call and put, \( X \) is the exercise price, \( P_{\text{Bid}} \) is the bid price of a put with the same exercise price and expiration date as the call, \( EEP \) is the early exercise premium in the put price, \( t_j \) is the time until the stock pays its jth dividend before the option expires, and \( D_j \) is the amount of the jth dividend. We approximate the dividends expected to be paid over the life of the option with the actual dividends from CRSP for 2008, and the previous quarter's dividend for 2009. The early exercise price for the put is calculated using the method of Barone-Adesi and Whaley (1987). Similarly, the proceeds generated by selling a share of stock synthetically is

\[ \text{Synthetic Stock } \text{Bid} = C_{\text{Bid}} + e^{-rT} X - p_{\text{Ask}} + EEP + \sum_{j=1}^{J} e^{-rT_j} D_j. \]

For every day from August 1, 2008 through October 21, 2008, we calculate the mean difference between the actual bid and the synthetic bid and between the synthetic ask and the actual ask using all options expiring in December 2008 with a bias that is no greater than $2.00 in absolute value. Averages are computed with clustered standard errors.
Figure 12. Marginal impact of the short sale ban on the difference between the synthetic spread midpoints and actual stock spread midpoints for all stocks and for financial stocks subject to the short sale ban.

Panel A. October 2008 expiration options.
Panel B. December 2008 expiration options.

Notes. Each day from August 1, 2008 through October 21, 2008, we calculate the mean difference between the actual bid and the synthetic bid (see Equation 4) and between the synthetic ask (see Equation 3) and the actual ask using all options expiring in October 2008 (Panel A) and in December 2008 (Panel B) and run the following cross-sectional regression with standard errors clustered by stock:

\[
\text{Bias} = \alpha_0 + \alpha_{\text{Banned}} + \alpha_{\text{FinBanned}} + \alpha_{\left(\frac{\delta}{\sigma}\right)} + \alpha_{\left(\frac{\delta}{\sigma}\right)^2} + \alpha_{s\text{ISD}} + \alpha_s \text{ISD} + \alpha_s \text{Penny} + \alpha_s \text{LnVol} + \alpha_s \text{Putprice} + \alpha_s ,
\]

where \( \text{Banned} \) takes a value of one if option \( i \) is on a stock with banned short selling, \( \text{FinBanned} \) takes a value of one if option \( i \) is on a stock an SIC code between 6000 and 6999 and banned short selling, \( \left(\frac{\delta}{\sigma}\right) \) is the ratio of the stock price to the exercise price, \( \left(\frac{\delta}{\sigma}\right)^2 \) is the implied standard deviation for option \( i \) (for puts, the ISD is calculated from calls with the same exercise price and expiration date), \( \text{Penny} \) is one if the option is part of the SEC’s Penny Pilot, \( \text{LnVol} \) is the logarithm of the average daily dollar volume of the stock over the previous 20 days and \( \text{Putprice} \) is the average price of the put on that day. We plot the daily estimate of \( \alpha_0 + \alpha_1 \) (black) and \( \alpha_0 + \alpha_1 + \alpha_2 \) (grey). Our daily OPRA files containing data for August 14\( \text{th} \) and August 26\( \text{th} \) are corrupt so we have no data for these days. Underlying regression results are available from the authors upon request. Our daily OPRA files containing data for August 14\( \text{th} \) and August 26\( \text{th} \) are corrupt so we have no data for these days.
Figure 13. The daily proportion of optionable banned and control stocks that are hard to borrow each day of September 2008.

Notes: We obtain the daily list of hard-to-borrow securities for September 2008 from a major investment bank. Banned includes the percentage of the 330 optionable stocks for which short selling is banned on September 19th, 2008 that are hard-to-borrow. Control refers to the percentage of optionable stocks not subject to the short sale ban that we match to the set of banned stocks that are hard-to-borrow.
Figure 14. Marginal impact of being on the daily hard-to-borrow list or on the list of stocks for which short sales are banned on September 19th on the difference between the synthetic and actual bid ask spread midpoint.

Notes. Banned includes the 330 optionable stocks for which short selling is banned on September 19th, 2008. Hard-to-borrow includes optionable banned and control stocks that appear on that day’s hard-to-borrow list which we obtain from a major investment bank. We calculate synthetic buy and sell prices at the end of each minute of each day during the sample period using all pairs of call and put options with the same exercise price and expiration date. The cost to buy a share of stock synthetically is

$$\text{Synthetic Stock}_{\text{Ask}} = C_{\text{Ask}} + e^{-rT} X - p_{\text{Bid}} + EEP + \sum_{j=1}^{J} e^{-r} D_{j}.$$  

where Cask is the ask price of a call, r is the riskless rate, T is the time to expiration for the call and put, X is the exercise price, Pbid is the bid price of a put with the same exercise price and expiration date as the call, EEP is the early exercise premium in the put price, tj is the time until the stock pays its jth dividend before the option expires, and Dj is the amount of the jth dividend. We approximate the dividends expected to be paid over the life of the option with the actual dividends from CRSP for 2008, and the previous quarter’s dividend for 2009. The early exercise price for the put is calculated using the method of Barone-Adesi and Whaley (1987). Similarly, the proceeds generated by selling a share of stock synthetically is

$$\text{Synthetic Stock}_{\text{Bid}} = C_{\text{Bid}} + e^{-rT} X - p_{\text{Ask}} + EEP + \sum_{j=1}^{J} e^{-r} D_{j}.$$  

For every day from September 2, 2008 through September 29, 2008, Each day, for each pair of options with a December expiration date, we calculate the average difference between the synthetic and actual stock price midpoints. We eliminate observations for which the difference is greater than $2.00 in absolute value. We then estimate daily cross-sectional regressions of these average differences on a dummy variable for a banned stock and a dummy variable that takes a value of one if the stock was on the hard-to-borrow list. Errors are clustered by underlying stock.