

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

Robert Battalio
241 College of Business Administration
University of Notre Dame
Notre Dame, IN 46530
(574) 631-9428
rbattali@nd.edu

Paul Schultz
260 College of Business Administration
University of Notre Dame
Notre Dame, IN 46530
(574) 631-3338
pschultz@nd.edu

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 four 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 increased bid ask spreads for options on banned stocks that are not solely attributable to inflated bid ask spreads on the underlying stocks. Indeed, on September 19th, we estimate that liquidity demanding investors trading December 2008 expiration puts and calls encountered bid ask spreads that were \$1.20 (24%) wider than the bid ask spreads of options on comparable stocks with no short sale restrictions. 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. Finally, we find the short sale ban increased the number of apparent arbitrage opportunities that involve the buying of synthetic shares and shorting of actual shares. Together, our results suggest trading costs in option markets increase dramatically and option and stock prices decouple when option market makers are not able to hedge easily and investors are unable to purchase short exposure. Our results also provide a reminder that regulations imposed in the middle of the night are likely to have unintended consequences that can be severe.

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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, 2008.¹

Early in the morning on September 19, 2008, the United States Securities and Exchange Commission (SEC) issued a surprise directive banning short selling in 797 financial stocks. The ban, which remained in effect until October 8, 2008, was intended to prevent short sellers from manipulating prices of financial stocks. Proponents of the ban argued it would prevent a ‘death spiral’ in which short sellers could force down prices, which would lead depositors to withdraw funds from financial institutions, which would put further downward pressure on financial stock prices, and so on. While the initial ban clearly permitted short sales as part of legitimate equity market making activity, it only allowed option market makers to go short when hedging their positions on September 19th, a triple witching day.

In this paper, we examine the impact of the short sale ban on the options market. The ban provides a unique opportunity to explore what happens when options market makers are confused about their ability to hedge. Initially, there was uncertainty about whether options market makers would be allowed to short for hedging purposes for the duration of the ban, and whether stock needed to be borrowed before shorting. Even after September 25th, when options market makers’ regulatory standing had been clarified, hedging was difficult. A number of institutions, like CalPERS, stopped lending stock. In addition, Boehmer, Jones, and Zhang (2009) find trading costs increased sharply for financial stocks in the equity markets.

In this paper we address four questions. 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. Harris, Namvar, and Phillips (2009) provide indirect evidence of a migration of shorting to the options market by showing that prices of stocks with options were

¹Doris Frankel (2008).

affected less by the ban than other stocks. However, the SEC ban, as amended shortly after 12:00am on the morning of September 22nd, only allowed market makers to sell short if they knew the customer or counterparty was not increasing a net economic short position.²

We find the ratio of option-to-stock volume is comparable for banned and control stocks throughout our sample period. Given the coarse nature of trade data, we next examine whether investors trading on the ISE and on the CBOE opened more long put positions and more short call positions in options on financial stocks during the ban. Surprisingly, we find little evidence that investors moved from the stock to the option market to gain short exposure in financial stocks.

Inflated trading costs may at least partially explain why investors do not seem to have migrated to the options market to obtain short exposure in the banned stocks. Our multivariate analysis reveals that 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. This translates into a difference of 24% in relative spreads on September 19th. On the morning of September 22nd, when there was still confusion regarding the ability of option market makers to hedge, relative quoted spreads remain elevated for options on financial stocks. From September 22nd through October 8th, 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%. Inflated bid ask spreads on the banned stocks explain most of the disruption in the option market, but they are unable to explain the extreme rise in relative spreads for options on banned stocks on September 19th.

Our analysis of intraday quotes suggests that the SEC's imposition of severe penalties on option market makers who failed to deliver shorted shares in a timely fashion actions affected the relative spreads of options on both banned and control stocks. For example, on September 17th, relative intraday quoted spreads

²See "Options Market Makers get Relief from SEC Ban on Short-Selling," published in Traders Magazine Online News on September 22, 2008.

averaged 10% for both sets of stocks. During the first hour of trading on September 19th, the intraday relative spread for puts on control stocks averaged more than 20%. We also find evidence suggesting that regulatory uncertainty led to wider bid ask spreads for all options, especially in the mornings, during the week of September 26th. Order data provided by a retail options broker suggests that, on average, liquidity demanding investors paid more than the quoted spread during the short sale ban. This suggests our analysis of quoted spreads understates the impact of the short sale ban on the cost of immediacy in the option market when the short sale ban was imposed.

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 and 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, we might expect option market makers to 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 of selling a share of stock synthetically, which is done by writing a call, purchasing a put, and selling a riskless asset. 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.³ The prices of actual and synthetic shares of control stocks only diverge on September 19th. A closer

³We obtain similar, but stronger results for December expiration options.

examination of the relationship between synthetic bid and actual bid prices and between synthetic ask and actual ask prices for shares of banned stocks suggests that the divergence in spread midpoints is most likely attributable to an asymmetric adjustment of quotes by option market makers. We also find that the prices of actual and synthetic shares of stock diverge when the actual shares of stock become hard to borrow, which again suggests that hedging costs are responsible for the divergence in actual and synthetic stock prices.

The fourth and final question we address in this paper is whether or not the short sale ban produced price discrepancies that would allow arbitrage profits to be earned during normal periods. It is widely believed that prices of equivalent or similar assets diverge significantly when short sales are restricted. We test whether the ban increased the likelihood that synthetic ask prices were less than contemporaneous bid prices of actual shares. In normal circumstances, arbitrageurs would exploit these price discrepancies by buying shares synthetically and shorting the stock itself. With the short-sale ban, arbitrage of this type became impossible and, as a result, prices may have diverged more than usual.

Our evidence suggests that the frequency of apparent arbitrage opportunities are similar for banned and control stocks prior to September 19th. During the ban, apparent arbitrage opportunities in which a synthetic share is sold and an actual share is purchased are actually more likely in control stocks than in banned stocks. This likely reflects the fact that bid ask spreads for options on banned stocks were wider than bid ask spreads for options on control stocks. Conversely, arbitrage opportunities involving the sale of an actual share and the purchase of a synthetic share are more prevalent in banned stocks after the short sale ban. Consistent with our analysis of actual and synthetic spread midpoints, we find that the short sale ban allowed stock prices to become high relative to options prices as investors could not sell short to take advantage of the put call parity violations.

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 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 of 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. Former Morgan Stanley CEO Phillip Purcell called for a short sale ban. 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 in great Britain 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.⁴ If a broker dealer failed 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) would be prohibited from executing

⁴See SEC Release 34-58572, September 18, 2008.

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.⁵ 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 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 financial stocks until 11:59 p.m. on September 19th. This exception suggested that option market makers 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

⁵See SEC Release 34-58592, September 19, 2008.

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 since 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 JPM 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.”⁶ The seven options exchanges and the OCC argue in a December 19, 2008 letter to the SEC

⁶See GAO-09-483.

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.”⁷

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 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

⁷See December 19, 2008 letter from option exchanges to the SEC.

short shares of a security even when 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 all options. On September 19th, it was not at all clear if options market makers would be able to hedge by shorting banned stocks at all 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 from being impounded in stock prices, thus resulting in 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 which are expensive to short have high valuations and low subsequent returns. Ofek and Richardson (2003) suggest that 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) model the impact of short sale restrictions on asset prices and conclude that short sale restrictions need not lead to overpriced assets. Investors will be 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 market 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. during the 1930's to explore the impact of short sale restrictions on liquidity and asset prices. During the thirties, 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 result likely reflects the fact that the uptick rule requires short sellers to supply liquidity to get their orders executed. Conversely, Diether, Lee, and Werner (2009) find the spreads widen when the uptick rule is removed.

The July 2008 Emergency Order and the September 2008 shorting ban provide sudden and drastic changes in short selling restrictions with which to test the impact of shorting restrictions in today's electronic

markets. The SEC's Office of Economic Analysis (OEA) produced a memorandum in January 2009 analyzing impact of the pre-borrowing requirement on the market. Relative to a sample of control stocks, the OEA found that stocks subject to the Emergency Order had "large and statistically significant drops in short selling volume" and "dramatic, but temporary, initial increases in stock lending rates followed by rates still higher than before the Order." The OEA found little change in quoted spreads, quoted depths, short interest, option trading volume, open interest, or stock trading volume. Finally, they did not find a significant migration of order flow in cross-listed stocks to London.

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 impacted by 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 costs of trading financial 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 for financial stocks during the short sale ban. Kolasinski, Reed, and Thornock (June 2009) find market quality, as measured by R^2 , falls during the ban.

There is also evidence that prices of financial stocks 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 financial 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.⁸

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.

⁸Kolasinski, 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.

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 of the squared percentage difference in price at the beginning of the sample period, and the squared percentage difference in capitalization

The OPRA quote records contains 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. In addition, options on a particular stock 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 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 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 provide an indication of 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 resulting from orders received prior to 9:45a.m. since we are not interested in trades that occur in the opening rotation. We eliminate 509 trades resulting from orders received after 3:51p.m. to avoid trades executed in closing rotations. We eliminate one order because the order receipt date is different from the execution date as a data error. 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. There are a total of 330 banned stocks with 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 expected, 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 contracts 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 sample of 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 the table report the number of options for which the stock price is 20% below the exercise price, the proportion with a stock price within 20% of the exercise price, and the proportion 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.

Panel C reports the average daily contract and share volume in our sample of banned and control stocks in August, September, and October 2008. The average daily volume of calls traded on banned stocks climbs from 1.18 million contracts in August to 1.3 million contracts in October. Over this same time interval, the average daily volume of puts traded on banned stocks rises from 1.06 million contracts to 1.45 million

contracts. While the average daily volume of option contracts traded is roughly comparable for control and banned stocks in August and October, there is a marked difference in September where the average daily volume of options traded is 3.22 million contracts for control stocks and 2.61 million contracts for banned stocks. The data presented in Panel C suggest the short sale ban did have an affect on the relative volume of options traded on banned stocks. However, the daily share volume in control stocks exceeds the daily share volume in banned stocks by an average of 967 million shares per day in September 2008. This suggests that the ratio of option-to-stock trading volume is similar for banned and control stocks.

We explore the ratio of option-to-stock trading volume further 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. Together, the evidence in Figure 1 and in Panel C of Table 1 suggest 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?

There are many reasons investors trade options. 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 financial 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.

As can be seen in Figure 1, there is little evidence in the OPRA data that investors seeking short exposure in financial stocks 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 financial 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, which decompose daily trading volume into four trade types and at least two investor classes, are similar to those used by Pan and Poteshman (2006). The four trade types are “open-buys”, “open-sells”, “close-buys”, and “close-sells”. “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 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 change in short exposure on these two exchanges separately for options on banned and control stocks as follows:

$$\text{Change in Short Exposure}_i = (\text{Put Open-Buy} + \text{Call Open-Sell}) - (\text{Put Close-Buy} + \text{Call Close-Sell}).$$

We compute the *Change in Short Exposure* separately for October, November, and December expiration options and for customers and firm proprietary traders. Figure 2 contains plots the time series of short exposure by customer type and expiration month. The top two plots contain the *Change in Short Exposure* in October expiration options, the middle two plots contain the *Change in Short Exposure* in November expiration options, and the bottom two plots contain the *Change in Short Exposure* in December expiration options. As can be seen in each of these plots, there appears to be little difference in the aggregate short exposure accumulated by customers trading put options on banned and control stocks. In untabulated results, we obtain similar results when we examine Net Put Buys and Net Put Sells separately. These results are consistent with the conclusions reached from the OPRA trading data – there is little evidence that investors migrated from the equity market to the option market to gain short exposure in stocks subject to the September 19th short sale ban.⁹ However, these results also suggest that investors were able to use option markets to gain short exposure in financial stocks during the short sale ban.

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

There are at least two possible reasons that investors did not migrate in mass to the equity option market to obtain long positions in puts and short positions in calls on financial stocks during the short sale ban. First, the SEC prohibition against such behavior may have been binding. Second, the cost of using option markets to gain short exposure in financial stocks may have been prohibitive for some investors. In this section, we examine how the short sale regulation affected the spreads of options on financial stocks.

⁹We 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 financial stocks early.

A. *Marginal impact of short sale regulation on daily spreads.*

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. A direct comparison of the trading costs for options on banned stocks with options on control stocks is problematic. 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. We examine how bid ask spreads were affected by running the following cross-sectional regression each day from August 1, 2008 through October 21, 2008, with standard errors clustered by underlying stock:

$$\begin{aligned}
 Pct\ Spread_i = & \alpha_0 + \alpha_1 Banned_i + \alpha_2 \left(\frac{S}{X}\right)_i + \alpha_3 \left(\frac{S}{X}\right)_i^2 + \alpha_4 \left(\frac{S}{X}\right)_i^{-1} \\
 & + \alpha_5 ISD_i + \alpha_6 ISD_i^2 + \alpha_7 ISD_i^{-1} + \alpha_8 \left(\frac{S}{X}\right)_i ISD_i + \alpha_9 Penny_i + \varepsilon_i \quad (1)
 \end{aligned}$$

where $Banned_i$ 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 on day t, $(S/X)_i^2$ and $(S/X)_i^{-1}$ are the square and inverse of the average value of (S/X) for day t, 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, ISD_i^2 and ISD_i^{-1} are square and inverse 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.¹⁰ Inverses and squares of the implied standard deviation and moneyness are included to capture non-linear relations between these variables

¹⁰ 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.

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 3 plots the daily estimates of the coefficient on Banned from cross-sectional regressions using December put options. The coefficient is not significantly different from zero for August and the first part of September, but jumps to 9% on September 18th when Temporary Rule 204T is put into place. This may reflect the fact that it was more costly to borrow shares of financial stocks. When the short sale ban is enacted on September 19th, the coefficient estimate jumps to 25%. So, if the bid ask spread on a non-financial 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 8th. 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 4 plots the daily coefficient estimates for Banned from regressions using call options expiring on December 20, 2008. The regressions include all call options with all strike prices that expired in December. As in the put regressions, standard errors are clustered on the underlying stock. Figure 4 reveals that, after adjustment for moneyness and volatility, the percentage spread for calls on banned stocks 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%, which is around 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 remains higher than it was prior to September 15th. Together, the information in Figure 3 and in Tables 3 and 4 suggest the short sale ban had similar effects on the relative spreads of puts and calls on financial 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 5 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 financial 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. The CBOE successfully lobbied the SEC to allow market makers to short for hedging purposes at least for September 19th, but it was uncertain if market makers 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 financial stocks during the banned period. Thus, even if hedging in the underlying stock was still possible, it was more expensive.

B. Marginal impact of short sale regulation on intraday spreads.

We explore whether the increase in option spreads is explained by the increase in the underlying stock spreads by reestimating (1) with the percentage spread of the underlying stock included. This time though, we estimate the cross-sectional regressions *each minute* of the 55 day period. There are two reasons for estimating the regressions on a minute-by-minute basis rather than daily. First, spreads on active stocks change continuously over the trading day. Market makers who are concerned about the costs of hedging their positions are likely to focus on current spreads. Second, the minute-by-minute cross-sectional regressions provide a check on the daily regressions estimated earlier.

Figure 6 plots the coefficient estimates for the banned indicator variable obtained from the 390 minute-by-minute regressions run each day of our sample period. A comparison of Figure 6 with Figure 3, which contains the daily plot of the coefficient estimates for the banned indicator variable obtained from the daily spread regressions for December expiration puts *without* the underlying stock spread as a control variable, reveals striking similarities. Prior to September 17th, the coefficient on the banned indicator variable is largely insignificant for both specifications. On September 18th, the day that Temporary Rule 204T is enacted, the coefficient estimate for the banned indicator variable is 9% in the daily regressions while it ranges from 5% early in the morning to around 20% in the last ten minutes of trading. On September 19th the banned indicator variable's coefficient is 25% in the daily regressions and the average of the 390 coefficients from the minute-by-minute regressions is 29%. A close inspection of Figure 6 reveals that the relative spreads of put options on banned stocks on the mornings of September 23rd and 24th were inflated. This result is likely due to the fact

options market participants were confused over the requirements of the short sale ban and Temporary Rule 204T.

After controlling for the underlying stock's relative spread, an inspection of the data used to construct Figure 6 suggests that the relative spreads of December expiration puts on banned stocks were significantly higher than the spreads of December expiration puts on control stocks for 99.2% of the 5,460 minutes that the short sale ban was in place. As is the case with the daily put regressions that do not have the underlying stock spread as an explanatory variable, the coefficient on the banned indicator variable is generally not significant at the 5% level after the ban expires.

We have also run daily cross-sectional regressions as in (1) including the average spread of the stock over the day as an explanatory variable. Not surprisingly, the coefficient on the percentage spread of the underlying stock is significant each day. Now however, the coefficient on Banned is only significant on September 19th. After accounting for the percentage bid ask spreads on the underlying stocks, our results indicate that if the bid ask spread on a non-financial stock put was 5%, the bid-ask spread on a similar put on a banned stock on September 19th would be 21% of the price. We obtain similar results when the relative spread for the underlying stock is included in our analysis of call relative spreads, and when examining relative spreads for puts and calls that expire in other months.

It is not clear why the coefficient on the banned stock dummy becomes insignificant on most days when the stock spread is included in the regressions. It is possible that the short-sale ban affects costs of options market making only through the costs of trading the underlying stock. We think this is unlikely though, given the minute-by-minute regression results. Boehmer, Jones, and Zhang (2009) document a sharp increase in spreads of financial stocks when the ban was implemented. It is possible that stock spreads may be a proxy for banned stocks.

While our cross sectional regression analyses allow us to assess the marginal impact of the events associated with the 2008 short sale ban on bid ask spreads of banned stocks relative to control stocks, they do

not reveal how the short sale ban affected the level of bid ask spreads in the options market. For this reason, we next examine intraday relative quoted spreads for puts on banned and control stocks.

C. 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 arithmetic 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 7.

Intraday relative spreads for puts on banned and control stocks on August 11th, a typical day in August 2008, provide a useful benchmark to evaluate spreads during the short sale ban. Relative spreads are 5% of the NBBO midpoint for puts on both sets of stocks throughout the day on August 11th. While there is little difference in the relative spreads of puts on banned and control stocks on September 17th, the day when SEC Regulation 204T was announced, intraday relative spreads are elevated to nearly 10% of the option value. 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 noon on September 18th, the day that Temporary Rule 204T was enacted. This likely reflects the fact that Temporary Rule 204T had a bigger impact on financial stocks.

The confusion associated with the announcement of the short sale ban at 12:01am on September 19th is clearly evidenced in the plots of intraday relative spreads on that day. Even the spreads of options on control stocks are affected by the announcement of the short sale ban. 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 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 7 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 22nd, 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 similar to the average intraday relative spreads for puts on control stocks prior to the SEC's implementation of Temporary Rule 204T on September 17th. Consistent with our regression results, average intraday relative spreads for puts on banned stocks appear to be higher than comparable spreads for puts on control stocks over this time period.

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. Because we have order data, we know whether the order is a buy or a sell, whether 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-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 options on our set of control stocks. We present these averages in Figure 8.

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, the statistics presented in Figure 8 suggest that if anything, our analysis of quoted spreads understates the impact of the short sale ban on investors seeking to trade options on banned stocks during the short sale ban.

D. Summary.

The SEC's actions had a dramatic impact on quoted spreads in the options market. While the impact is most severe for options on banned stocks, other options are also affected. For a put option with a value of \$1.00, the failure to include an option market maker exemption for the entirety of the short sale ban in the initial order caused quoted spreads for put options on banned stocks with a December 2008 expiration to be \$0.25 wider than the quoted spreads for put options on control stocks. 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.¹¹ Data obtained from a retail broker suggest 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. Our analysis of intraday spreads suggests that confusion over the requirements of Temporary Rule 204T and the short sale ban led to inflated relative spreads, especially during the first hour of trading. Overall, our analysis suggests that the inflated spreads in the option market were not solely attributable to the elevated bid ask spreads of banned stocks. Rather, they likely are the result of regulatory uncertainty and increases in the cost of shorting shares brought on by Temporary Rule 204T.

VI. Biases in Prices Arising from the Short Sale Ban

We next examine the impact of the ban on the difference in prices of synthetic shares created from options and the price of the underlying shares. There are two reasons why the price of synthetic shares may fall relative to the price of actual shares. First, the stock may be overpriced if the short sale ban results in stock prices held to artificially high levels. Harris, Namvar, and Phillips (2009) provide evidence that suggests prices

¹¹Each 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 $\frac{1}{2}$ of the spread, we multiply this estimate by 0.5.

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 is created by 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

$$\text{Synthetic Stock}^{Ask} = C^{Ask} + e^{-rT} X - P^{Bid} + EEP + \sum_{j=1}^J e^{-rt_j} D_j \quad (2)$$

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

$$\text{Synthetic Stock}^{Bid} = C^{Bid} + e^{-rT} X - P^{Ask} + EEP + \sum_{j=1}^J e^{-rt_j} D_j \quad (3)$$

To examine biases in option prices we compare the average of the synthetic bid and ask with the bid-ask midpoint of the underlying stock. 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 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. The price discrepancy between the synthetic and actual stock bid-ask midpoint of banned stocks declines steadily but remains statistically negative until the short sale ban ended. This is not surprising, since the only day during the ban on which option investors could legally purchase short exposure was September 19th. 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.

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 dashed 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 solid 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 was asymmetric, exactly as we might expect if market makers were attempting to discourage short selling.

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 create synthetically implied stock midpoints:

$$Bias_i = \alpha_0 + \alpha_1 Banned_i + \alpha_2 \left(\frac{S}{X}\right)_i + \alpha_3 \left(\frac{S}{X}\right)_i^2 + \alpha_4 \left(\frac{S}{X}\right)_i^{-1} + \alpha_5 ISD_i + \alpha_6 ISD_i^2 + \alpha_7 ISD_i^{-1} + \alpha_8 \left(\frac{S}{X}\right)_i ISD_i + \alpha_9 Penny_i + \varepsilon_i \quad (4)$$

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 and the remaining explanatory variables are identical to those used in the daily spread regressions. Standard errors are clustered by stock.

Table 3 contains the results for the regressions that use October 2008 expiration options to create synthetic bid ask spread midpoints 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 18th. On September 18th, the bias for banned stocks computed using October 2008 expiration options becomes about \$0.077 lower than the bias for control stocks. On September 18th, 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.

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 12. 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 18, 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 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.¹²

Daily coefficients on the banned and hard-to-borrow dummies are depicted in Figure 13. 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 than 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.

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. It is

¹²The 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.

possible, however, that price discrepancies that would have allowed apparent arbitrage opportunities in the absence of short sale restrictions became more frequent with the short sale ban.

We examine two types of apparent arbitrages. The first is when a synthetic share of stock could be sold for more than it would cost to buy an actual share. That is,

$$\text{Synthetic Stock}^{\text{Bid}} = C^{\text{Bid}} + e^{-rT} X - P^{\text{Ask}} + EEP + \sum_{j=1}^J e^{-rt_j} D_j > S^{\text{Ask}} \quad (5)$$

The second type of apparent arbitrage opportunity occurs when a synthetic share of stock could be purchased for a lower price than would be received if an actual share of stock was sold at the bid price. Or,

$$\text{Synthetic Stock}^{\text{Ask}} = C^{\text{Ask}} + e^{-rT} X - P^{\text{Bid}} + EEP + \sum_{j=1}^J e^{-rt_j} D_j < S^{\text{Bid}} \quad (6)$$

For each minute of every day during the sample period, we calculate synthetic bid and ask prices for each pair of put and call options with the same strike price and expiration date using all expiration dates. We then count the number of each type of apparent arbitrage opportunity for each option pair each day. Figure 14 provides a plot of the average percentage of minutes each day that banned and control stocks have share prices and option prices that create apparent arbitrage opportunities of at least \$0.05 (two figures on the left) and at least \$0.10 (two figures on the right).

The graph on the upper left hand corner (upper right hand corner) of Figure 14 plots the percentage of end-of-minute stock and option quotes that imply that an investor could have sold an actual share of stock and purchased a synthetic share of stock and earned at least \$0.05 per share (\$0.10 per share) for both banned and control stocks. There is very little difference in these two plots, suggesting that most apparent buy synthetic/sell actual arbitrage opportunities generated at least \$0.10 per share in profit.

Prior to September 12th, the daily percentage of end-of-minute quotes creating apparent arbitrage opportunities generating at least \$0.05 per share is around 4%. On September 19th, the prevalence of apparent buy synthetic/sell actual arbitrage opportunities jumps to around 6.5% for banned stocks and is around 2.3% for control stocks. Apparent buy synthetic/sell actual arbitrage opportunities generating at least \$0.05 per share remain more prevalent in banned stocks until September 29th, after which there is little difference. The elevation

of apparent buy synthetic/sell actual arbitrage opportunities for banned stocks during the initial portion of the short sale ban is consistent with the argument that the inability of investors to short shares of banned stocks led to inflated bid prices for shares of those stocks.

The graph on the lower left hand corner of Figure 14 plots the percentage of end-of-minute stock and option quotes that imply that an investor could have purchased an actual share of stock and sold a synthetic share of stock and earned at least \$0.05 per share for both banned and control stocks. As is the case with the apparent buy synthetic/sell actual arbitrage opportunities, around 4% of the end-of-minute stock and option quotes imply apparent sell synthetic/buy actual arbitrage opportunities for both banned and control stocks. Beginning on September 11th, apparent sell synthetic/buy actual arbitrage opportunities become more prevalent in control stocks. Indeed, on September 17th, 7% of the intraday stock and option quotes for control stocks imply this type of apparent arbitrage, versus 4% for banned stocks. The graph on the lower right hand corner of Figure 14 suggests that apparent sell synthetic/buy actual arbitrages were more prevalent for control stocks throughout the short sale ban. This likely reflects the fact that the bid ask spreads of options on and shares of banned stocks were inflated during the short sale ban. While the magnitude of the differences is lower, similar conclusions are reached when our analysis is restricted to apparent sell synthetic/buy actual arbitrages generating at least \$0.10 per share.

Differences in arbitrage opportunities for control and banned stocks may reflect differences in volatility and moneyness. Hence, each day we estimate the following Probit model to examine the marginal impact of the short sale ban on the frequency of apparent arbitrage opportunities:

$$\begin{aligned}
 Pct\ Arb_t = & \alpha_0 + \alpha_1 Banned + \alpha_2 \left(\frac{S}{X}\right)_t + \alpha_3 \left(\frac{S}{X}\right)_t^2 + \alpha_4 \left(\frac{S}{X}\right)_t^{-1} \\
 & + \alpha_5 ISD_t + \alpha_6 ISD_t^2 + \alpha_7 ISD_t^{-1} + \alpha_8 \left(\frac{S}{X}\right)_t ISD_t + \alpha_9 Penny_t + \varepsilon_t \quad (7)
 \end{aligned}$$

where $Pct\ Arb_t$ is the proportion of minutes during day t where an arbitrage bound is violated and the remaining explanatory variables are identical to those used in the daily spread regressions. Standard errors are clustered

by stock. The regressions are run separately for the percentage of minutes where the synthetic bid exceeds the actual ask, and the percentage of minutes where the synthetic ask is less than the actual bid.

Table 4 reports probit estimates for differences involving synthetic prices derived from October options. The first four rows provide the coefficient estimates for the banned variable and the penny variable along with the pseudo R^2 and number of observations when the dependent variable is the percentage of minutes when synthetic bid price exceeds the actual ask price. We restrict the sample to option pairs where $0.8 < S/X < 1.2$. Our main concern in these regressions is the sign and significance of the banned variable. Prior to the shorting ban, it is typically slightly negative but insignificant. From September 19th, the day the ban is initiated, until September 26th, *Banned_t* is significantly negative at the 1% level each day. Banned stocks were less likely to present arbitrage opportunities that involves buying the stock and shorting synthetically than were control stocks. This may reflect the widening of spreads for banned stocks.

The next four rows of the table present results when the dependent variable is the proportion of the day where actual share bid prices were greater than synthetic share ask prices. Now we see that the coefficient on the banned stock variable is positive and significant throughout the period when short sales were banned. It was much more common for banned stocks than control stocks, to encounter situations where it was possible to sell shares and receive more than it cost to buy them synthetically. This is not surprising. Banned stocks couldn't be sold short, so arbitrage opportunities that required a short sale of the actual shares could not be exploited. Following the short sale ban, inability to arbitrage loosened the normally tight connections between option and stock prices and allowed stocks to float to higher prices than options.

Table 5 repeats the analysis of Table 4 with options that expire in December. Here again we see that the likelihood of a synthetic bid price exceeding an actual ask price was not significantly different for banned stocks than others before the ban. For days after the ban was initiated, the coefficient on *Banned_t* is consistently negative and significant. With the imposition of the ban, the probability that synthetic bid prices exceeded actual ask prices declined significantly. We also see similar results when examining the likelihood of an actual

bid price exceeding a synthetic ask. After the short sale ban takes effect, $Banned_t$ is positive and significant. Again, the effect of the ban is to allow stock prices to become high relative to options prices. Arbitrage requires selling stock when the stock is overpriced, hence it cannot bring prices into line after the short sale ban.

Some caution should be used in drawing inferences from these results. Even in the absence of short sale restrictions, it is not clear if these seeming arbitrage opportunities could be exploited in practice. We considered any case where the synthetic ask (bid) was less (greater) than the actual bid (ask) to be an arbitrage opportunity regardless of the size of the difference. In some cases commissions would wipe out any arbitrage profits. In other cases, even short delays in executing either trade could eliminate any gains. Finally, even though dividends and the early exercise premium are typically small, errors in estimation of either of these components of the synthetic price could make it appear that there were arbitrage opportunities when none existed.

Nevertheless, the arbitrage results are strikingly clear. When short sales were banned, arbitrage opportunities that involved buying synthetic shares and selling actual shares increased. Option and share prices had become uncoupled.

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 too 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. Third, the short sale ban increased the number of apparent arbitrage opportunities that involve buying synthetic shares and shorting actual shares.

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 dramatically 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.

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Table 1. Relevant regulatory events and clarifications.

Date	Event	How action impacted option market participants
September 18 th	Adopted temporary Rule 204T	<ul style="list-style-type: none"> 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).
September 19 th	Short sale ban	<ul style="list-style-type: none"> Option market makers only allowed to sell short pursuant to bona fide market making and hedging activities until 11:59pm on September 19th.
September 22 nd	Extension of option market maker exemption	<ul style="list-style-type: none"> Option market makers allowed to sell short pursuant to bona fide market making and hedging for the remainder of the short sale ban.
September 23 rd	SEC clarification of Rule 204T	<ul style="list-style-type: none"> 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	<ul style="list-style-type: none"> 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.

	Price		Market Capitalization (\$ Millions)	
	330 Banned Stocks	330 Control Stocks	330 Banned Stocks	330 Control Stocks
Mean	\$30.76	\$30.76	8,727	8,716
25 th Percentile	\$12.69	\$12.77	818	1,177
Median	\$23.75	\$22.00	2,314	2,948
75 th Percentile	\$39.38	\$38.28	5,763	6,721

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.

	Banned Stocks			Control Stocks		
	Mean	Minimum	Maximum	Mean	Minimum	Maximum
All Options	29,678	27,434	34,088	32,619	30,540	38,072
August Exp.	4,875	4,600	4,920	5,287	5,026	5,338
September Exp.	5,194	4,776	5,388	5,885	5,558	6,080
October Exp.	4,653	2,368	5,984	4,812	2,174	6,310
November Exp.	2,651	1,036	5,678	3,165	1,514	6,344
December Exp.	2,622	2,248	4,846	2,996	2,678	6,118
Expire After 2008	15,919	12,422	21,156	17,262	13,580	23,732
S/X < 0.8	11,572	8,107	20,930	13,232	9,530	23,254
0.8 < S/X < 1.2	9,663	7,084	10,286	12,295	8,482	13,362
1.2 < S/X	8,443	4,660	12,712	7,091	3,650	9,054

Table 2 (continued)

Panel C. Average daily trading volume.

	Banned			Control		
	Puts (contracts)	Calls (contracts)	Stock (shares)	Puts (contracts)	Calls (contracts)	Stock (shares)
August	1,060,620	1,182,536	1,131,035,112	1,022,102	1,010,101	1,399,967,568
September	1,360,579	1,251,039	1,561,408,951	1,706,065	1,509,402	2,528,752,454
October	1,448,395	1,306,088	1,829,735,132	1,486,937	1,400,710	2,256,674,540

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. 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.

Table 3
 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.

	20080801 - 20080912				915	916	917	918	919
	Min	Median	Max	Days $p \leq 0.01$					
October 2008 Options									
Ban Dummy	-\$0.0632	-\$0.0328	\$0.0027	3	-\$0.0336	-\$0.0415	-\$0.0280	-\$0.0773	-\$0.2688
Constant	-\$0.0944	\$0.0346	\$0.2771	4	\$0.1588	\$0.1865	\$0.2026	\$0.0862	-\$0.3090
Pseudo R ²	2.69%	6.32%	12.60%		4.64%	4.09%	3.22%	7.38%	14.96%
N	1,529	3,331	3,424		3,312	3,328	3,237	3,348	3,413
December 2008 Options									
Ban Dummy	\$0.0074	\$0.0397	\$0.1081	0	\$0.0733	\$0.0601	\$0.0415	-\$0.0142	-\$0.2580
Constant	-\$0.2315	\$0.0361	\$0.3357	0	\$0.0369	\$0.2386	\$0.5452	-\$0.4462	-\$0.4462
Pseudo R ²	4.13%	8.36%	12.57%		8.20%	7.62%	6.57%	8.82%	18.86%
N	1,731	1,804	1,840		1,746	1,754	1,712	1,744	1,737

Note: Shading indicates $p \leq 0.01$.

Table 3 (continued)

Panel B. September 22, 2008 through October 3, 2008.

	922	923	924	925	926	929	930	1001	1002	1003
October 2008 Options										
Ban Dummy	-\$0.2280	-\$0.1922	-\$0.1736	-\$0.1417	-\$0.1392	-\$0.1252	-\$0.1386	-\$0.1357	-\$0.1479	-\$0.1329
Constant	-\$0.0159	-\$0.0778	-\$0.1002	-\$0.1624	-\$0.0851	\$0.1480	-\$0.1037	-\$0.0606	\$0.0972	-\$0.1253
Pseudo R ²	12.25%	12.01%	14.17%	11.61%	13.00%	10.51%	10.26%	10.61%	12.15%	12.30%
N	3,494	3,462	3,354	3,360	3,233	3,179	3,103	3,145	3,119	3,080
December 2008 Options										
Ban Dummy	-\$0.2232	-\$0.2310	-\$0.2517	-\$0.2401	-\$0.1763	-\$0.1646	-\$0.1398	-\$0.1827	-\$0.1667	-\$0.1420
Constant	-\$0.0199	-\$0.2630	-\$0.0488	-\$0.1192	-\$0.0023	\$0.2638	-\$0.0485	-\$0.0230	-\$0.0747	-\$0.1858
Pseudo R ²	9.61%	12.47%	13.67%	13.26%	10.22%	11.50%	10.71%	12.86%	11.69%	13.06%
N	1,777	1,758	1,770	1,786	1,689	1,702	1,658	1,687	1,687	1,691

Note: Shading indicates $p \leq 0.01$.

Table 3 (continued)

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

				20081009 - 20081017			
	1006	1007	1008	Min	Median	Max	Days $p \leq 0.01$
October 2008 Options							
Ban Dummy	-\$0.1138	-\$0.0961	-\$0.0619	-\$0.0779	-\$0.0394	-\$0.0200	2
Constant	\$0.0266	\$0.0061	\$0.1943	-\$0.1040	\$0.1126	\$1.3023	1
Pseudo R ²	7.31%	10.15%	8.37%	7.20%	9.35%	15.36%	
N	2,894	2,845	2,792	1,636	1,631	2,687	
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
Pseudo R ²	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:

$$\begin{aligned}
 Bias_i = & \alpha_0 + \alpha_1 Banned_i + \alpha_2 \left(\frac{S}{X}\right)_i + \alpha_3 \left(\frac{S}{X}\right)_i^2 + \alpha_4 \left(\frac{S}{X}\right)_i^{1/2} \\
 & + \alpha_5 ISD_i + \alpha_6 ISD_i^2 + \alpha_7 ISD_i^{1/2} + \alpha_8 \left(\frac{S}{X}\right)_i ISD_i + \alpha_9 Penny_i + \varepsilon_i
 \end{aligned}$$

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, $Banned_i$ takes a value of one if option i is on a stock with banned short selling and zero otherwise, $(S/X)_i$ is the 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) for day t , 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, ISD_i^2 and $ISD_i^{1/2}$ 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 4
 Probit analysis of the frequency of apparent arbitrage opportunities generated purchasing (selling) actual shares
 and using October 2008 expiration options to sell (buy) synthetic shares

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

	20080801 - 20080912				915	916	917	918	919
	Min	Median	Max	Days $p \leq 0.01$					
Buy Actual	-0.4889	-0.1511	0.0295	4	-0.2667	-0.2412	-0.1957	-0.1994	-0.3730
Penny	0.7632	1.6503	2.2903	24	1.5296	1.8486	1.6060	1.8508	0.8539
Pseudo R ²	3.05%	11.21%	24.19%		8.90%	14.13%	11.75%	15.31%	5.61%
N	732	1,958	2,029		1,934	1,948	1,871	1,866	1,855
Buy Synth.	-0.1571	0.0265	0.2020	0	0.0753	0.0860	0.1444	0.3780	0.1061
Penny	0.0531	0.5345	1.0475	2	0.9650	1.2378	0.9576	0.9198	1.2690
Pseudo R ²	1.82%	5.24%	12.51%		10.30%	11.86%	11.24%	12.49%	7.20%
N	732	1,958	2,029		1,934	1,948	1,871	1,866	1,855

Note: Shading indicates $p \leq 0.01$.

Table 4(continued)

Panel B. September 22, 2008 through October 3, 2008

	922	923	924	925	926	929	930	1001	1002	1003
Buy Actual	-0.6675	-0.6629	-0.6158	-0.6379	-0.4775	-0.2215	-0.1234	-0.2087	-0.4511	-0.0784
Penny	1.5702	1.6446	2.0901	2.0395	1.8406	2.0377	2.0069	1.8859	1.9264	1.9401
Pseudo R ²	17.75%	18.13%	23.46%	24.35%	20.76%	22.05%	24.84%	25.04%	21.93%	24.22%
N	1,937	1,935	1,902	1,924	1,862	1,847	1,809	1,817	1,802	1,774
Buy Synth.	0.9313	0.7580	0.8065	0.7453	0.8450	0.5473	0.5895	0.5444	0.5241	0.6688
Penny	1.1917	1.0293	0.7975	0.7611	0.8017	1.1322	0.6639	0.9259	0.7054	0.7845
Pseudo R ²	19.34%	13.35%	13.12%	12.49%	14.80%	12.27%	15.05%	15.19%	13.71%	14.26%
N	1,937	1,935	1,902	1,924	1,862	1,847	1,809	1,817	1,802	1,774

Note: Shading indicates $p < 0.01$.

Table 4 (continued)

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

				20081009 - 20081017			
	1006	1007	1008	Min	Median	Max	Days $p \leq 0.01$
Buy Actual	-0.1879	-0.0508	-0.0612	-0.1504	0.1095	0.3359	0
Penny	1.8945	1.9632	2.0292	0.5698	1.2970	1.7205	7
Pseudo R ²	19.68%	19.49%	18.86%	9.29%	14.81%	20.19%	
N	1594	1577	1522	912	1298	1494	
Buy Synth.	0.4847	0.5843	0.3305	0.1535	0.2373	0.5173	2
Penny	1.1397	1.0419	1.0229	0.9328	1.3875	1.7726	7
Pseudo R ²	15.71%	11.59%	14.06%	8.79%	13.64%	18.19%	
N	1594	1577	1522	912	1298	1494	

Note: Shading indicates $p < 0.01$. For each minute of every day during the sample period, we calculate synthetic bid prices at the end of each minute of each day during the sample period using all pairs of call and put options with October expirations, the same exercise price, and $0.8 < S/X < 1.2$. The proceeds generated by selling a share of stock synthetically are

$$\text{Synthetic Stock Bid} = C^{\text{Bid}} + e^{-rT}X - P^{\text{Ask}} + EEP + \sum_{j=1}^J e^{-rt_j} D_j$$

where C^{bid} is the bid 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^{ask} is the ask 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 count the number of each type of arbitrage opportunity for each option pair each day. We then estimate the following Probit model for each trading day:

$$\text{Pct Arb}_t = \alpha_0 + \alpha_1 \text{Banned}_t + \alpha_2 \left(\frac{S}{X}\right)_t + \alpha_3 \left(\frac{S}{X}\right)_t^2 + \alpha_4 \left(\frac{S}{X}\right)_t^{1/2} + \alpha_5 \text{ISD}_t + \alpha_6 \text{ISD}_t^2 + \alpha_7 \text{ISD}_t^{1/2} + \alpha_8 \left(\frac{S}{X}\right)_t \text{ISD}_t + \alpha_9 \text{Penny}_t + \varepsilon_t$$

where Pct Arb_t is the proportion of minutes during day t where the synthetic bid price exceeded the actual ask price of a share of the stock, Banned_t takes a value of one if the stock was included in the short sale ban and zero otherwise, $(S/X)_t$ is the average ratio of stock price to exercise price over 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_t is the mean implied standard deviation for the call for day t , and ISD_t^2 and $\text{ISD}_t^{1/2}$ are square and square root of the average implied standard deviation for day t , and Penny_t is one if the option was quoted in pennies, zero otherwise. Errors are clustered at the stock level. Two days are missing because either $\text{banned}=1$ predicts perfectly (813) or $\text{penny}=0$ predicts perfectly (827).

Table 5
 Probit analysis of the frequency of arbitrage opportunities generated purchasing (selling) actual shares and
 using December 2008 expiration options to sell (purchase) synthetic shares

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

	20080801 - 20080912				915	916	917	918	919
	Min	Median	Max	Days $p \leq 0.01$					
Buy Actual	-0.5081	-0.3755	-0.2045	3	-0.3294	-0.3475	-0.2473	-0.5054	-0.7534
Penny	-0.5569	0.0925	0.8293	0	-0.1549	-0.0355	-0.3715	-0.1277	0.6075
Pseudo R ²	1.77%	3.78%	5.64%		2.64%	3.41%	2.79%	3.66%	9.10%
N	802	844	869		824	825	792	771	811
Buy Synth.	-0.2541	0.0217	0.3203	0	-0.0048	-0.1115	-0.1203	0.0598	0.0883
Penny	1.0920	1.7372	2.0683	25	2.0126	2.1218	2.0127	2.0359	2.0581
Pseudo R ²	5.64%	14.52%	19.44%		19.42%	16.23%	22.60%	20.74%	9.50%
N	802	846	869		824	825	792	771	811

Table 5 (continued)

Panel B. September 22, 2008 through October 3, 2008.

	922	923	924	925	926	929	930	1001	1002	1003
Buy Actual	-0.9965	-1.1502	-1.0678	-0.9142	-0.9614	-0.8780	-0.9226	-1.0368	-1.0092	-0.9851
Penny	0.1486	0.0066	0.0356	0.1153	0.3463	0.5039	0.6612	0.5111	1.0365	0.4261
Pseudo R ²	14.19%	16.52%	14.56%	12.24%	13.06%	11.15%	13.97%	14.52%	16.51%	15.09%
N	831	834	849	839	824	815	803	798	787	772
Buy Synth.	0.6428	0.6821	0.5437	0.6742	0.6775	0.4148	0.5832	0.5307	0.4249	0.4915
Penny	1.8801	1.7565	1.8700	1.7948	1.7314	1.6263	1.6169	1.7265	0.8760	1.6638
Pseudo R ²	14.33%	12.88%	13.83%	13.91%	13.55%	11.81%	12.16%	13.47%	6.54%	11.39%
N	831	834	849	839	824	815	803	798	787	772

Note: Shading indicates $p < 0.01$.

Table 5 (continued)

Panel C. October 6, 2008 through October 21, 2008.

	20081009 - 20081021						
	1006	1007	1008	Min	Median	Max	Days $p \leq 0.01$
Buy Actual	-0.8493	-0.7840	-0.8748	-0.8526	-0.6457	-0.3595	5
Penny	0.5847	0.7684	1.0759	0.8251	0.9572	1.6826	1
Psuedo R ²	12.77%	14.45%	16.07%	9.52%	12.21%	14.30%	
N	698	709	672	536	658	708	
Buy Synth.	0.1677	0.2731	0.4320	0.1720	0.3481	0.4509	0
Penny	1.3968	1.5287	1.3328	1.1713	1.5255	1.6674	4
Psuedo R ²	8.16%	9.96%	7.37%	4.99%	9.35%	10.04%	
N	698	709	672	536	658	708	

Note: Shading indicates $p < 0.01$. For each minute of every day during the sample period, we calculate synthetic bid prices at the end of each minute of each day during the sample period using all pairs of call and put options with December expirations, the same exercise price, and $0.8 < S/X < 1.2$. The proceeds generated by selling a share of stock synthetically are

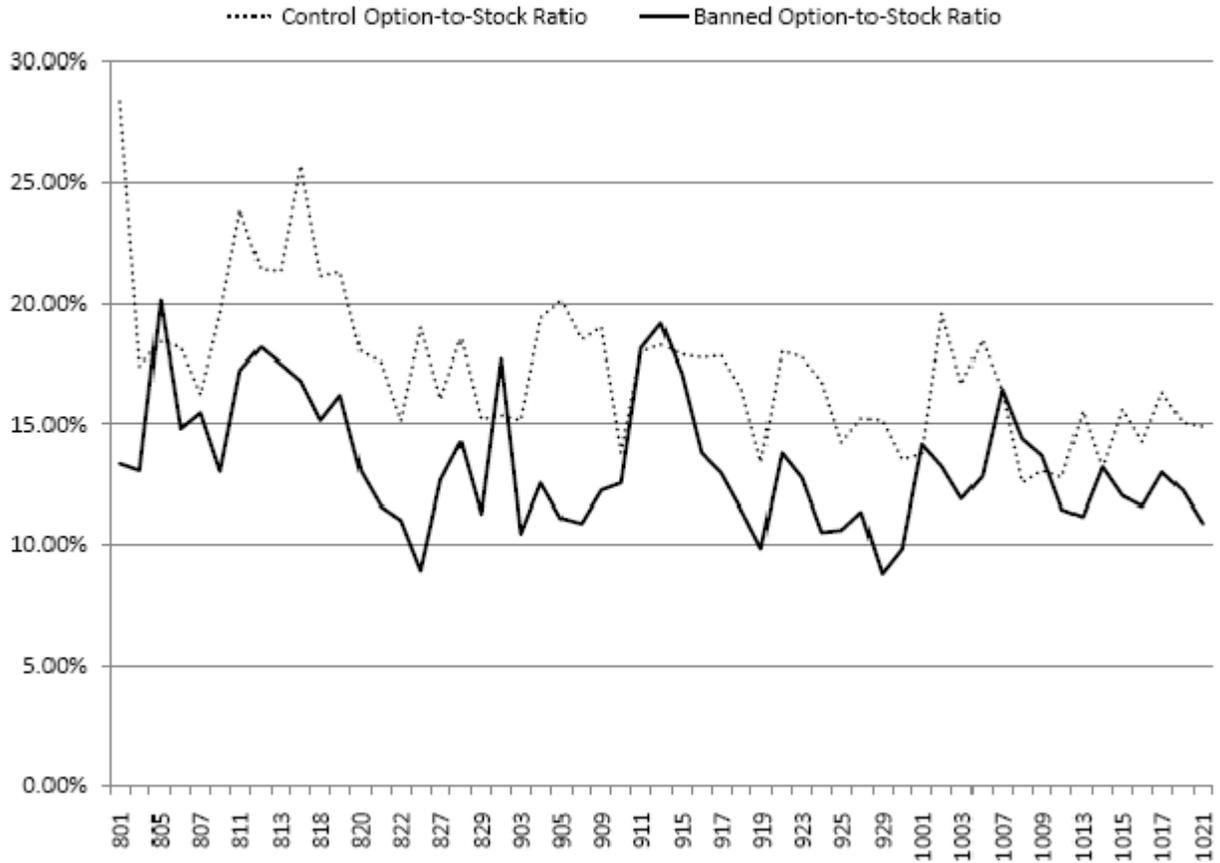
$$\text{Synthetic Stock Bid} = C^{\text{Bid}} + e^{-rT} X - P^{\text{Ask}} + EEP + \sum_{j=1}^J e^{-rt_j} D_j$$

where C_{bid} is the bid 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^{Ask} is the ask 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 count the number of each type of arbitrage opportunity for each option pair each day. We then estimate the following model using a Probit for each trading day:

$$\text{Pct Arb}_t = \alpha_0 + \alpha_1 \text{Banned}_t + \alpha_2 \left(\frac{S}{X} \right)_t + \alpha_3 \left(\frac{S}{X} \right)_t^2 + \alpha_4 \left(\frac{S}{X} \right)_t^{1/2} + \alpha_5 \text{ISD}_t + \alpha_6 \text{ISD}_t^2 + \alpha_7 \text{ISD}_t^{1/2} + \alpha_8 \left(\frac{S}{X} \right)_t \text{ISD}_t + \alpha_9 \text{Penny}_t + \varepsilon_t$$

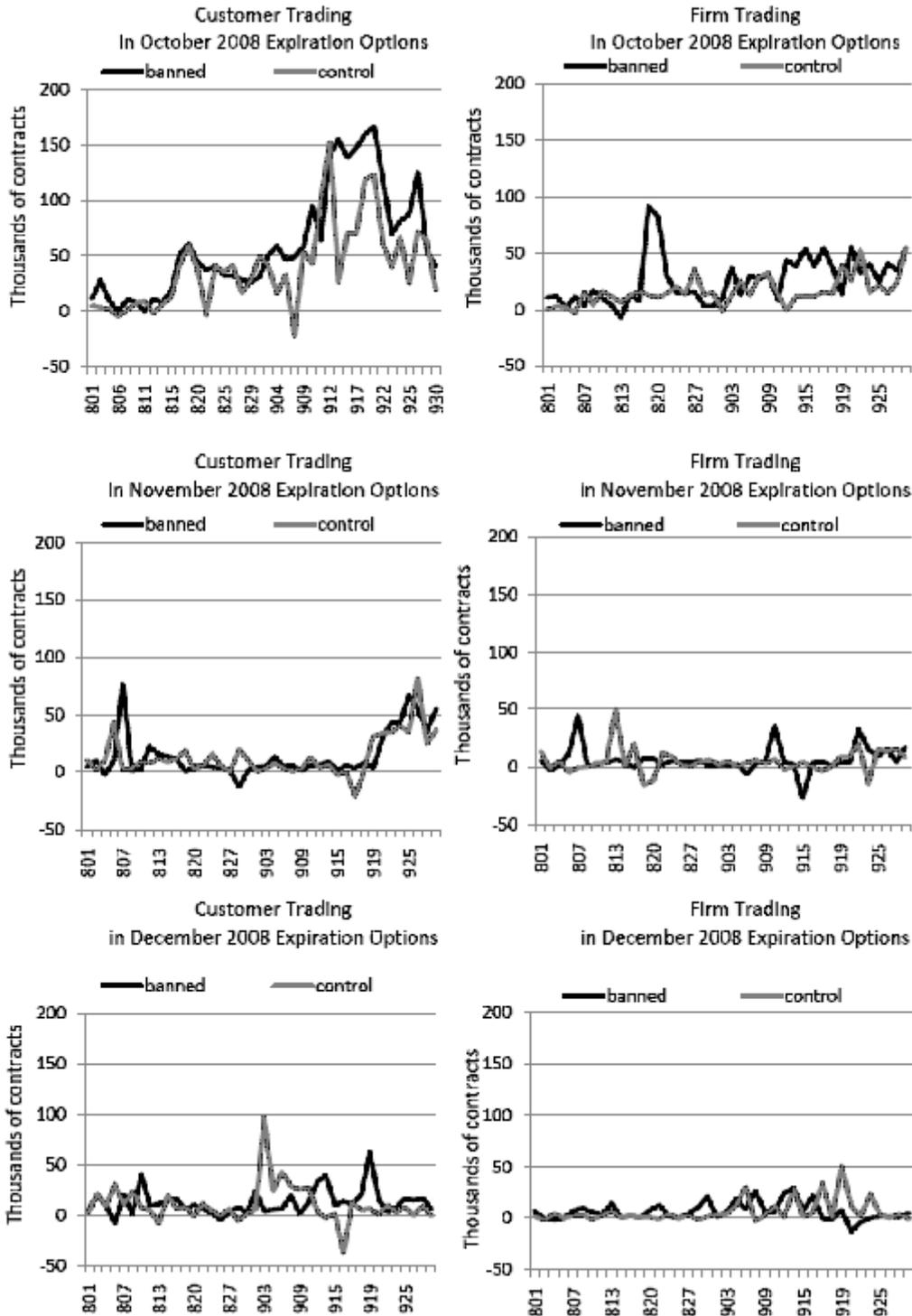
where Pct Arb_t is the proportion of minutes during day t where the synthetic bid price exceeded the actual ask price of a share of the stock, Banned_t takes a value of one if the stock was included in the short sale ban and zero otherwise, $(S/X)_t$ is the average ratio of stock price to exercise price over 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_t is the mean implied standard deviation for the call for day t , and ISD_t^2 and $\text{ISD}_t^{1/2}$ are square and square root of the average implied standard deviation for day t , and Penny_t is one if the option was quoted in pennies, zero otherwise. Errors are clustered at the stock 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.

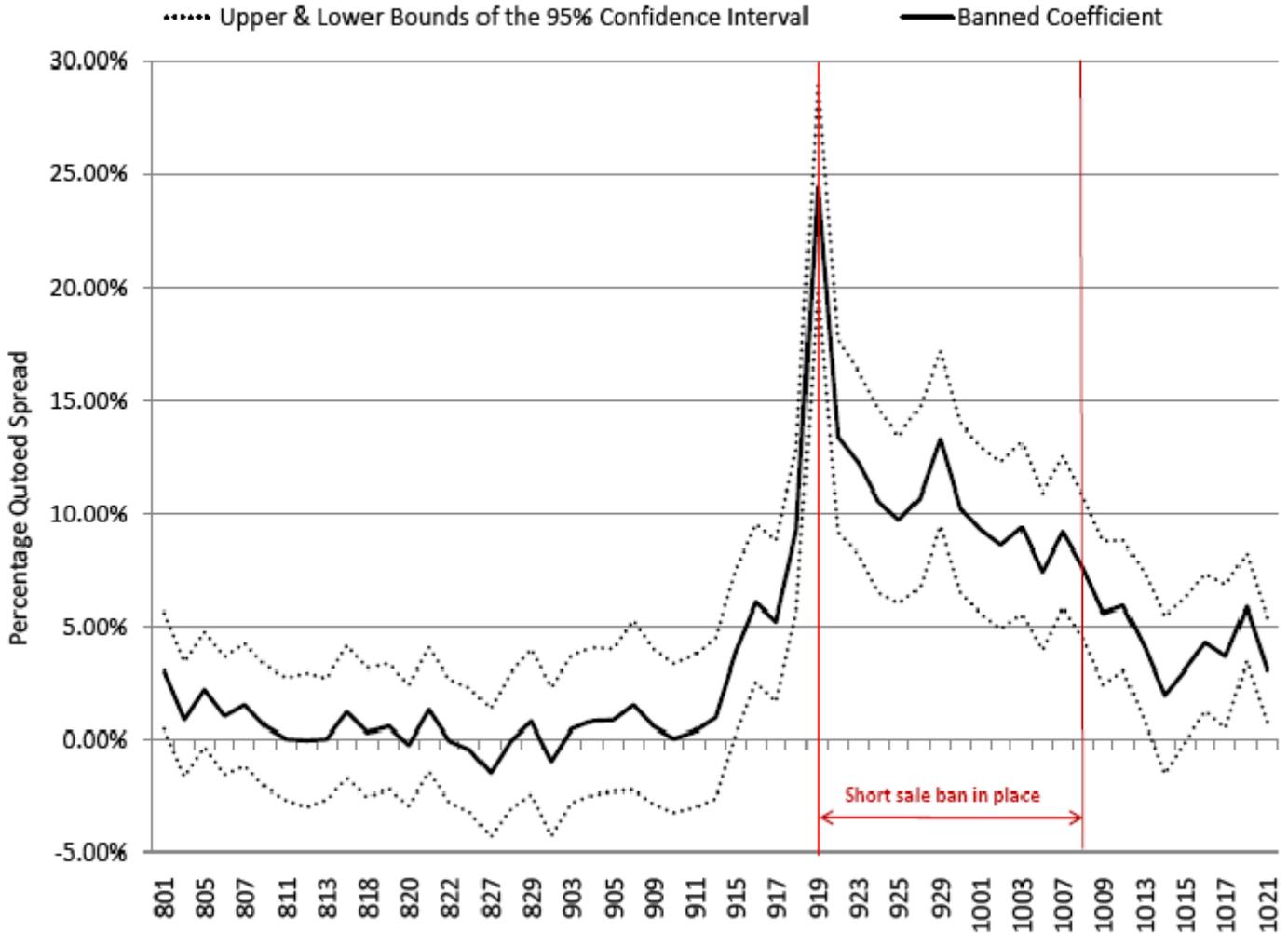
Figure 2. Daily initiations of short exposure on the CBOE and ISE in August and September 2008.



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 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:

$$\text{Changes in Short Exposure}_i = (\text{Put Open-Buy} + \text{Call Open-Sell}) - (\text{Put Close-Buy} + \text{Call Close-Sell}).$$

Figure 3. Marginal impact of the short sale ban on the relative bid ask spreads of December 2008 expiration puts on banned stocks.

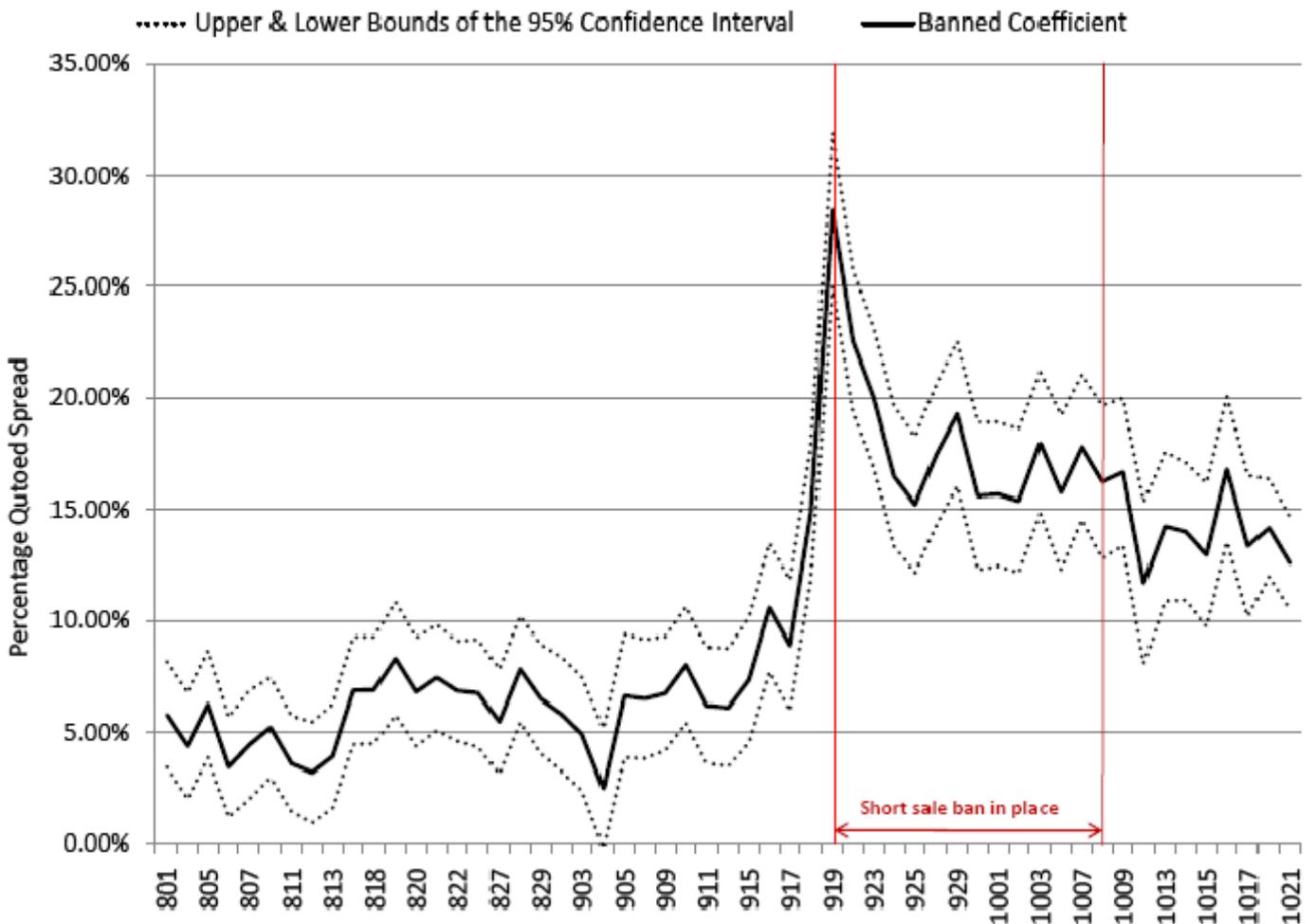


Notes. For each put option I expiring on December 20, 2008, we compute the National Best Bid and Offer (NBBO) by taking the highest valid bid and the lowest valid offer posted at one of the seven venues currently trading equity options in the United States. Next, we calculate an average percentage spread, $Pct\ Spread_t$, 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:

$$Pct\ Spread = \alpha_0 + \alpha_1 Banned_t + \alpha_2 \left(\frac{S}{X}\right)_t + \alpha_3 \left(\frac{S}{X}\right)_t^2 + \alpha_4 \left(\frac{S}{X}\right)_t^3 + \alpha_5 ISD_t + \alpha_6 ISD_t^2 + \alpha_7 ISD_t^3 + \alpha_8 \left(\frac{S}{X}\right)_t ISD_t + \alpha_9 Penny_t + \varepsilon_t$$

where $Banned_t$ 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 $(S/X)_t^3$ are the square and cube root of the average value of (S/X) for day t , 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, ISD_t^2 and ISD_t^3 are square and cube root of the average implied standard deviation for day t , and $Penny_t$ 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 4. Marginal impact of the short sale ban on the relative bid ask spreads of December 2008 expiration calls on banned stocks.

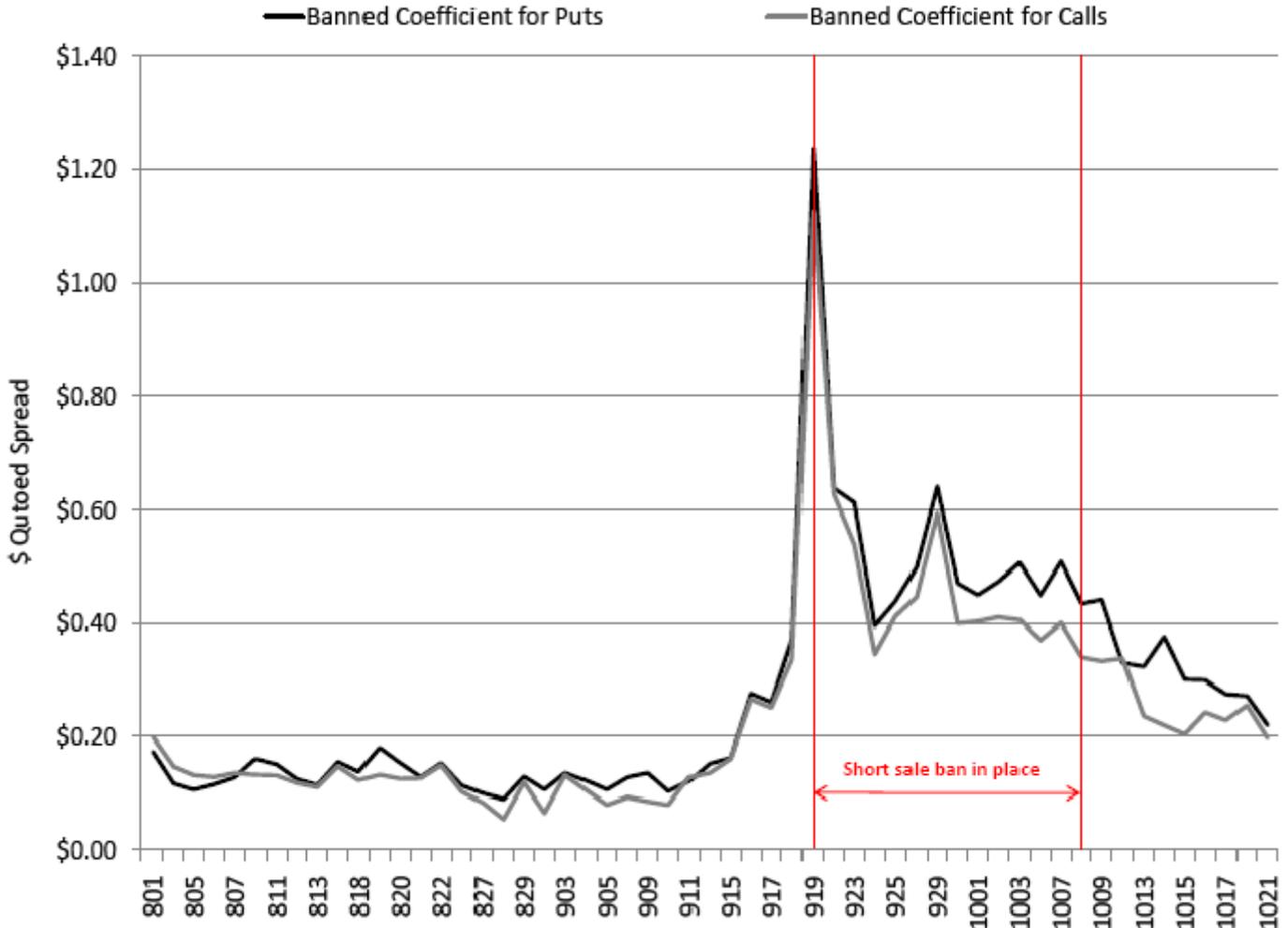


Notes. For each call option I expiring on December 20, 2008, we compute the National Best Bid and Offer (NBBO) by taking the highest valid bid and the lowest valid offer posted at one of the seven venues currently trading equity options in the United States. Next, we calculate an average percentage spread, $Pct\ Spread_i$, 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:

$$Pct\ Spread_i = \alpha_0 + \alpha_1 Banned_i + \alpha_2 \left(\frac{S}{X}\right)_i + \alpha_3 \left(\frac{S}{X}\right)_i^2 + \alpha_4 \left(\frac{S}{X}\right)_i^{1/2} + \alpha_5 ISD_i + \alpha_6 ISD_i^2 + \alpha_7 ISD_i^{1/2} + \alpha_8 \left(\frac{S}{X}\right)_i ISD_i + \alpha_9 Penny_i + \varepsilon_i$$

where $Banned_i$ takes a value of one if option I is on a stock with banned short selling and zero otherwise, $(S/X)_i$ is the 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) for day t , ISD_i is the mean implied standard deviation for option I on day t for the call, ISD_i^2 and $ISD_i^{1/2}$ 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.

Figure 5. Marginal impact of the short sale ban on the quoted bid ask spreads of December 2008 expiration puts and calls on banned stocks.

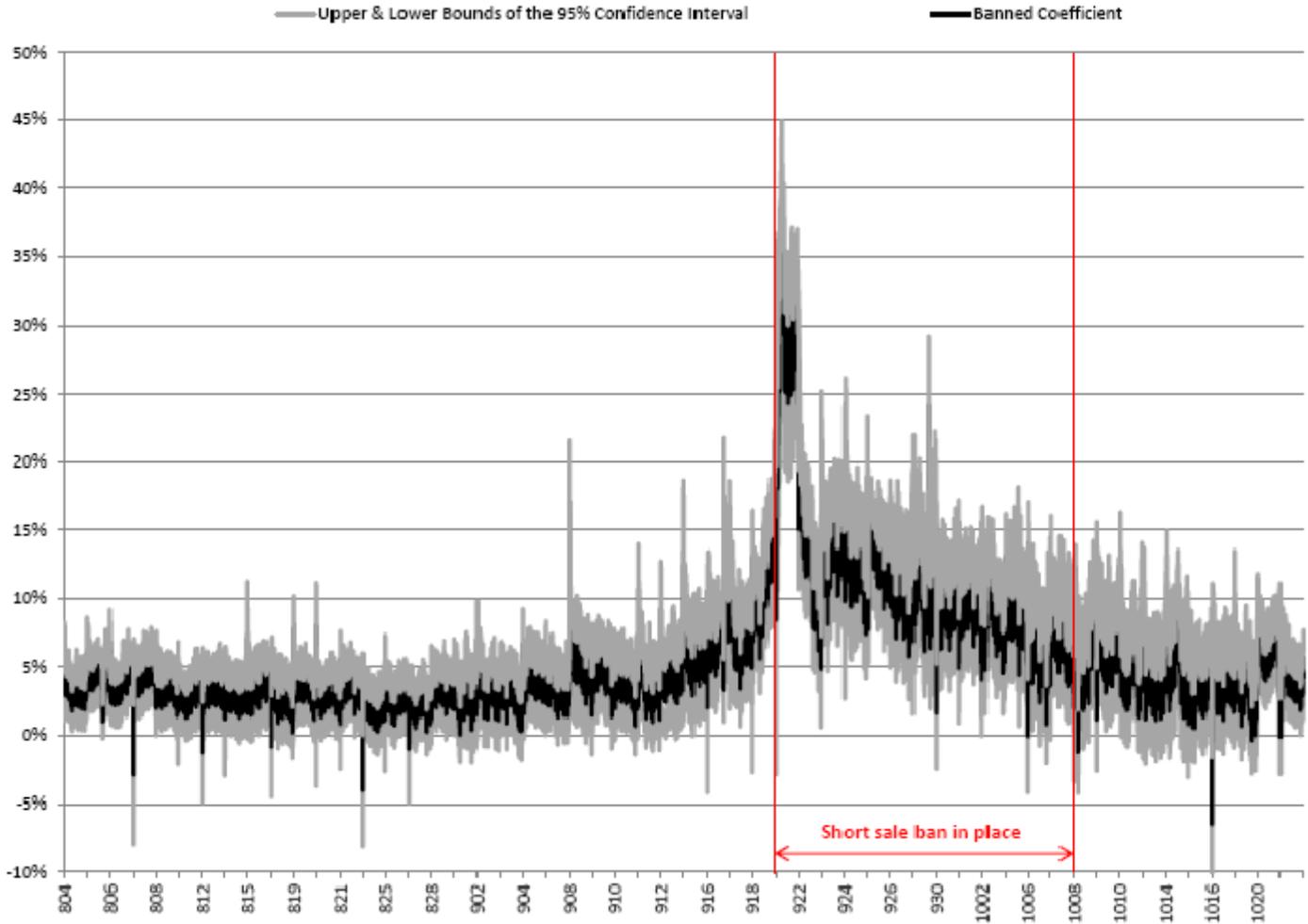


Notes. For each option I expiring on December 20, 2008, we compute the National Best Bid and Offer (NBBO) by taking the highest valid bid and the lowest valid offer posted at one of the seven venues currently trading equity options in the United States. Next, we calculate an average quoted spread, $Qte\ Spread_i$, 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:

$$Qte\ Spread_i = \alpha_0 + \alpha_1 Banned_i + \alpha_2 \left(\frac{S}{X}\right)_i + \alpha_3 \left(\frac{S}{X}\right)_i^2 + \alpha_4 \left(\frac{S}{X}\right)_i^{1/2} + \alpha_5 ISD_i + \alpha_6 ISD_i^2 + \alpha_7 ISD_i^{1/2} + \alpha_8 \left(\frac{S}{X}\right)_i ISD_i + \alpha_9 Penny_i + \varepsilon_i$$

where $Banned_i$ takes a value of one if option I is on a stock with banned short selling, $(S/X)_i$ is the ratio of the stock price to the exercise price, ISD_i 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 α_1 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.

Figure 6. Intraday 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, $Pct\ Spread_i$, 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 at the end of each minute, each day from August 1, 2008 through October 21, 2008, with standard errors clustered by underlying stock:

$$Pct\ Spread_i = \alpha_0 + \alpha_1 Banned_i + \alpha_2 \left(\frac{S}{X}\right)_i + \alpha_3 \left(\frac{S}{X}\right)_i^2 + \alpha_4 \left(\frac{S}{X}\right)_i^{1/2} + \alpha_5 ISD_i + \alpha_6 ISD_i^2 + \alpha_7 ISD_i^{1/2} + \alpha_8 \left(\frac{S}{X}\right)_i ISD_i + \alpha_9 Penny_i + \alpha_{10} Stock\ Spread + \varepsilon_i$$

where $Banned_i$ takes a value of one if option I is on a stock with banned short selling and zero otherwise, $(S/X)_i$ is the 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) for day t , 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, ISD_i^2 and $ISD_i^{1/2}$ are square and square root of the average implied standard deviation for day t , $Penny$ is one if the option is part of the SEC's Penny Pilot and zero otherwise, and $Stock\ Spread$ is the relative spread of the underlying stock. 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 7. Average minute-by-minute relative spreads for puts on banned and control stocks

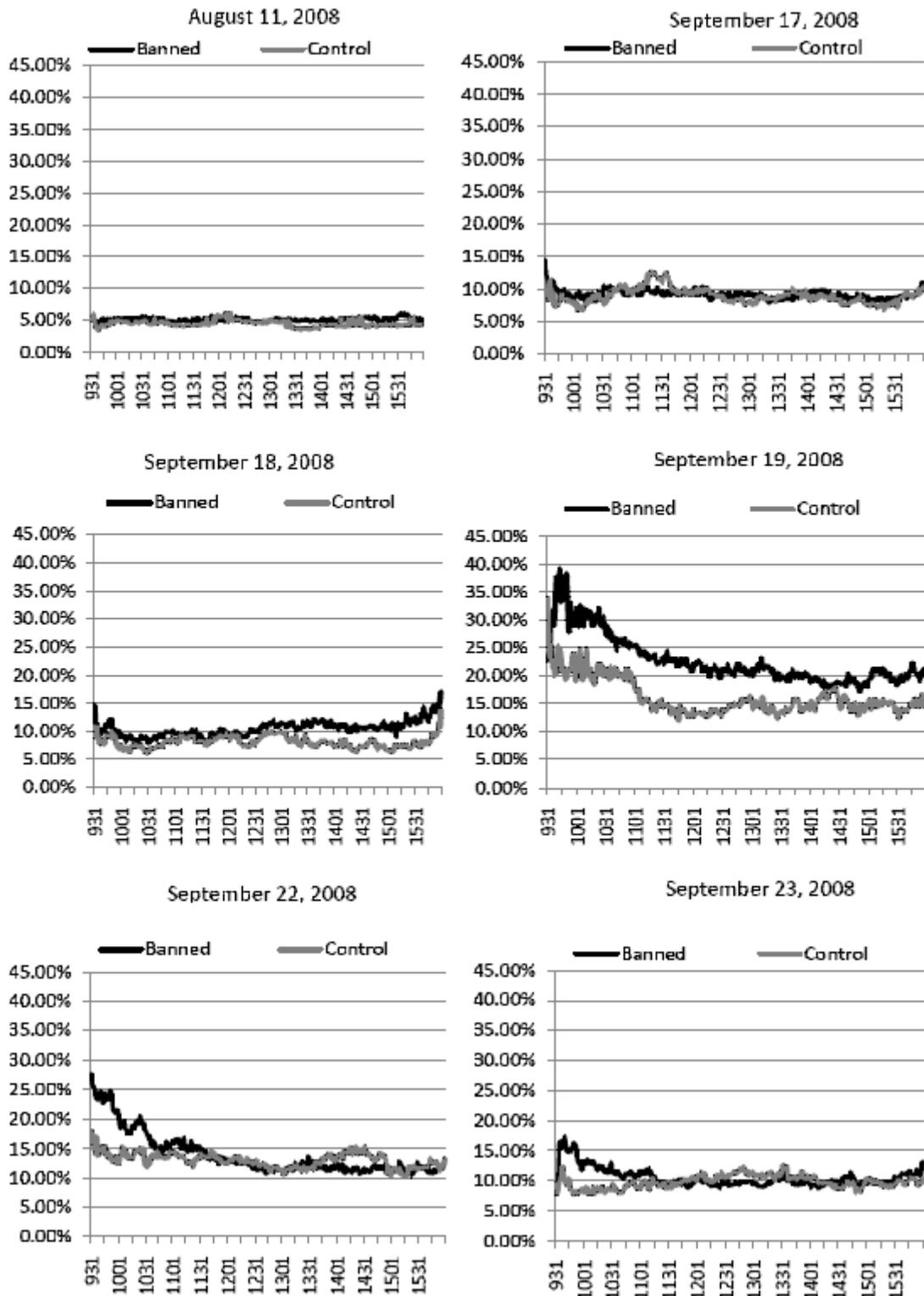
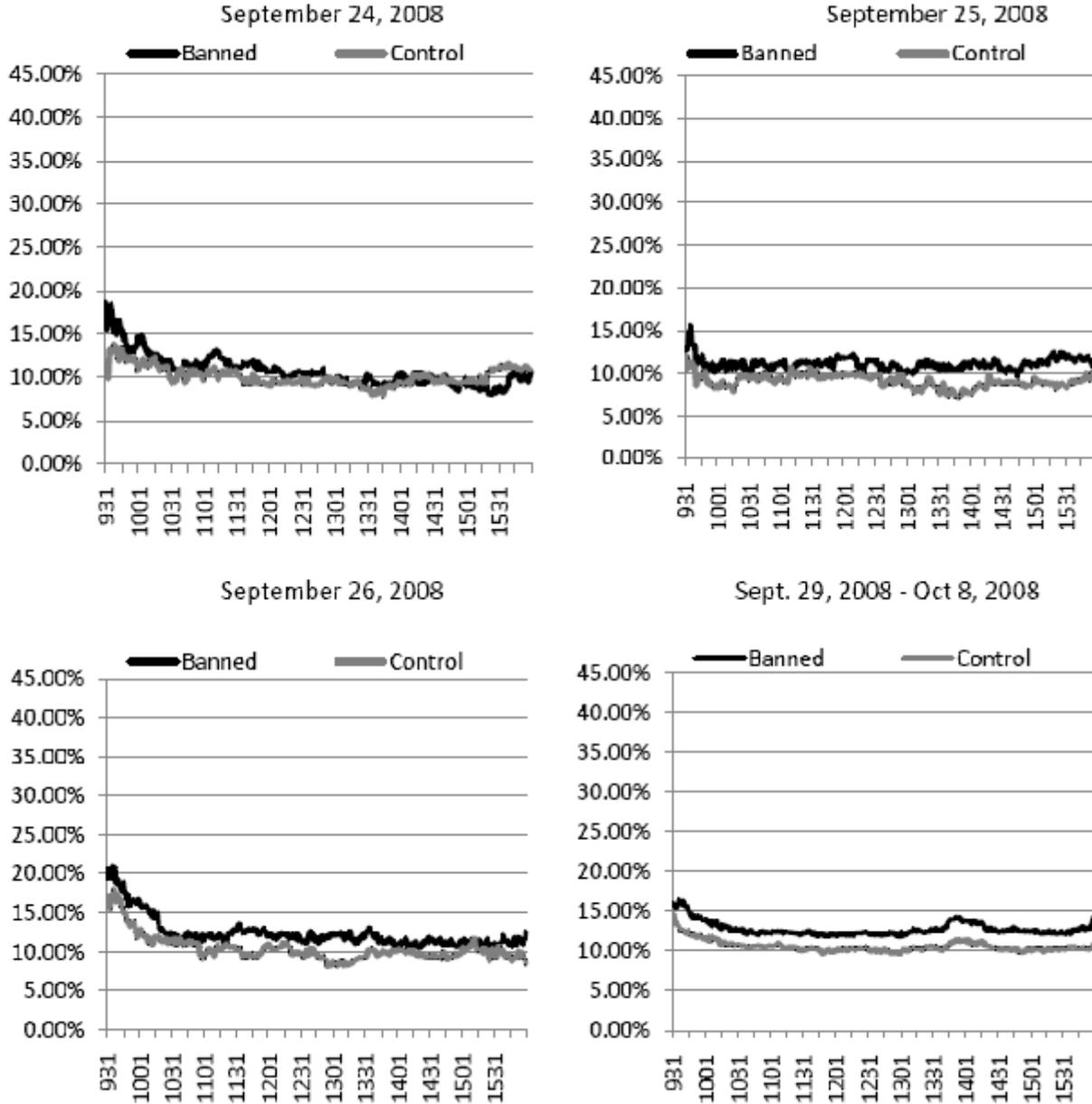
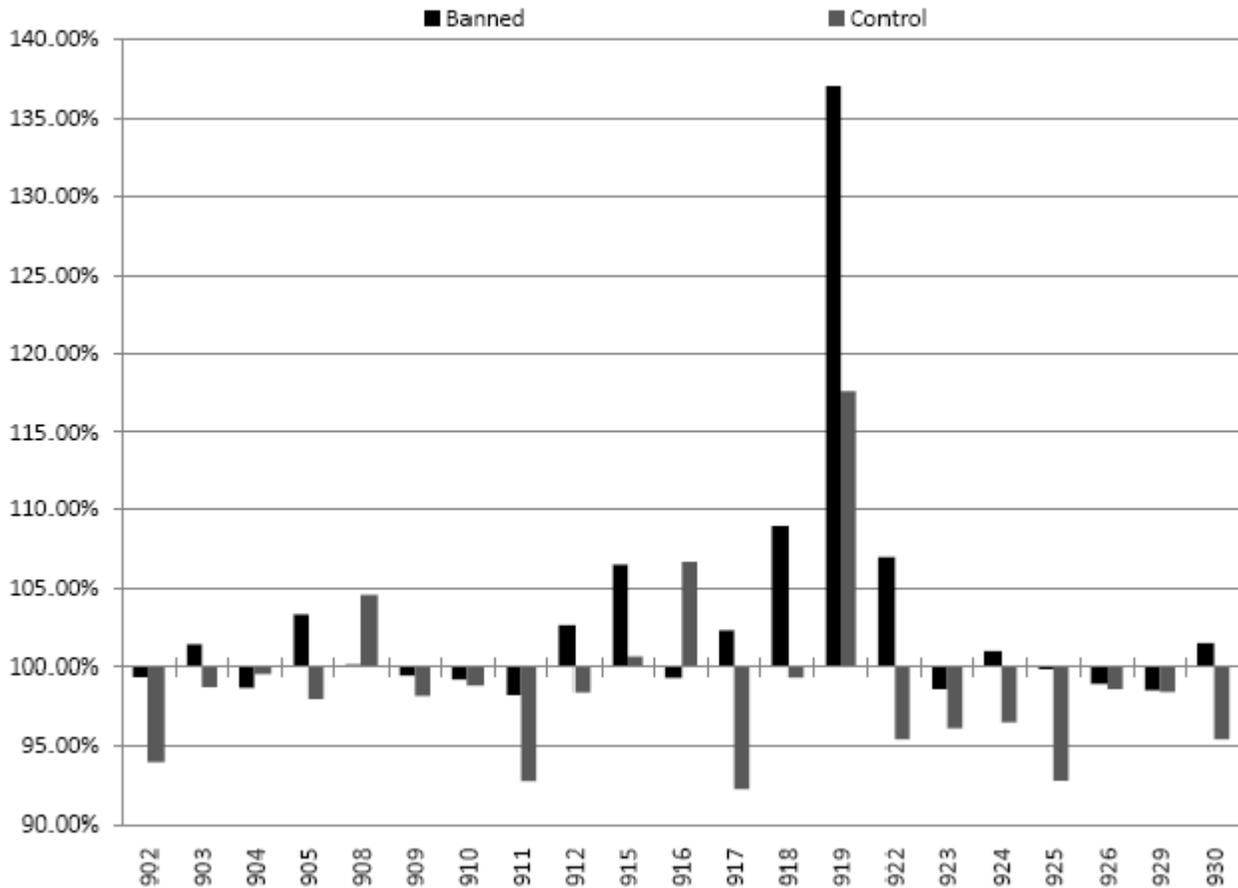


Figure 7 (continued).



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.

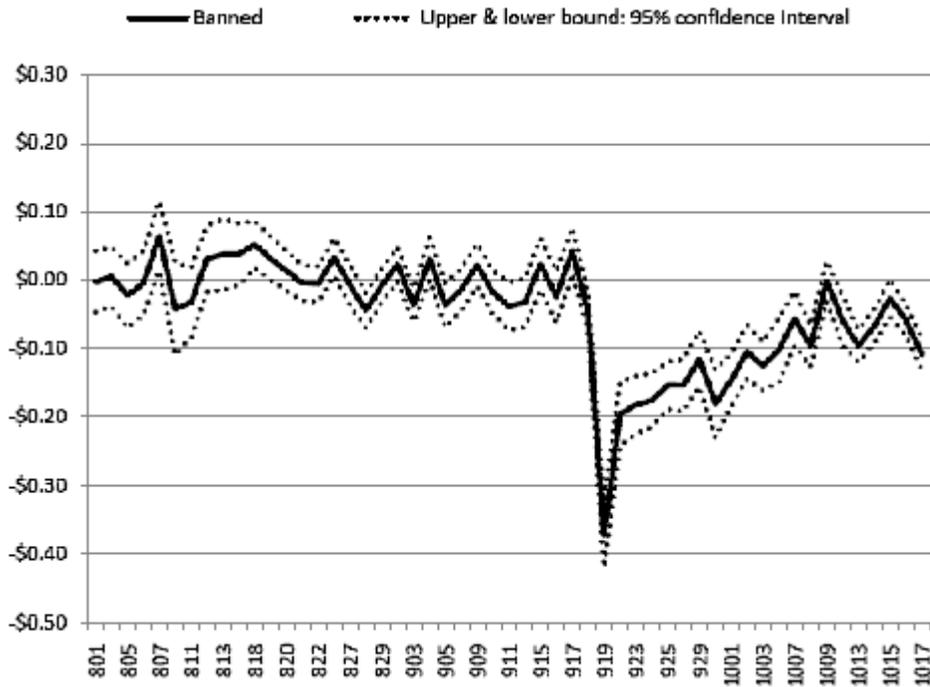
Figure 8. Ratio of the relative effective-to-relative quoted bid ask spread for marketable orders placed with a major retail broker in September 2008



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. 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 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.

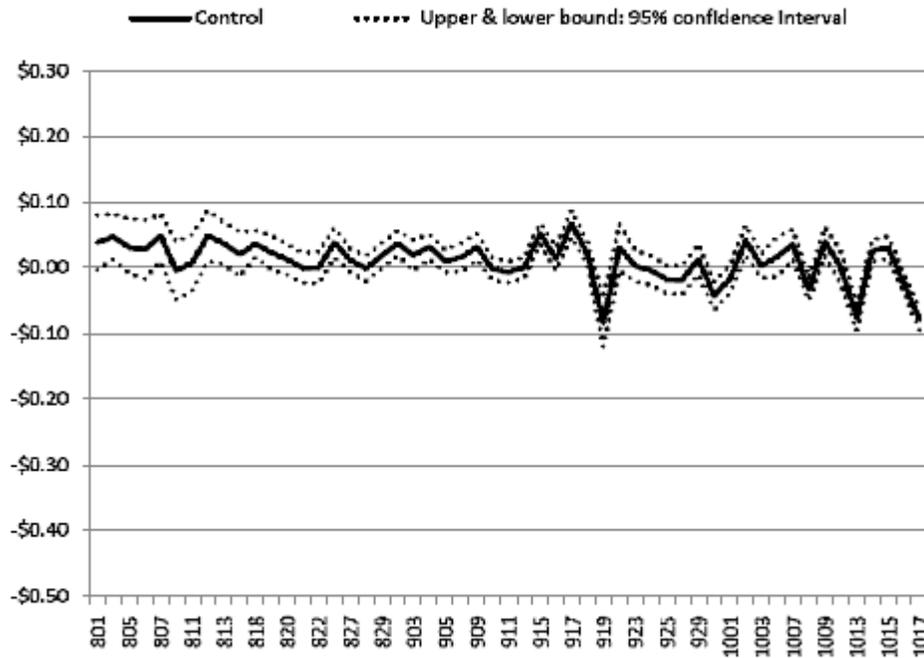


Figure 9 (continued)

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

$$\text{Synthetic Stock}^{Ask} = C^{Ask} + e^{-rT} X - P^{Bid} + EEP + \sum_{j=1}^J e^{-rt_j} D_j \quad .$$

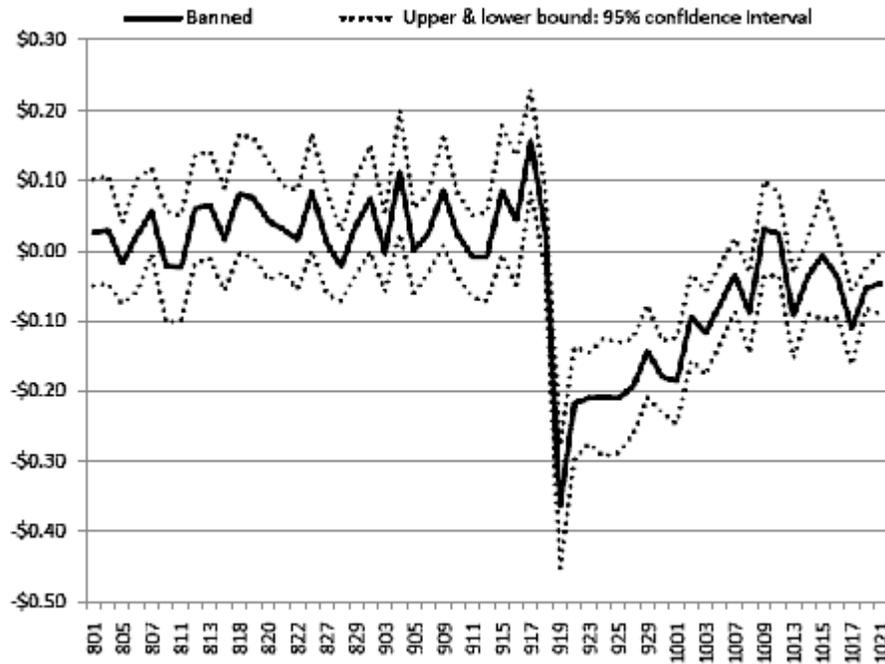
where C^{ask} is the ask price of a call, r is the riskless rate, T is the time to expiration for the call and put, X is the exercise price, P^{bid} is the bid price of a put with the same exercise price and expiration date as the call, EEP is the early exercise premium in the put price, t_j is the time 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 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

$$\text{Synthetic Stock}^{Bid} = C^{Bid} + e^{-rT} X - P^{Ask} + EEP + \sum_{j=1}^J e^{-rt_j} D_j \quad .$$

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.

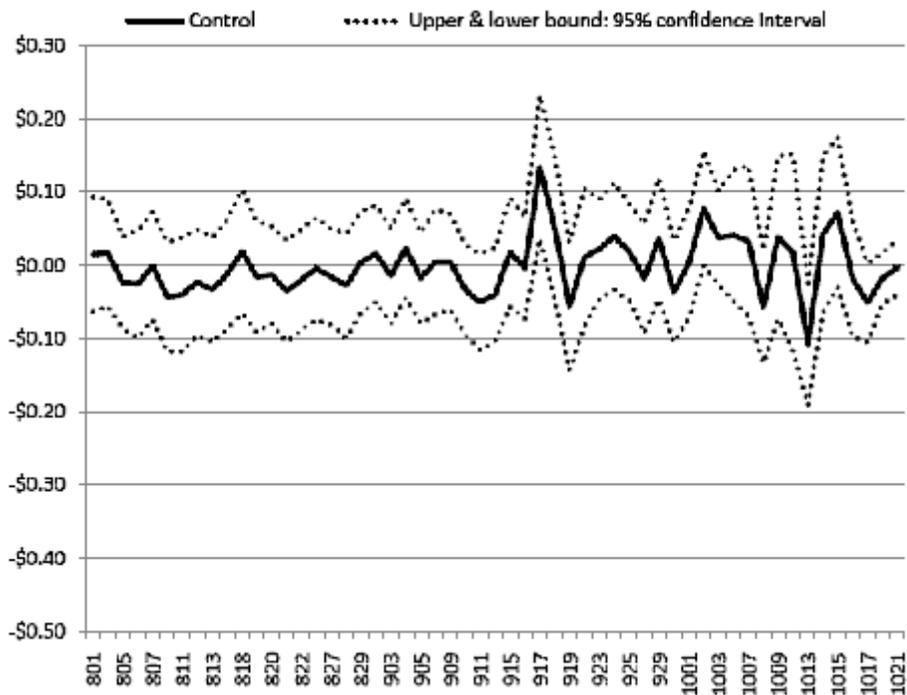


Figure 10 (continued)

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

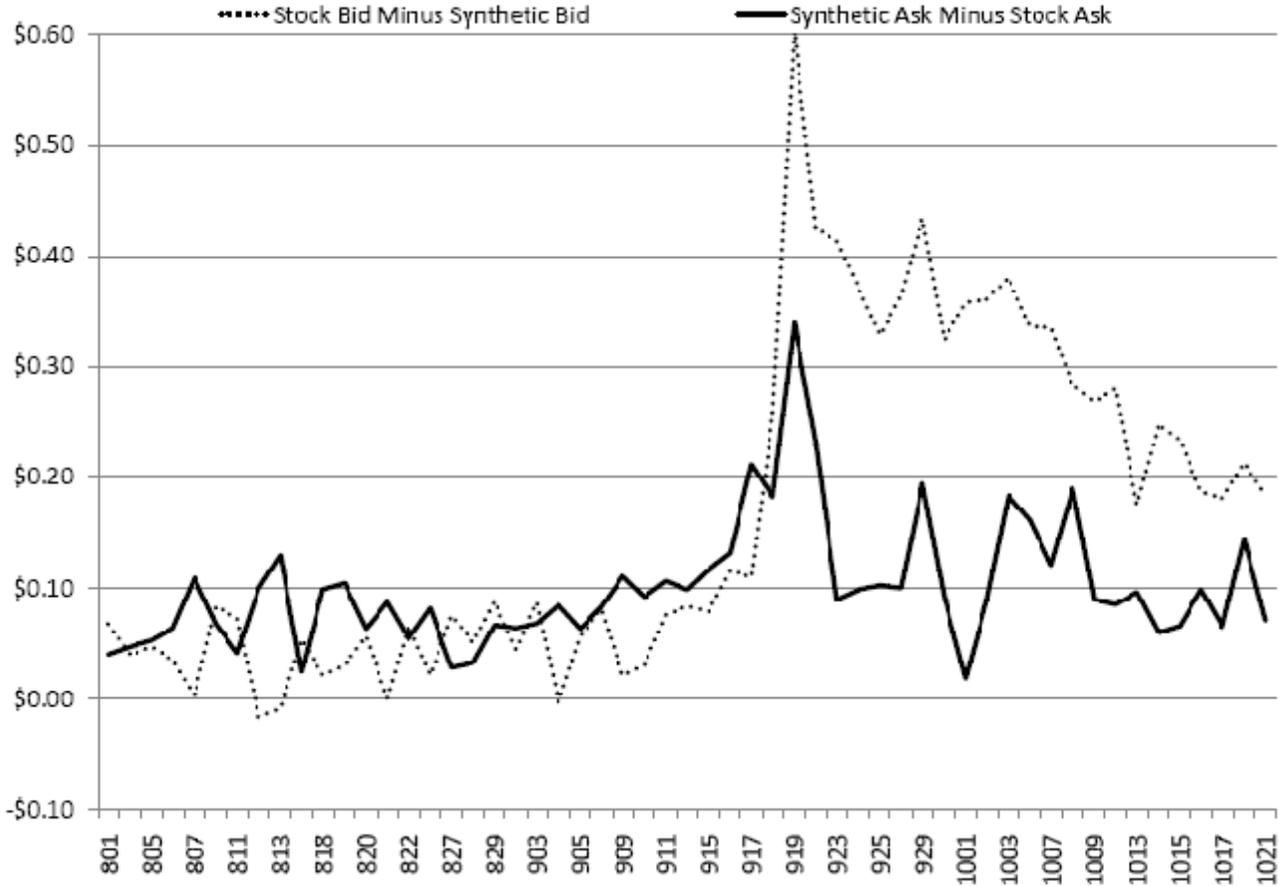
$$\text{Synthetic Stock}^{Ask} = C^{Ask} + e^{-rT} X - P^{Bid} + EEP + \sum_{j=1}^J e^{-rt_j} D_j \quad .$$

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 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

$$\text{Synthetic Stock}^{Bid} = C^{Bid} + e^{-rT} X - P^{Ask} + EEP + \sum_{j=1}^J e^{-rt_j} D_j \quad .$$

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 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

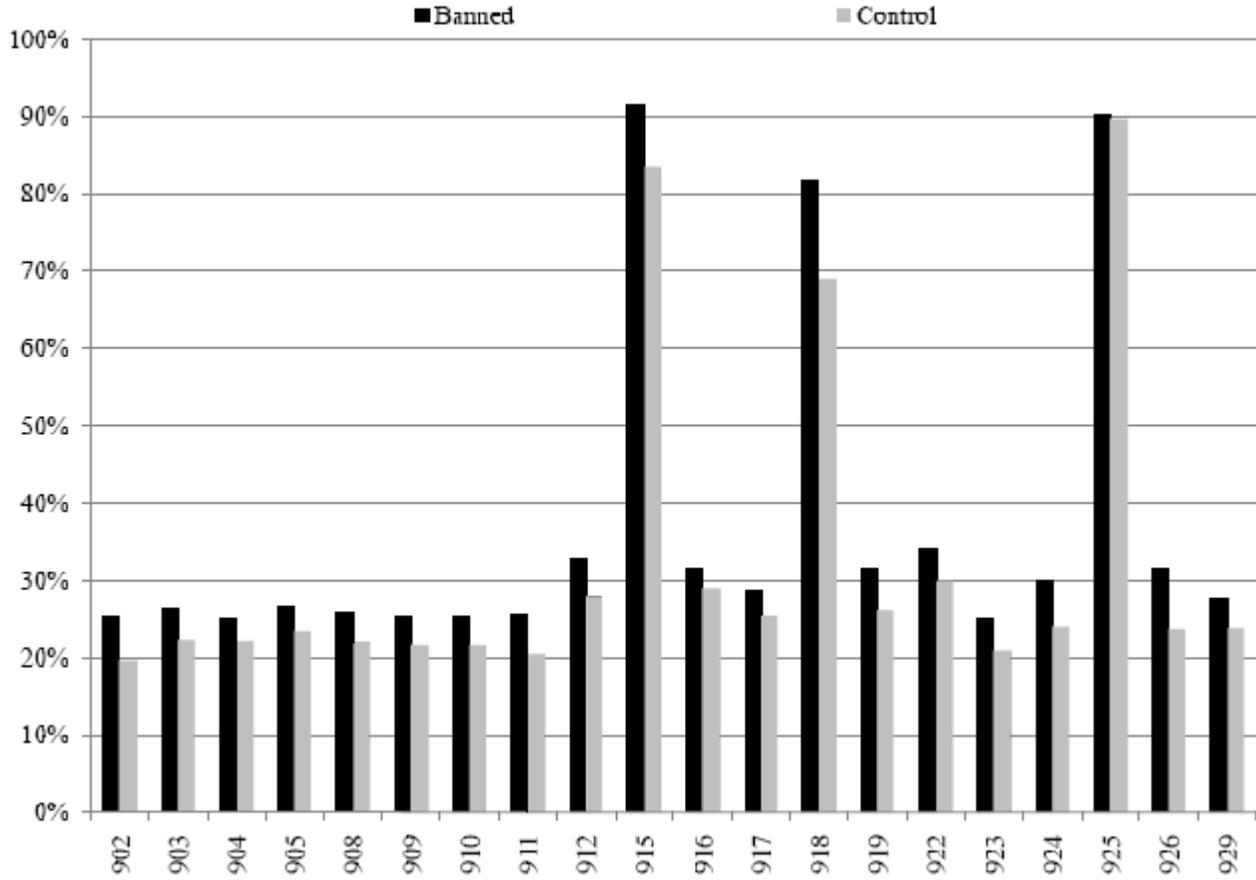
$$\text{Synthetic Stock}^{Ask} = C^{Ask} + e^{-rT}X - P^{Bid} + EEP + \sum_{j=1}^J e^{-rt_j} D_j \quad .$$

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 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

$$\text{Synthetic Stock}^{Bid} = C^{Bid} + e^{-rT}X - P^{Ask} + EEP + \sum_{j=1}^J e^{-rt_j} D_j \quad .$$

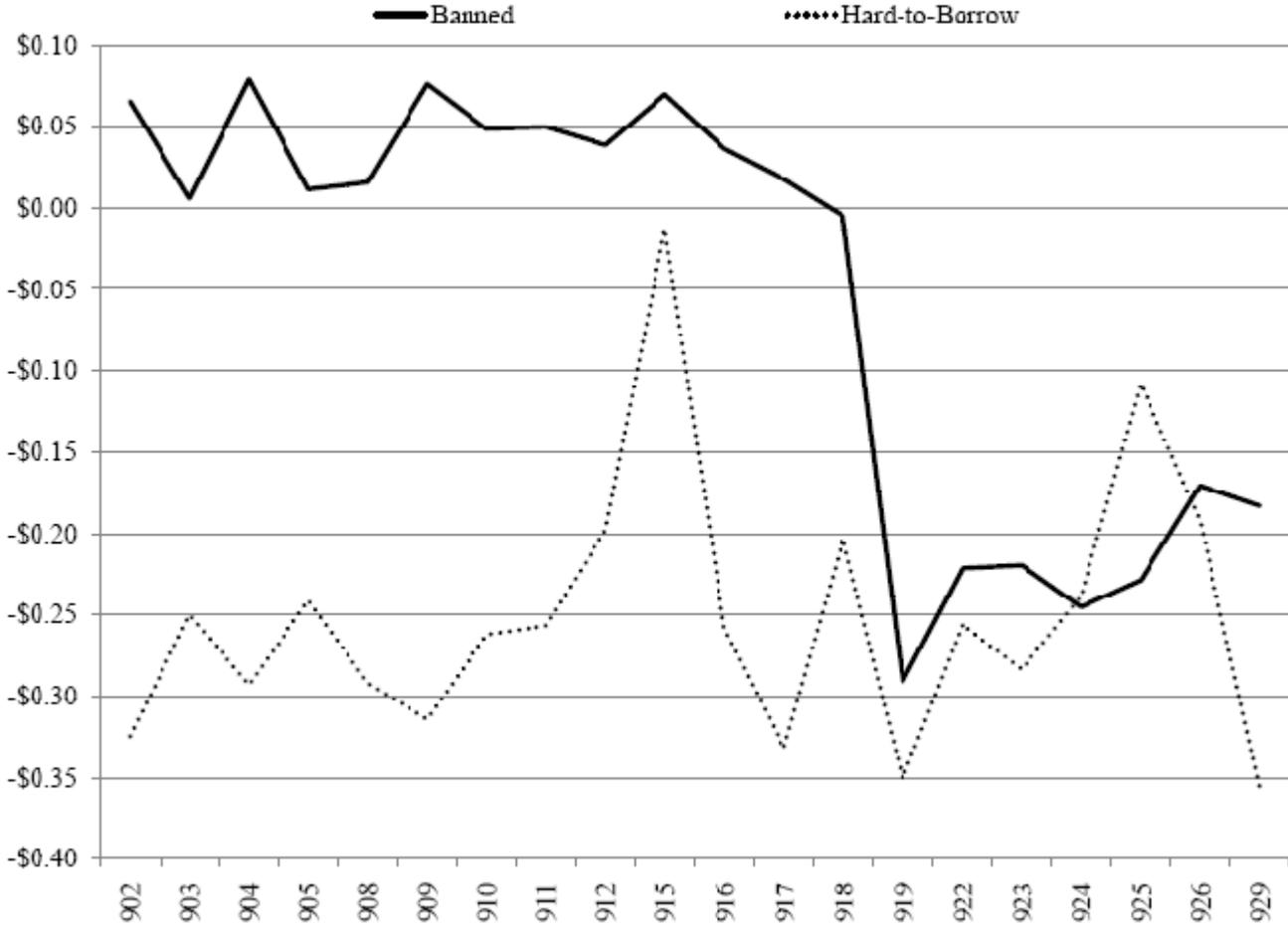
For every day from August 1, 2008 through October 21, 2008, we calculate the mean difference between the actual bid and the synthetic bid and between the synthetic ask and the actual ask using all options expiring in December 2008 with a bias that is no greater than \$2.00 in absolute value. Averages are computed with clustered standard errors.

Figure 12. 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 13. 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

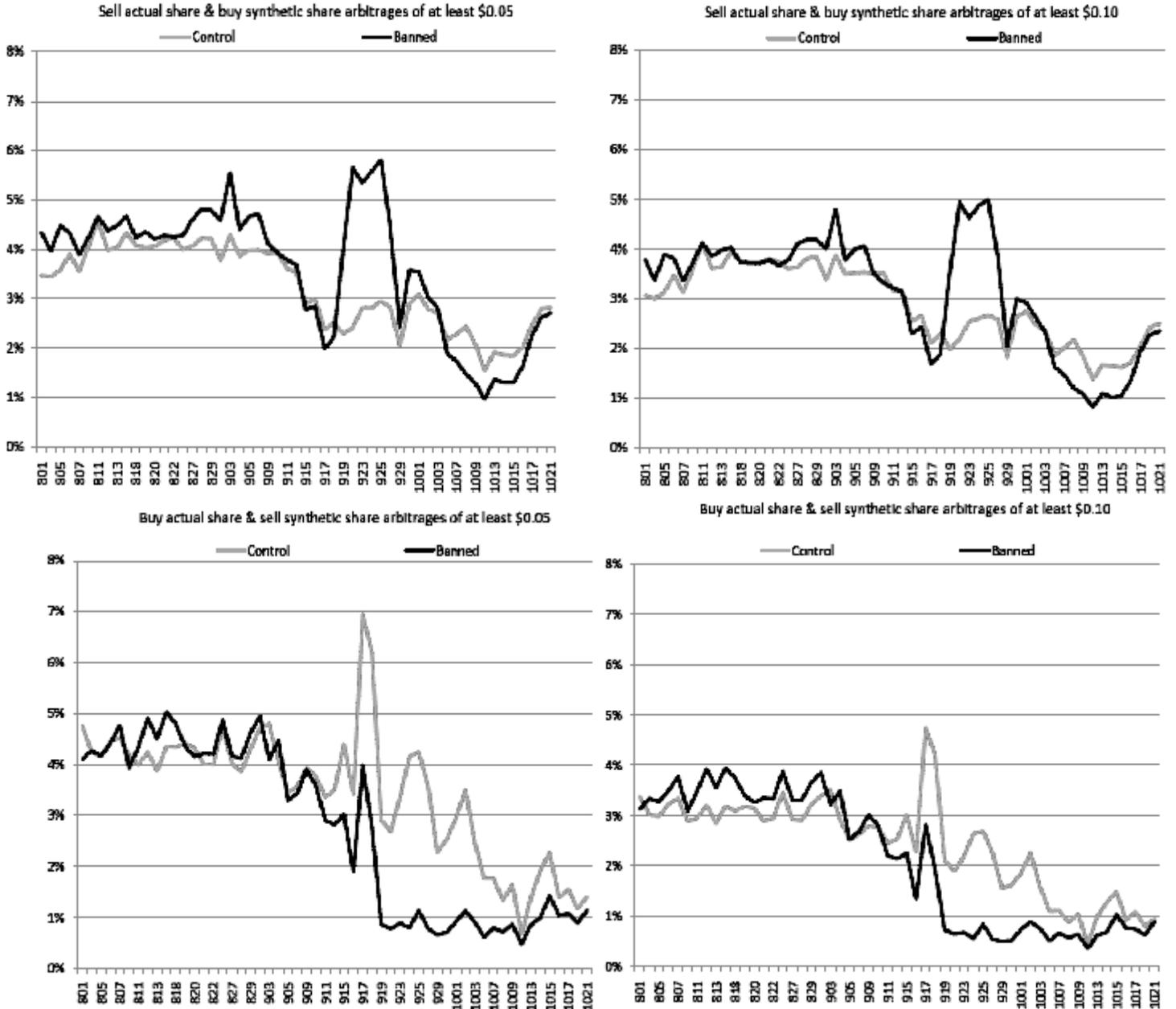
$$\text{Synthetic Stock}^{\text{Ask}} = C^{\text{Ask}} + e^{-rT} X - P^{\text{Bid}} + EEP + \sum_{j=1}^J e^{-rt_j} D_j$$

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 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 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.

Figure 14. Average daily frequency of apparent arbitrage opportunities during the trading day



Notes: We examine two types of apparent arbitrages. The first is when a synthetic share of stock could be sold for more than it would cost to buy an actual share. That is,

$$\text{Synthetic Stock}^{\text{Bid}} = C^{\text{Bid}} + e^{-rT} X - p^{\text{Ask}} + EEP + \sum_{j=1}^J e^{-rt} D_j > S^{\text{Ask}}$$

The second type of apparent arbitrage opportunity occurs when a synthetic share of stock could be purchased for a lower price than would be received if an actual share of stock was sold at the bid price. Or,

$$\text{Synthetic Stock}^{\text{Ask}} = C^{\text{Ask}} + e^{-rT} X - p^{\text{Bid}} + EEP + \sum_{j=1}^J e^{-rt} D_j < S^{\text{Bid}}$$

For each minute of every day during the sample period, we calculate synthetic bid and ask prices for each pair of put and call options with the same strike price and expiration date using all expiration dates. We then count the number of each type of apparent arbitrage opportunity for each option pair each day. We plot the average percentage of minutes each day that banned and control stocks have share prices and option prices that create apparent arbitrage opportunities of at least \$0.05 (two figures on the left) and at least \$0.10 (two figures on the right).