Put-Call Parity Violations and Return Predictability: Evidence from the 2008 Short Sale Ban*

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Abstract

Using the put-call parity no-arbitrage relation we empirically investigate the link between stock and options markets for the period around the 2008 short sale ban in the US. We document a significant increase in the magnitude of put-call parity violations in the direction of short sale constraints during the ban period relative to both the pre- and post-ban periods. More importantly, we find that the magnitude of put-call parity violations is a significant predictor of stock returns during the short selling ban period, while synthetic stock returns do not respond to this documented mispricing. A portfolio formed on the trading signal that the put-call parity violation is in the top 10% quantile underperforms the financial sector index by an average of 3.5% on a daily basis during the ban period. These results suggest a stock overvaluation during the short sale ban period and a delayed feedback from the options to the stock markets. We also show that the short sale ban period is characterized by a rapidly increasing stock implied volatility and higher options market bid-ask spreads, which are accompanied by higher trading volume and open interest. The ratio of put to call open interest increases during the ban period and peaks in the post-ban period, consistent with an increase in the demand for puts relative to calls. Our findings indicate that the implementation of the short sale ban is associated with a decoupling of the stock and options markets, resulting in market inefficiencies.

Keywords: Short selling ban; put-call parity; return predictability; limits to arbitrage; market efficiency.

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The recent financial crisis brought about severe government interventions in financial markets, one of the most notable being the 2008 short sale ban in the United States. The ban period was initiated with a permanent naked short selling ban on all stocks effective on September 18, 2008 followed by a covered short sale ban on a large number of financial stocks effective on September 19. The covered short selling ban was lifted on October 8, 2008. The naked short selling ban remained in effect beyond the October 8 date. To put the severity and rarity of this event in perspective it suffices to note that the previous short selling ban in the US took place back in September of 1931 (see Jones (2008)).

Short selling restrictions have been studied widely in the literature at both the theoretical and empirical level. In this paper we exploit this rare natural experiment setup to investigate the effect of the short selling ban on the US option and stock markets. More specifically, we examine deviations from the put-call parity no-arbitrage relation around the short sale ban and evaluate the ability of put-call parity violations to predict future stock returns. We shed new light to the previous literature that reports mixed findings on these issues, in addition to providing valuable new evidence on the implications of this drastic policy act on financial markets.

Our sample covers the period August 1st, 2008 to November 28th, 2008. It spans 84 trading days and includes a pre- and post-ban period. Our final sample includes 211 firms on the short sale ban list with traded options and 77,925 option pairs. An analysis of the characteristics of the options market during our sample period indicates some interesting findings. First, we document a higher average daily volume for both puts and calls during the ban period with a spike in volume on the first day of the short sale ban period. Second, the options open interest also exhibits a significant spike on September 19th, while the average put-call open interest ratio increases to 4.46 during the ban period relative to a value of 2.34 in the pre-ban period for medium term at-the-money options. The put-call open interest ratio peaks in the post-ban period at 7.07. This increase is consistent with a rise in the demand for puts relative to calls. Average daily open interest is at its highest for both calls and puts during the ban period and is dramatically reduced in the post-ban period. The option price bid-ask spreads increased substantially during the ban period for both puts and calls and despite a decline in the post-ban period, they still remained above

their pre-ban period level. Finally, the short sale ban period is characterized by a rapidly increasing stock implied volatility, which remains at high levels in the post-ban period as the uncertainty surrounding the financial crisis continued.

The empirical estimation of the put-call parity relation reveals some interesting facts pointing in the direction of a decoupling of the stock and options markets associated with the short sale ban. First, for the whole sample period the actual stock price is on average higher than the synthetic stock price (positive violation) consistent with previous evidence in the literature. Second, the mean violation of put-call parity is significantly higher during the ban period relative to both the pre- and post-ban periods. However, in the post-ban period it remains significantly higher relative to the pre-ban period, perhaps due to the continuing naked short selling ban. Finally, during the ban period we observe both a significant increase in the average magnitude of the violation and an increase in its variability.

We further investigate this apparent decoupling of the stock and options markets by examining the ability of put-call parity violations to predict actual and synthetic stock returns. While we document strong evidence of actual stock return predictability, we fail to document any evidence of synthetic stock return predictability. We first compute daily average excess returns conditional on the violation of the put-call parity relation.[1] We form our portfolios conditional on the end-of-day violation and estimate returns using the next day open and close stock prices. We find that portfolios formed conditional on positive violations exhibit negative average daily excess returns for the whole sample period, but are only statistically significant in the period covering the short sale ban. Furthermore, changing the portfolio formation criteria from all positive violations to violations in the top 10% quantile reduces the mean daily excess return from -1.2% to -3.5% during the short sale ban period. Conditioning on negative violations of the put-call parity we document significant positive daily excess returns only in the pre-ban period in the magnitude of 0.68% and 0.8%, for all negative violations and violations in the bottom 10% quantile respectively. Overall, our results indicate a strong stock overvaluation and a delayed feedback from the options to the stock markets.

The remainder of the paper is organized as follows. Section 1 offers a brief literature

[1] Returns are estimated in excess of the financial sector returns.

review and highlights our contribution. Section 2 discusses the put-call parity no arbitrage relation and the details of the 2008 short sale ban. Section 3 describes our sample formation process and provides an analysis of various option market characteristics during our sample period. Section 4 empirically estimates the put-call parity relation and conducts an analysis of the time series and distribution properties of its violations. Section 5 evaluates the ability of put-call parity violations to forecast stock returns. Finally, section 6 offers some concluding remarks.

1 Literature Review

Short selling restrictions have been argued to have significant effects on financial markets. Theoretical models such as Miller (1977) and Harrison and Kreps (1978) argue that limits on short selling exclude pessimistic investors from the markets resulting in the overpricing of stocks. On the other hand, Diamond and Verrechia (1987) develop a rational expectations model and show that short sale restrictions do not on average lead to overpricing. However, their model also shows that short selling restrictions slow down the price discovery process by making it difficult for informed investors with negative information to participate in the markets. Extending this view Abreu and Brunnermeier (2002, 2003) and Scheinkman and Xiong (2003) directly link short sale constraints to bubbles and excessive volatility.

Consistent with this, other papers provide empirical evidence that short sale restrictions have a significant impact on subsequent stock returns. For example Jones and Lamont (2002) using data from the 1920's and 1930's show that expensive to short stocks exhibit high valuations and low subsequent returns, while Ofek and Richardson (2003) show that short sale constraints in the form of option lock-ups exhibit a persistent negative impact on future returns. Furthermore, Asquith and Meulbroek (1995), Aitken et al. (1998) and Danielsen and Sorescu (2001), Asquith, Phatak and Ritter (2005), Diether, Malloy, and Scherbina (2002), and Boehmer, Jones and Zhang (2008) document that short sale constraints are associated with negative future returns. Bris, Goetzmann, and Zhu (2007) using international data on short sale restrictions find that prices incorporate information faster when short sales are allowed and practised. Saffi and Sigurdsson (2010) and Boehmer

and Wu (2008) also provide evidence linking short selling to enhanced informational efficiency of market prices, while Bris (2008) links short selling restrictions to a decline in market efficiency.

Further empirical work has investigated the effects of short selling constraints in options markets through violations of put-call parity. Lamont and Thaler (2003) document that a small number of equity carve-outs in US technology stocks appear to violate the law of one price. Using option prices they find evidence that shorting costs were extremely high, eliminating exploitable arbitrage opportunities and conclude that "these stocks were unambiguously overpriced, and it is difficult to explain why in equilibrium anyone would own these shares". They attribute this persistent mispricing to the sluggish functioning of the shorting market. Ofek, Richardson and Whitelaw (2004) investigate the put-call parity no-arbitrage relation in the presence of short sale restrictions. They find that violations of put-call parity are asymmetric in the direction of short sale constraints and that their magnitudes are strongly related to the costs and difficulty of short selling. Furthermore, they document that these violations are significant predictors of future returns for individual securities. The aforementioned papers argue that their evidence is consistent with a behavioral finance theory of over-optimistic stock investors and market segmentation. Evans et al. (2009) also document that shorting costs move options out of parity and that the disparity grows as the rebate rate falls. However, they show that market-makers enjoy and share important advantages from getting short exposure in hard to borrow stocks through naked short selling and through their option to fail to deliver. As a result the growth in disparity is curtailed when rebate rates fall below zero, consistent with option market-makers choosing failure to deliver over negative rates and sharing some of the benefits.

Battalio and Schultz (2006) have questioned the evidence of put-call parity violations in Ofek et al. (2004) showing that the violations mostly disappear once you use intraday options data rather than closing quotes. However, as Cohrane (2005) points out, Battalio and Schultz (2006) do not address the finding of negative expected returns in Ofek et al. (2004). In a more recent paper Cremers and Weinbaum (2010) also document that deviations from put-call parity contain information on future prices of underlying stocks. One important difference from the findings in Ofek et al. (2004) is that they document

return predictability for both directions of put-call parity violations, which can not be explained by short sale constraints. That is, they document both a positive abnormal performance in stocks with relatively expensive calls and negative abnormal performance in stocks with relatively expensive puts. Using rebate rates they document that their findings are not driven by stocks that are hard to borrow. Furthermore, they show that the degree of predictability is decreasing over their sample period of January 1996-December 2005, indicating that the level of mispricing is gradually reduced over time. They attribute their findings to the trading activity of informed investors in the options markets rather than the stock market, along the lines of the equilibrium model of Easley, O'Hara, and Srinivas (1998). In this paper we exploit the 2008 short sale ban in the US, as it provides a unique opportunity to re-evaluate the aforementioned contradicting findings within a period marked by unexpected and strict regulation change. This natural experiment also provides a valuable alternative to the reliance on the rebate rate to proxy for short sale constraints, an almost inescapable practise in previous literature.

Our paper differs significantly from other concurrent papers that examine the effects of the 2008 short sale ban on the stock market. Boehmer, Jones and Zang (2009) find large stock price increases upon the announcement of the ban followed by a decrease during the ban period. However, it is difficult to assign these price reactions to the ban because of confounding bank bailout announcements. In fact, they document no positive price effects in a smaller number of stocks that were added to the ban list at a later date. Harris, Namvar and Phillips (2009) using a factor analytic model that extracts common valuation information from the prices of stocks that were not in the ban list, find that banned stocks earned positive abnormal returns during the ban period, which persisted after the ban was lifted. Beber and Pagano (2010) recognizing the difficulty of identifying the stock price effects of the short selling ban in the US due to confounding events highlight the importance of international evidence. They examine short sale bans imposed and lifted in different countries in the financial crisis period of 2007-2009. They find that bans were detrimental to liquidity especially for stocks with no listed options and slowed down price discovery. They also document that the bans failed to support stock prices, with the US being a possible exception. Our US based analysis circumvents the confounding events surrounding the

short sale ban because it is based on the violation of an arbitrage relation that links the stock and option markets, namely the put-call parity. The examination of the relative pricing of financial instruments constitutes a unique feature that differentiates our analysis from other studies that concentrate purely on the US stock market, as it neutralizes the pricing effects of news events that impact both the stocks and their corresponding options. Thus our analysis allows for more conclusive empirical evidence on the effects of the short selling ban on both the stock and option markets in the US.

Our analysis and findings also complement and significantly extend the findings of other concurrent papers that either directly or indirectly examine the effects of the short selling ban on the options markets. Kolasinski et al. (2010) argue that the information content of short sales increased during the ban especially for stocks with listed options. They document significantly stronger relationship between publicly unobserved lagged short sale volume and returns during the ban and even stronger for stocks with listed options. They argue that this finding is consistent with informed traders migrating to the options markets. This is consistent with findings in Harris et al. (2009) who find that prices of stocks with options were less affected by the ban relative to other stocks. Battalio and Schultz (2010) using intraday options data investigate the impact of the short sale ban on the options market. They conclude that investors did not migrate to the options market to avoid the short sale ban. They document a significant widening of bid-ask spreads for options on banned stocks and lower synthetic stock prices relative to actual prices. Battalio and Schultz (2010) offer two plausible alternatives to explain the put-call parity violations. First, that the stock prices are too high. Second market-makers set high ask prices for puts and low bid prices for calls to make-up for their difficulty in hedging their client's long put or short call positions. They conclude that the second explanation is more likely. Our finding that only violations of the put-call parity in the direction of the short sale ban provide a strong predictability of stock returns constitutes direct evidence consistent with the first explanation. Stocks became overpriced as the stock and option markets decoupled during the short sale ban period. Furthermore, our finding of no predictability of synthetic stock returns is not consistent with an undervaluation of the synthetic stock price as an explanation of the documented put-call parity violation. Our results could be explained

by informed trader migration to the options markets or by informed traders trading first in the options markets to begin with as in Cremers and Weinbaum (2010) with the short sale ban delaying the feedback from the options to the stock markets.

2 Put-call parity and the 2008 short sale ban

It is well known that under the no-arbitrage condition, European options on dividend paying stocks must satisfy the put-call parity, i.e.,

$$C_t^E(K,\tau) - P_t^E(K,\tau) = S_t e^{-\delta\tau} - Ke^{-r\tau}, \tag{1}$$

where S_t is the current stock price, δ is the dividend yield, r is the risk-free interest rate, and $C_t^E(K,\tau)$ and $P_t^E(K,\tau)$ are the call and put prices at time t, respectively, on European options with strike price K and time-to-maturity τ. For American options, equation (1) can be written as:

$$C_t^A(K,\tau) - \pi_t^C(K,\tau) - P_t^A(K,\tau) + \pi_t^P(K,\tau) = S_t e^{-\delta\tau} - Ke^{-r\tau}, \tag{2}$$

where $C_t^A(K,\tau)$ and $P_t^A(K,\tau)$ are the call and put prices at time t, respectively, on American options with strike price K and time-to-maturity τ, while $\pi_t^C(K,\tau)$ and $\pi_t^P(K,\tau)$ are the early exercise premia on the American call and put options, respectively.

If equation (2) is violated at least two conditions must be met. First, although it is no longer strictly an arbitrage relation as the values of the early exercise premia are incorporated directly, there must be some limits to arbitrage that prevent the convergence of the two sides of the equality. The most commonly cited limit is short sales restrictions (see Ofek et al. (2004)). Without short sales, if the present value of the stock price at expiration, $S_t e^{-\delta\tau}$, exceeds the present value implied by the options and bonds markets, then there does not exist a mechanism that will automatically lead to convergence of the two values. In this case, relation (2) can only be restored if investors that physically possess stocks are willing to sell them. Second, there must be a reason why these assets have diverging prices in the first place, thus violating the law of one price. The most popular

explanation for that phenomenon lies in the roots of behavioral finance (see Lamont and Thaler (2003)). Of course, these price differences can only persist in the presence of limited arbitrage, which can be due to short sales restrictions.

On Wednesday, September 17, 2008 the SEC imposed a permanent ban on naked shorting in all US stocks, effective at 12.01 am ET on Thursday, September 18 (*Exchange Act release No. 58572*). On September 18, after the US market closed for the day, the SEC announced the temporary ban on all short sales in 797 financial stocks, and it was effective immediately (*release No. 58592*). The initial order covered 10 business days, terminating at 11.59 pm ET on October 2, 2008, unless further extended by the Commission. Options market-makers were exempt from the shorting ban with the following caveat, introduced on September 21 (*release No. 58611*): "...we are limiting the exception so that if a customer or counterparty position in a derivative security based on a Covered Security is established after 12:01 am E.D.T. on September 22, 2008, a market-maker may not effect a short sale...if the market-maker knows the customer's or counterparty's transaction will result in the customer or counterparty establishing or increasing an economic net short position (i.e., through actual positions, derivatives, or otherwise) in the issued share capital of a firm covered by this Order." The purpose of this statement was to prevent the use of options to take bearish positions in the stock, though one may doubt its effectiveness (see Boehmer, Jones and Zhang (2009)). Furthermore, the SEC on September 21, delegated to each national securities exchange the authority to identify additional listed companies that qualify for inclusion in the list of companies covered by the revised prohibition. The following days a number of additions to the list of banned stocks were announced. On October 3, after an extension given to the shorting ban the previous day, the SEC announced that the ban would expire at 11.59 pm ET on Wednesday, October 8, 2008. However, the naked short selling ban remained in effect even after the 8th of October.

On September 19 the US Treasury announced a temporary guarantee program for money market funds, the Fed announced a program to lend against high-quality asset-backed commercial papers and most importantly the Treasury secretary Henry Paulson announced the creation of what came to be known as the Troubled Asset Relief Program (TARP). Financial firm equity holders were expected to respond positively to the announcement of this

program.

3 Data and Descriptive Statistics

The sample period extends from August 1 through November 28, 2008, spanning 84 trading days. We use data from two sources. The first data set comes from OptionMetrics, providing end-of-day bid and ask quotes, open interest and volume on every call and put option on individual stocks traded on US exchanges. The second dataset comes from DataStream and includes the dividend yield, reported on a daily basis, as well as the open and close prices of the stocks. The risk-free interest rates, whose maturities match the expiration dates of the options, are calculated using linear interpolation from the term structure of the LIBOR rates.

There were 976 stocks on the SEC and exchange ban lists, as of the end of the shorting ban period on Wednesday, October 8, 2008.[2] Using the list of traded stock options at the CBOE on September 24, 2009, we found that 293 stocks in the initial ban list had a traded option contract on this date. To be included in the final sample, options must have at least one recorded price each day of our period and DataStream must provide dividend yield data for this period. American Depository Receipts and closed-end funds are also excluded from the final sample. These three filters have excluded 53, 8 and 21 firms from the final sample, respectively, leaving us with 211 firms. 154 of them were added on the shorting ban list on Friday, September 19, 2008, while 25 and 12 firms were added on the list on September 22, and September 23, respectively. The remaining 20 firms were added on the list in the period of September 24 to October 7.

We constructed our final sample of option prices after applying the following filters:

1. On each date, we eliminate options that have zero open interest. We use open interest as a proxy for liquidity in options market.

2. We eliminate options that violate the boundary conditions.

3. We eliminate options with maturities of less than 30 days or greater than 365 days.

[2] See http://www.nyse.com/about/listed/1222078675703.html. There were also 10 firms that opted to be removed from the list before the official end of the ban period. These firms are not included in our sample.

4. We eliminate options that are either deep in- or deep out-of-the money (i.e. $|\ln(S_t/K)| > 0.3$).

5. On each date, we eliminate call or put options that do not have a corresponding put or call option with the same maturity and strike price.

We restrict our sample to homogenous sets of option pairs in terms of moneyness and maturity. Therefore, we sort option pairs into three moneyness groups as follows: At-the-money (ATM), $-0.1 < \ln(S_t/K) < 0.1$, In-the-money (ITM), $0.1 < \ln(S_t/K) < 0.3$ and Out-of-the money (OTM), $-0.3 < \ln(S_t/K) < -0.1$. We also sort them into three maturity groups as follows: Short maturity, 30-90 days, Medium maturity, 91-182 days and Long maturity, 183-365 days. On any given date and for any given stock there may be multiple pairs that satisfy the moneyness and expiration criteria. If this is the case, we select the option pair that is closest to the middle of the range. Thus, there is a single option pair per moneyness per expiration each day for every stock in the final sample. As the stock options traded by the CBOE are American we need to estimate the early exercise premium. To this end, we use the method of Ho et al. (1994) to estimate this premium for each option (call or put) on each date.

Table 1, describes our final sample of option pairs that will be used in the remainder of this study. The sample includes a total of 77,925 option pairs across the period, with approximately 185 firms per date and 2 option pairs per firm. The median number of observations per firm is 81, which is very close to the total sample period of 84 days. The median and mean moneyness of the option pairs are -0.0038 and -0.0031, respectively, while the median and mean maturity are 122 and 124 days, respectively. The table also presents the summary statistics for the three maturity and the three moneyness groups that the sample is broken into. These summary statistics indicate that for the period examined the medium-term ATM options have the highest trading activity, while the long-term ITM options have the lowest.

Table 2, presents the options descriptive statistics for the data that are included in the sample. These include daily volume, open interest, Black-Scholes implied volatility, bid-ask spread as a percentage of the midpoint of the corresponding option quotes, and the

early exercise premium estimated using the Ho et al. (1994) approach. The table reports summary statistics for the full sample (see Panel A) and for the medium maturity ATM option pairs, which are the most liquid contracts (see Panel B), for the periods before, during and after the short sale ban. We also present these descriptive statistics for the subsets of firms added on the ban list on Friday September 19 (154 firms), on Monday 22 (25 firms) and on Thursday 23 of September (12 firms). As mentioned above a small fraction of firms included in the sample were added the following days.

The results of Table 2 indicate that overall the daily volume is larger during the ban period compared to the pre- and post-ban period. This holds for both calls and puts. However, this large average value is due to a considerable increase in daily volume on September 19, and in some cases on September 18. This holds even for firms added to the ban list in subsequent days. It is also confirmed by the graphs in Figure 1, which present the average, across firms, daily volume and open interest for the medium-term ATM calls and puts. These graphs correspond to the values of Table 2, Panel B. As shown by Buraschi and Jiltsov (2006) option trading volume is an excellent proxy for dispersion of beliefs, better than the trading volume of the underlying asset. Thus, the aforementioned results indicate that the ban on shorting activity announced and implemented on September 18 and 19 and probably the uncertainty surrounding the TARP and other government programs to assist the financial sector exacerbated the dispersion of beliefs among investors.

Open interest was also severely affected from the shorting ban announced on September 18 and 19. The open interest of both calls and puts increases around these days. The numbers of Table 2, Panel A for the full sample of option pairs, indicate that in most cases the average open interest is similar, if not larger, in the pre-ban relative to the ban period. This is mainly due to the observations of September 18 (which belongs to the pre-ban period) and that of September 19 (which also belongs to the pre-ban period for the firms added on the list at a later day). For the more liquid medium term ATM options both the put and call open interest typically peaks during the ban period. This is also seen in Figure 1. Another interesting observation from the results of Table 2 is that the put open interest exceeds that of the calls. For the medium term ATM options, the average put-call open interest ratio increases from 2.34 in the pre- ban period to 4.46 during the ban.

If we assume that the put-call open interest ratio is driven by customer demand rather than supply when there are limits to arbitrage (see Han (2008)) then investors demand more put options relative to calls. During the ban period, where there are indisputable limits to arbitrage, the put-call ratio becomes even larger strongly indicating a demand pressure for puts either for protection or for constructing a synthetic short position in the stock. However, it appears that the SEC imposed limits to the market maker short selling exemption during the ban period may have partially curtailed the demand for put relative to call options as the put-call open interest ratio exhibits a further significant jump to 7.07 after the ban is lifted.

The argument of demand driven prices can also be supported by the Black-Scholes implied volatility descriptive statistics (see Table 2 and Figure 2). The put implied volatility is larger compared to the implied volatility of the corresponding call option with the same strike price and maturity. Again, this implied volatility spread increases during the short sales ban period, consistent with the findings of Bollen and Whaley (2004) that related the daily change in implied volatility of a given option to its net buying pressure. Note here that the increase of the implied volatility spread implies a larger violation of the put-call parity relation during the ban period, which we will exploit in the remainder of the paper.

The results of Table 2 also indicate that, in general, the average bid-ask spread as a percentage of the midpoint of the corresponding option quotes is larger in magnitude during the shorting ban period relative to the pre-ban period. In the post-ban period the bid-ask spreads are reduced, but still remain higher than the pre-ban period. For the calls the average bid-ask spread in the pre-ban period is 6.7%, increases to 10.37% during the ban period and is reduced to 8.46% in the post-ban period. The corresponding numbers for the puts are lower at 5.88%, 8.83%, and 7%, respectively, but follow the same trend. The above findings are also seen in Figure 2, which presents the daily average, across firms, bid-ask spread and implied volatility for the medium-term ATM calls and puts. Finally, the descriptive statistics of the early exercise premium (EEP) measured as a percentage of the midpoint of the bid and ask quotes indicate a low value, typically lower than 1%.

4 Put-call parity relation: An empirical examination

In this section we perform an empirical analysis of equation (2) in order to examine whether hindering arbitrage via the short selling ban has affected the direction and magnitude of the put-call parity violation. We expect the short sale ban to exacerbate the magnitude and perhaps the occurrence of put-call parity violations in the direction of the short sale ban. That is, we expect the actual stock prices to be more expensive than their corresponding synthetic share prices because short selling, the mechanism that could restore parity in this case, is not available.[3]

Table 3 presents distribution statistics of the put-call parity violation as well as the percentage of violation in each direction for the full sample (see Panel A) and for the medium maturity ATM option pairs, which are the most liquid contracts (see Panel B). All statistics are given for the period before, during, and after the short sale ban. As previously, we also look at the subset of firms that were added to the ban list on Monday 22nd and on Tuesday 23rd of September, 2008. Following Ofek et al. (2004) this table reports the ratio

$$R = \ln(S_t e^{-\delta\tau}/S_t^*)$$

where

$$S_t^* = C_t^A(K,\tau) - \pi_t^C(K,\tau) - P_t^A(K,\tau) + \pi_t^P(K,\tau) + Ke^{-r\tau}$$

is the synthetic stock price implied by the options market. Panel C of Table 3 reports the test statistics and the corresponding p-values for testing the mean and the median equality of the variable R observed before the shorting ban period (denoted as D_b), during the shorting ban period (denoted as D_d) and after the ban period (denoted as D_a). These tests are based on the full sample of medium-term ATM options.

There are several interesting observations from the results reported in Table 3. First, in the sample period examined, R is on average positive across firms. This is in accordance with the findings of previous studies (see Ofek et al. (2004) and Cremers and Weinbaum

[3] Duffie et. al. (2002) argue that stock prices might differ from "fundamental value" because stock prices should include the benefits arising from the ability to lend the stock to short sellers. During the short sale ban period such benefits are not expected to be significant.

(2010)). Second, the violation is larger in the shorting ban period than before. This holds for all the subsets of firms reported in the table. This is also confirmed by the test statistics and the corresponding p-values reported in Panel C. The null hypotheses that the mean and median R are equal before and during the shorting ban period as well as before and after the ban period are rejected at the 1% significance level. However, while we can reject the null hypothesis that the mean R is equal during and after the short sale ban period we can not reject the corresponding hypothesis for the median R. During the one and a half month period after October 8 the put-call parity violation was not restored to its pre-ban period level. Note however, that in the post-ban period the options volume and open interest are at their lowest levels (see Table 2 and Figure 2). A third observation that can be made from the results of Table 3 is that during the shorting ban period R takes more extreme positive and negative values compared to the values reported before and after the ban period. This is confirmed by the 5th and 95th percentiles and the graphs of Figure 3. These graphs present the empirical distribution of the put-call parity violation measure (R) before, during and after the shorting ban period for the full sample of option pairs.[4] The shorting ban did not only affect the magnitude of the put-call parity violation, but it is also associated with an increase in its variability. This is also apparent in the percentage of positive and negative violations reported in the last two columns of Table 3. During the short sale ban period the average percentage of negative violations is larger compared with those before and after the ban period.

To closer examine the relation between the time dimension and magnitude of the put-call parity violation and verify that the values of Table 3 are not driven by outliers, Table 4 and Figure 4 present the average daily value of R across firms as well as the daily percentage of positive violations. The numbers in Table 4 and the graphs of Figure 4 correspond to the medium-term ATM option pairs.

On September 18, when the permanent ban of naked shorting was implemented, we observe an increase in the put-call parity violation and in the percentage of positive violations

[4] This distribution is estimated using a Gaussian kernel and bandwidth:

$$h = \frac{1.8\sigma}{\sqrt[5]{n}}$$

where σ is the standard deviation of R and n is the number of observations.

(90% compared to 49% the previous day). This sharp increase is evident in all subsets of firms examined. The next day, when all shorting activity on financial stocks was banned (with the exception of options market-makers) we observe a further increase in both the magnitude of R and in the percentage of positive violations. For the firms included in the initial ban list the violation was substantially larger in magnitude and frequency (on average equal to 0.047 with an astonishing 98% of the firms having a positive R). For all the firms included in our sample, the percentage of positive violations exceeded the 90% mark on this day. Thus, even firms that were added on the ban list in the following days experienced an increase in put-call parity violation on September 19. A possible explanation for this could be the permanent ban on naked shorting in all US stocks already initiated the day before, or perhaps a difficulty in shorting even these stocks after the announcement of the ban affecting a large number of financial stocks. On Monday, September 22, the put-call parity violation measure showed a decrease, which again was larger for the firms added on the ban list on September 19. This decrease might be attributed to the clarification by the SEC that market-makers were exempt from the short sale ban, albeit with some limits, which took place the day before.

On Monday, September 29, the violation evidence appears to be reversed. This is the only day on which we observe a negative average violation of put-call parity with the percentage of positive violations across firms dropping to 38%, the lowest during the short sale ban period. This holds for all subsets of firms examined. These numbers seem to contradict the relation between positive violations of the put-call parity and the short sale ban that we observe on all other days. Interestingly, on this day we also observe an increase in both the options open interest and bid-ask spreads as seen in Figures 1 and 2. An unexpected event that took place on September 29 might help explain this reversal in put-call parity violations. The much anticipated $700 billion bailout plan was abruptly rejected by Congress with House leaders trading partisan words.[5] The stock markets reacted violently sending the Dow Jones industrial average down 778 points, a nearly 7% drop.

[5] See article by Chris Isidore titled "Bailout plan rejected-supporters scramble", http//money.cnn.com/2008/09/29/news/economy/bailout/index.htm

During the period between October 3 and October 8, when the SEC had already announced that the short selling ban would be lifted on Thursday, October 9, we observe a decrease in the put-call parity violation and in the percentage of positive violations across firms. A possible explanation for this behavior is that S_t^* converged towards S_t as the markets anticipated the resumption of short selling. Thus, on October 9, i.e., the first day after the expiration of the shorting ban period, we observe a mean value of R that is close to the values in the pre-ban period. However, after that date and for the remaining of the period examined, the put-call parity violation experienced larger magnitudes and variability compared to the pre-ban period, as already seen from the results of Table 3 and the empirical distribution of put-call parity violations in Figure 3. This could be attributed to the naked short selling ban, which remained in effect.

5 Predictability of stock returns

In this section we examine the ability of the documented violations in put-call parity to forecast future stock returns. If the options and stock markets are segmented in terms of investor classes into informed and uninformed or into rational and over-optimistic, we would expect the short sale ban to slow down the price discovery process in the stock market by delaying the feedback from the options market to the stock market. A direct implication of this explanation is that the violations of put-call parity could predict future stock returns during the ban period. On the other hand, if the short sale ban resulted in deterioration of the options market quality beyond that of the stock market quality, as perhaps measured by an increase in bid-ask spreads, we would not expect to document any feedback from the options market to the stock market.

One way to assess predictability is to examine the excess portfolio return over the sample period, conditional on available information such as the current put-call parity violation. As in Ofek et al. (2004) we measure the excess return on each stock by subtracting out the financial sector industry return. We perform our analysis using the medium-term at-the-money option pairs. To avoid spurious predictability we form portfolios based on the end-of-day put-call parity violation, but we estimate returns based on the open and close

prices of the following day (see Cremers and Weinbaum (2010)). We form six different portfolios that satisfy one of six alternative criteria: (1) stocks with positive put-call parity violation, (2) stocks with put-call parity violation larger than the median violation of that day, (3) stocks with put-call parity violation larger than the 90% quantile of violations, (4) stocks with negative violation, (5) stocks with put-call parity violation smaller than the median violation, and (6) stocks with put-call parity violation smaller than the 10% quantile of violations. Each portfolio has equal weights on all stocks satisfying the relevant criteria and is rebalanced on a daily basis.[6] This exercise is performed on the 154 firms added on the ban list on September 19.

Table 5 reports the statistical properties of both the raw and and excess returns of these six portfolios. The average raw returns are negative in the ban and post-ban periods, but they are consistently significantly diferent from zero only in the ban period. While the raw returns are reported to provide a more complete picture of our analysis, we concentrate our discussion on the excess returns. In general, the mean excess return is positive during the pre-ban period and negative during the ban and the post-ban periods for all portfolios examined. Also, for the whole sample period, portfolios with positive put-call parity violation (i.e., portfolios (1)-(3)) have negative mean excess returns, while portfolios with negative violation (i.e., portfolios (4)-(6)) typically exhibit positive returns. For the pre-ban period, only the mean excess return conditional on strictly negative violation (portfolios (4) and (6)) is positive and significantly different from zero at the 5% level.[7] During the ban period, only the mean excess portfolio return conditional on positive put-call parity violation (portfolios (1)-(3)) is negative and significantly different from zero. These returns are more negative the greater the put-call parity violation. Indeed, changing the portfolio selection criteria from $R > 0$ to $R > Q_{90}$ significantly decreases the daily mean excess return from -0.012 to -0.035. For the post-ban period, the results of the table indicate no apparent predictability of stock returns. Figure 5 graphs the daily cumulative excess returns on portfolios (1) and (4) over the sample period. Inspection of Figure 5 leads to several

[6] We perform the same tests using a 2-day rebalancing of the portflios and the qualitative results do not change.

[7] The median put-call parity violation is, in general, positive therefore the portfolio constructed based on $R < Q_{50}$ contains stocks with positive violations.

interesting observations. First, portfolio (4) outperforms portfolio (1) across the sample period. Second, the returns of the two portfolios are closely related in the pre- and the post-ban period. The correlation coefficient is 97% and 90%, respectively. However, during the ban period the returns of the two portfolios follow different patterns (the correlation coefficient is −38%). Portfolio (1) experiences poor returns, consistent with the results of Table 5, compared to the performance of portfolio (4). It is therefore evident from figure 5 that our mean based results in Table 5 are not driven by a few extreme observations.

The results in Table 5 and in Figure 5 show that a positive put-call parity violation predicts a negative stock return the following day. The natural conclusion is that the bias in the pricing of the actual stock relative to the synthetic is driven by an overvaluation in the actual stock price, which adjusts downwards the following day. Battalio and Schultz (2001) provide an alternative explanation for the positive put-call parity violation. They argue that because it was difficult for market makers to hedge customers' long positions in puts and short positions in calls they increased ask prices for puts and lowered bid prices for calls. This explanation implies that the bias in the relative prices of stocks and options, documented by the positive put-call parity violations, is driven by the options markets. That is the mispricing is in the form of an undervalued synthetic stock price. This is directly contradicted by our evidence in Table 5 and Figure 5 that imply a stock overvaluation and a next day correction. As a robustness test of this result we test whether the synthetic stock prices respond to the put-call parity violation. More explicitly, we test whether a positive put-call parity violation predicts a positive synthetic share price return the following day. Table 6 reports the corresponding synthetic share raw and excess returns of six portfolios formed with the same selection criteria as the six portfolios in Table 5. The results reveal no evidence that put-call parity violations predict the next day synthetic share ruturns, reinforcing our conclusion that actual shares are overpriced.[8]

We proceed to perform a further robustness test on the aforementioned predictability

[8] We perform the same tests using a 2-day rebalancing of the portflios and the qualitative results do not change.

results, by estimating the following panel data model:

$$r = c + a_1 \cdot R + a_2 \cdot (\mathbf{1}_{R>0} \cdot R) + a_3 \cdot (\mathbf{1}_{\{R \in D_d, R<0\}} \cdot R) + a_4 \cdot (\mathbf{1}_{\{R \in D_d, R>0\}} \cdot R) + \epsilon, \quad (3)$$

where the dependent variable is the daily stock excess return r and the independent variables are the put-call parity violation measure R calculated on the previous day and three dummy variables accounting for positive violations, negative violations during the ban period and positive violations during the ban period. We use three different methods to estimate the model. First, we apply generalized least squares with a groupwise correction for heteroskedasticity and an AR(1) correction for autocorrelation. The second method uses a one-way fixed firm effects estimation with robust standard errors, while the third applies a one-way fixed firm effects estimation with bootstraped standard errors. Table 6 reports the results. Panel A reports the estimated coefficients and the p-values of the t-statistics in parentheses. Panel B presents the test statistics and the corresponding p-values of three combined restriction tests of the model parameters. These test statistics have an asymptotic $\chi^2(1)$ distribution under the null hypotheses. Independent of the estimation method used, the estimates of the panel regression model confirm that positive put-call parity violations during the ban period strongly predict significant next-day negative stock returns. The coefficient estimate of a_4 is negative and highly significant indicating that a positive violation measure R is associated with significantly more negative excess returns during the short sale ban period relative to the other periods in the sample. The combined restriction test statistic, $a_1 + a_2 + a_4 = 0$, is highly significant indicating that the overall coefficient on positive R during the ban period (-0.153 or -0.226 in methods 1 and 2, respectively) is statistically significant. Moreover, the other coefficient estimates and combined restriction tests, in all three estimation methods, indicate no significant predictability of returns by either negative violations or by positive violations outside the short selling ban period.

6 Conclusions

We document a significant increase in the magnitude of put-call parity violations in the direction of short sale constraints during the 2008 short sale ban period relative to both the pre- and post-ban periods. The short sale ban period is characterized by higher option market bid-ask spreads, which are also accompanied by higher trading volume and open interest. The put-call open interest ratio increases during the ban period and peaks in the post-ban period. We also find that the magnitude of put-call parity violations is a significant predictor of stock returns during the short selling ban period.

Our finding of strong return predictability during the short sale ban period provides strong evidence that the stocks in the short sale ban list became overvalued. Furthermore, our finding of no predictability of synthetic stock returns is not consistent with an undervaluation of the synthetic stock price as an explanation of the documented put-call parity violations. The short sale ban helps explain the existence of significant violations in put-call parity. However, the source of this apparent mispricing is not immediately obvious. While our findings are consistent with the behavioral finance explanation given in Ofek et. al. (2004), they might also be explained by the findings in Cremers and Weinbaum (2010) that informed investors trade first in the options market along the lines of sequential trading as proposed in Easley, O'Hara and Srinivas (1998). In the first case, the short sale ban prevents potential irrational (over-optimistic) investor sentiment in the stock market to be arbitraged immediately, while in the second case the short sale ban delays the informational feedback from the options market to the stock market. We might only conjecture which of the two explanations is more prevalent. The behavioral finance explanation appears likely as the violations of put-call parity and the return predictability are one-sided and in the direction of short sale constraints during the ban period. However, the financial crisis and the relatively short period the ban was in effect could be biasing against predictability in the other direction, which is evident, though weaker, in the pre-ban period. Independent of the likely explanation of stock return predictability, one implication is clear: The implementation of the short sale ban of 2008 is associated with a decoupling of the options and stock markets, resulting in market inefficiencies.

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Table 1: Sample description

Variable	Mean	Median	5th pctl	95th pctl
Panel A: Full sample of option pairs ($N = 77,925$)				
Days to expiration	122.3	124	38	225
Moneyness ($\ln(S_t/K)$)	−0.0038	−0.0031	−0.23	0.23
Number of firms per date	184.01	185.5	156	202
Number of obs. per firm	70.2	81	18	84
Number of option expirations per firm	2	2.28	0.22	2.75
Number of strikes per expiration	1.46	1	0	3
Panel B: Summary statistics across maturities				
Panel B1: Short maturity option pairs ($N = 26,720$)				
Moneyness ($\ln(S_t/K)$)	0.00041	−0.00044	−0.22	0.23
Number of firms per date	148.7	156	105	177
Number of obs. per firm	59.2	70	1	83
Number of strikes per date per firm	1.51	1	0	3
Panel B2: Medium maturity option pairs ($N = 34,369$)				
Moneyness ($\ln(S_t/K)$)	−0.0053	−0.0047	−0.23	0.24
Number of firms per date	169.2	167.5	121	198
Number of obs. per firm	67.3	78	12	84
Number of strikes per date per firm	1.93	2	0	3
Panel B3: Long maturity option pairs ($N = 16,836$)				
Moneyness ($\ln(S_t/K)$)	−0.0071	−0.005	−0.24	0.24
Number of firms per date	91.7	82	48	148
Number of obs. per firm	36.4	41	0	62
Number of strikes per date per firm	0.94	0	0	3

(Continued)

Panel C: Summary statistics across moneyness				
Panel C1: ATM option pairs ($N = 30,222$)				
Days to expiration	120.1	123	38	222
Number of firms per date	159.6	157	117	188
Number of obs. per firm	63.5	74	9	84
Number of option expirations per date per firm	1.71	2	0	3
Panel C2: ITM option pairs ($N = 23,163$)				
Days to expiration	123.6	128	39	222
Number of firms per date	135	135.5	90	166
Number of obs. per firm	53.7	60	1	83
Number of option expirations per date per firm	1.31	1	0	3
Panel C3: OTM option pairs ($N = 24,540$)				
Days to expiration	126.5	130	40	222
Number of firms per date	143	148	107	165
Number of obs. per firm	56.9	67	2	84
Number of option expirations per date per firm	1.38	2	0	3

This table reports descriptive statistics for the sample of paired options that remain after applying the various filters reported in the text that match the relevant criteria. The data span 84 days between August 1, 2008 and November 28, 2008. Panel A reports summary statistics for the full sample of options pairs, while Panels B and C report summary statistics across maturity and moneyness categories, respectively.

Table 2: Descriptive statistics

Panel A: Full sample of option pairs

		All firms ($N = 77,925$)		Firms added on 19/09 ($N = 56,769$)		Firms added on 22/09 ($N = 9,138$)		Firms added on 23/09 ($N = 5,041$)	
Variable		Mean	Median	Mean	Median	Mean	Median	Mean	Median
Open interest (call)	pre-ban	2,416.5	301	2,424.6	297	2,879.6	412	2,230.2	252
	ban	2,311.1	230	2,541.6	249	2,074.4	200	1,348.2	144
	post-ban	1,138.3	132	1,211.6	138	983.7	148	1,037.1	83
	total	1,905.5	204	1,958.8	205	2,042.8	236	1,691.7	169
Open interest (put)	pre-ban	2,943.2	299	2,893.9	300	3,230.5	321	4,407.9	365
	ban	2,908.2	340	2,811.2	352.5	3,380.5	477	5,335.1	229
	post-ban	2,266.3	254	2,262.5	245	3,017.6	312	2,377.3	194.5
	total	2,675.1	282	2,633.2	278	3,167.4	332	3,821.9	254
Put/call OI ratio	pre-ban	5.11	1.04	5.34	1.03	3.68	1.01	6.82	1.11
	ban	6.34	1.26	6.19	1.19	6.79	1.52	6.58	1.21
	post-ban	8.72	1.72	7.80	1.62	11.45	2.13	6.95	1.64
	total	6.67	1.31	6.42	1.28	7.09	1.43	6.83	1.30
Daily volume (call)	pre-ban	36.5	0	37.4	0	43.1	0	40.1	0
	ban	47.2	0	55	0	37.1	0	33.1	0
	post-ban	29.5	0	31.3	0	34.6	0	29.9	0
	total	35.1	0	37.2	0	39.1	0	35.6	0
Daily volume (put)	pre-ban	37.8	0	38.5	0	54.2	0	34.4	0
	ban	46.2	0	48.2	0	59.1	0	33.2	0
	post-ban	36.2	0	39.3	0	49.6	0	20	0
	total	38.2	0	40.1	0	49.9	0	29.2	0

(Continued)

		All firms ($N = 77,925$)		Firms added on 19/09 ($N = 56,769$)		Firms added on 22/09 ($N = 9,138$)		Firms added on 23/09 ($N = 5,041$)	
		Mean	Median	Mean	Median	Mean	Median	Mean	Median
Spread % of mid (call)	pre-ban	6.95	5.26	6.78	5.12	6.71	4.76	7.99	6.66
	ban	10.49	9.33	10.47	9.27	10.33	9.25	11.63	10.52
	post-ban	8.81	7.35	8.72	7.31	8.08	6.55	10.49	9.09
	total	8.11	6.57	8.02	6.45	7.71	6.06	9.36	8
Spread % of mid (put)	pre-ban	6.12	4.58	6.05	4.54	5.79	3.84	6.64	5.37
	ban	8.68	7.36	8.76	7.46	8.34	6.84	9.69	8.42
	post-ban	6.88	5.55	6.89	5.6	6.45	4.95	8.06	6.66
	total	6.73	5.26	6.73	5.26	6.37	4.76	7.55	6.25
EEP % of mid (call)	pre-ban	0.51	0.0009	0.36	0.0006	0.76	0.035	2.04	0.049
	ban	0.32	0.0016	0.26	0.001	0.21	0.015	1.27	0.021
	post-ban	0.45	0.036	0.37	0.026	0.42	0.11	1.49	0.16
	total	0.46	0.0078	0.35	0.0053	0.56	0.053	1.74	0.1
EEP % of mid (put)	pre-ban	0.43	0.15	0.44	0.15	0.36	0.11	0.27	0.03
	ban	0.58	0.25	0.6	0.24	0.48	0.24	0.31	0.12
	post-ban	0.28	0.1	0.29	0.11	0.21	0.078	0.26	0.037
	total	0.39	0.13	0.41	0.14	0.32	0.11	0.27	0.04
IV (%) (call)	pre-ban	47.1	42.9	47.6	43	48.1	43.1	51.5	48.6
	ban	63.5	56.3	63.4	56.2	73.3	67	72.1	66.3
	post-ban	75.6	69.4	75.1	68.8	80.3	73.7	84	78.5
	total	60.3	55.2	60.5	55.6	63.7	57.7	65.7	63.6
IV (%) (put)	pre-ban	50.4	45.1	50.8	44.8	50	45.2	53.5	47
	ban	68.3	59.9	68.4	59.6	75.7	71.3	73.9	65.2
	post-ban	79.9	73	79.1	72.1	83.2	77.6	85.2	79.4
	total	64.1	58.7	64.3	59.1	66.1	59.7	67.4	63

(Continued)

Panel B: Medium-term ATM option pairs									
		All firms ($N = 12,607$)		Firms added on 19/09 ($N = 9,217$)		Firms added on 22/09 ($N = 1,436$)		Firms added on 23/09 ($N = 757$)	
Variable		Mean	Median	Mean	Median	Mean	Median	Mean	Median
Open interest (call)	pre-ban	3,149.7	563	3,378.1	527	4,038.1	685	2,770.3	819
	ban	3,781.3	453	3,941.9	604	3,888.3	395	3,472.2	270
	post-ban	577.8	113	626.8	118	437.9	94.5	317.1	94
	total	2,401	271	2,400.7	276	2,977.5	256.5	2,041.7	250
Open interest (put)	pre-ban	4,025.7	505	3,590.7	488	4,780.7	663	8,788.8	615
	ban	5,213.4	787	4,536.4	802	5,481.6	915	18,482.5	596
	post-ban	1,243.8	212	1,237.7	206	1,720.3	328.5	1,323.7	218
	total	3,142.8	383	2,820.3	370	3,761.7	483.5	7,660.1	411
Put/call OI ratio	pre-ban	2.34	0.96	2.31	0.91	2.78	1.02	3.58	0.96
	ban	4.46	1.38	4.43	1.27	3.81	1.51	8.07	1.72
	post-ban	7.07	1.77	6.17	1.66	12.16	2.77	5.89	1.49
	total	4.41	1.26	4.09	1.25	6.37	1.43	5.01	1.11
Daily volume (call)	pre-ban	32.4	0	31.7	0	42.1	0	32.9	0
	ban	56.9	0	68.2	0	29.6	0	21.6	0
	post-ban	11.9	0	11.6	0	21.3	0	9.03	0
	total	28.1	0	29.1	0	32.7	0	23.2	0
Daily volume (put)	pre-ban	29.3	0	27.6	0	59.6	0	34.1	0
	ban	46.2	0	49.6	0	33.1	0	46.9	0
	post-ban	17.6	0	17.9	0	23.5	0	7.91	0
	total	27.6	0	26.8	0	42.5	0	27.1	0
Spread % of mid (call)	pre-ban	6.7	5.26	6.62	5.08	6.44	4.76	7.04	6.49
	ban	10.37	9.09	10.38	8.86	10.69	9.85	10.85	9.54
	post-ban	8.46	7.24	8.45	7.14	7.71	6.66	9.59	7.89
	total	7.86	6.54	7.85	6.45	7.54	6.26	8.45	7.56

(Continued)

		All firms ($N = 12,607$)		Firms added on 19/09 ($N = 9,217$)		Firms added on 22/09 ($N = 1,436$)		Firms added on 23/09 ($N = 757$)	
		Mean	Median	Mean	Median	Mean	Median	Mean	Median
Spread % of mid (put)	pre-ban	5.88	4.63	5.89	4.54	5.49	4.22	5.81	5.09
	ban	8.83	7.69	8.9	7.69	9.07	7.89	9.09	7.69
	post-ban	7	5.88	7.07	5.92	6.47	5.49	7.69	6.38
	total	6.71	5.55	6.77	5.55	6.37	5.22	6.92	6.06
EEP % of mid (call)	pre-ban	0.53	0.0026	0.34	0.0011	0.82	0.077	2.53	0.31
	ban	0.29	0.0013	0.23	0.0006	0.26	0.032	1.11	0.063
	post-ban	0.56	0.08	0.45	0.06	0.51	0.28	2.05	0.18
	total	0.51	0.02	0.37	0.011	0.63	0.14	2.16	0.19
EEP % of mid (put)	pre-ban	0.37	0.28	0.38	0.29	0.31	0.16	0.2	0.032
	ban	0.47	0.33	0.49	0.34	0.46	0.26	0.23	0.28
	post-ban	0.25	0.16	0.27	0.17	0.19	0.13	0.13	0.082
	total	0.34	0.23	0.35	0.24	0.29	0.16	0.18	0.091
IV (%) (call)	pre-ban	44.7	40.4	44.7	40.2	46.5	41.2	50.2	46.5
	ban	58.8	52.3	58.1	51.8	67.2	66.1	69.1	66.9
	post-ban	71.5	65.8	70.9	65.3	76.2	69	80.2	75.8
	total	56.7	52.4	56.7	52.9	60.4	53	63.1	62.9
IV (%) (put)	pre-ban	47.9	42.6	48	42.3	48.5	44.3	51.2	44.9
	ban	64.3	56.5	63.9	56.5	69.8	66.9	72.3	63.9
	post-ban	75.9	69.6	75.1	68.8	79.3	73.6	81.2	76.6
	total	60.7	55.8	60.7	56.5	62.9	56.1	64.3	60.9

This table reports descriptive statistics on a number of variables relating to the call and put options in our sample. These variables are the open interest, the put/call open interest ratio, the daily trading volume, the bid-ask spread (as percentage of the midpoint of the corresponding option quotes), the early exercise premium (denoted as EEP) estimated using the Ho et. al. (1994) approach and the Black-Scholes implied volatility (denoted as IV). These summary statistics are estimated for the full sample of firms added on the ban list as well as for the firms added on September 19, September 22 and September 23. For each one of these four different categories the table reports descriptive statistics for the pre-ban, the ban, and the post-ban periods as well as for the entire sample period. Panel A presents the numbers for the full sample of option pairs, while Panel B for the medium-term ATM contracts.

Table 3: The put-call parity violation

		Mean	5th pctl	25th pctl	Median	75th pctl	95th pctl	$R < 0$ (%)	$R > 0$ (%)
Panel A: Full sample									
All firms	pre-ban	0.0094	-0.012	0.0003	0.0048	0.01	0.053	23.4	76.3
	ban	0.011	-0.027	-0.0022	0.0072	0.018	0.074	29.5	70.5
	post-ban	0.011	-0.017	0.0003	0.0074	0.017	0.054	23.9	76.1
	total	0.01	-0.016	0.00015	0.0058	0.013	0.057	24.5	75.5
Firms added on 19/9	pre-ban	0.0081	-0.012	0.00021	0.0046	0.0097	0.045	24.1	75.9
	ban	0.012	-0.027	-0.0024	0.0069	0.017	0.078	30	70
	post-ban	0.0096	-0.017	0.00032	0.0073	0.016	0.047	24.1	75.9
	total	0.0092	-0.016	0.00047	0.0057	0.013	0.05	24.8	75.2
Firms added on 22/9	pre-ban	0.005	-0.0064	0.00023	0.0043	0.0082	0.019	23.6	76.4
	ban	0.0069	-0.026	-0.0027	0.0081	0.017	0.039	30.6	69.4
	post-ban	0.0078	-0.011	0.00061	0.0065	0.014	0.032	22.9	77.1
	total	0.0064	-0.01	0.00017	0.0053	0.011	0.028	24.2	75.8
Firms added on 23/9	pre-ban	0.0078	-0.023	-0.0037	0.0046	0.015	0.059	33.4	66.6
	ban	0.0073	-0.041	-0.0059	0.0072	0.022	0.059	34.7	65.3
	post-ban	0.0054	-0.038	-0.0049	0.0055	0.017	0.045	36.4	63.6
	total	0.0069	-0.029	-0.0042	0.0051	0.016	0.053	34.7	65.3
Panel B: Medium-term ATM options									
All firms	pre-ban	0.01	-0.013	0.0015	0.0059	0.01	0.061	20	80
	ban	0.016	-0.023	0.0005	0.0089	0.0214	0.1	23.8	76.2
	post-ban	0.013	-0.019	0.0017	0.0094	0.0196	0.062	20.8	79.2
	total	0.012	-0.016	0.0014	0.007	0.0152	0.065	20.8	79.2
Firms added on 19/9	pre-ban	0.0089	-0.013	0.0016	0.0058	0.01	0.053	19.8	80.2
	ban	0.016	-0.025	0.0004	0.0086	0.02	0.108	24	76
	post-ban	0.012	-0.02	0.0017	0.0094	0.019	0.054	20.8	79.2
	total	0.011	-0.017	0.0015	0.0069	0.014	0.06	20.8	79.2

(Continued)

		Mean	5th pctl	25th pctl	Median	75th pctl	95th pctl	$R<0$ (%)	$R>0$ (%)
Firms added on 22/9	pre-ban	0.0061	-0.0076	0.0011	0.0059	0.0089	0.024	20.3	79.7
	ban	0.0073	-0.026	-0.0005	0.01	0.018	0.035	26.3	76.7
	post-ban	0.0094	-0.0096	0.0013	0.0084	0.015	0.034	21.3	78.7
	total	0.0075	-0.01	0.0009	0.0067	0.012	0.031	21.5	78.5
Firms added on 23/9	pre-ban	0.0061	-0.025	-0.01	0.0048	0.015	0.064	36	64
	ban	0.01	-0.033	-0.0021	0.0083	0.023	0.063	28.4	71.6
	post-ban	0.0062	-0.042	-0.0044	0.0069	0.019	0.051	34	66
	total	0.0067	-0.031	-0.0065	0.0055	0.0179	0.06	34.2	65.8

Panel C: Hypothesis testing

Test		Statistic	p-value
$E(R\|R\in D_b) =$	$E(R\|R\in D_d)$	5.80	0.00
$E(R\|R\in D_a) =$	$E(R\|R\in D_d)$	2.26	0.02
$E(R\|R\in D_a) =$	$E(R\|R\in D_b)$	5.84	0.00
$med(R\|R\in D_b) =$	$med(R\|R\in D_d)$	8.93	0.00
$med(R\|R\in D_a) =$	$med(R\|R\in D_d)$	0.62	0.53
$med(R\|R\in D_a) =$	$med(R\|R\in D_b)$	15.43	0.00

This table reports the distribution of the put-call parity violation measure R. The last two columns present the average percentage negative and positive values of R across the relevant sub-samples and periods. The distribution statistics are estimated for the full sample of firms added on the ban list as well as for the firms added on September 19, September 22 and September 23. For each one of these four different categories the table reports descriptive statistics for the pre-ban, the ban, and the post-ban periods as well as for the entire sample period. Panel A presents the numbers for the full sample of option pairs, while Panel B for the medium-term ATM contracts. Panel C reports six tests that examine the equality of means and medians (denoted as med) before (denoted as D_b), during (denoted as D_d) and after (denoted as D_a) the shorting ban period. These test statistics have an asymptotic $N(0,1)$ distribution under the null hypotheses and are based on the full sample of medium-term ATM options.

Table 4: The put-call parity violation: A time-series analysis

	All firms	Firms added on 19/9	Firms added on 22/9	Firms added on 23/9
17/9/2008	0.0045	0.0057	-0.0009	0.0009
	49%	47%	48%	41%
18/9/2008	0.023	0.02	0.016	0.02
	90%	88%	88%	100%
19/9/2008	0.034	0.047	0.021	0.017
	95%	98%	97%	93%
22/9/2008	0.015	0.016	0.012	0.014
	76%	76%	83%	70%
23/9/2008	0.016	0.017	0.009	0.019
	76%	77%	73%	64%
29/9/2008	-0.011	-0.014	-0.016	-0.019
	38%	39%	32%	34%
3/10/2008	0.015	0.015	0.008	0.0076
	77%	77%	73%	69%
8/10/2008	0.01	0.0078	0.0042	0.0026
	62%	62%	62%	43%
9/10/2008	0.0046	0.0037	-0.0053	0.003
	51%	54%	37%	49%
10/10/2008	0.022	0.021	0.038	0.028
	74%	73%	84%	69%

This table reports the average put-call parity violation measure R across firms along with the corresponding percentage of positive violations for specific days of our sample. These numbers are provided for the full sample of firms added on the ban list as well as for the firms added on September 19, September 22 and September 23; they are based on the medium-term ATM option pairs.

Table 5: Portfolio returns

				Daily raw returns			Daily excess return		
Portfolio	Criterion	Avrg. num. of stocks		Mean	St. Dev	p-value	Mean	St. Dev.	p-value
(1)	$R > 0$	88.4	pre-ban	0.0019	0.023	0.42	0.0039	0.013	0.12
			ban	−0.0269	0.04	0.00	-0.012	0.025	0.02
			post-ban	−0.0047	0.057	0.48	-0.0011	0.035	0.72
			total	−0.0045	0.046	0.28	-0.0004	0.028	0.83
(2)	$R > Q_{50}$	57.2	pre-ban	0.0016	0.024	0.53	0.0036	0.014	0.17
			ban	−0.0269	0.043	0.00	-0.013	0.027	0.01
			post-ban	−0.0066	0.059	0.35	-0.0031	0.038	0.38
			total	−0.0054	0.047	0.21	-0.0015	0.03	0.52
(3)	$R > Q_{90}$	10.8	pre-ban	0.0044	0.029	0.35	0.0068	0.022	0.19
			ban	−0.047	0.06	0.00	-0.035	0.057	0.00
			post-ban	−0.012	0.077	0.22	-0.0088	0.057	0.15
			total	−0.0078	0.069	0.25	-0.0042	0.055	0.39
(4)	$R < 0$	24.5	pre-ban	0.0047	0.025	0.09	0.0068	0.015	0.04
			ban	-0.0198	0.052	0.03	-0.0054	0.03	0.48
			post-ban	-0.0058	0.062	0.43	-0.0022	0.038	0.54
			total	-0.0027	0.05	0.54	0.0013	0.03	0.59
(5)	$R < Q_{50}$	55.8	pre-ban	0.0037	0.025	0.16	0.0058	0.015	0.08
			ban	−0.021	0.045	0.007	-0.0073	0.027	0.3
			post-ban	−0.0032	0.057	0.62	0.0003	0.033	0.9
			total	−0.0023	0.046	0.57	0.0017	0.027	0.41
(6)	$R < Q_{10}$	10.7	pre-ban	0.0055	0.032	0.1	0.008	0.021	0.05
			ban	−0.023	0.055	0.02	-0.0092	0.035	0.11
			post-ban	−0.0087	0.069	0.24	-0.0059	0.048	0.19
			total	−0.0041	0.056	0.41	-0.0003	0.039	0.92

This table presents the statistical properties of six alternative portfolios formed based on the end-of-day put-call parity violation that match one of the following criteria: (1) stocks with positive put-call parity violation, (2) stocks with put-call parity violation larger than the median violation of that day, (3) stocks with put-call parity violation larger than the 90% quantile of the violation, (4) stocks

with negative violation, (5) stocks with put-call parity violation smaller than the median violation, and (6) stocks with put-call parity violation smaller than the 10% quantile of the violation. The put-call parity violation is measured for medium-term ATM options pairs for the firms added on the ban list on September 19. These portfolios are equally weighted and rebalanced each day from August 1 to November 28, 2008. The table presents the average daily portfolio raw return and the average daily return in excess of the industry return for the pre-ban, the ban and the post-ban periods as well as for the entire sample period. It also reports their corresponding standard deviations and p-values, which test the equality of the mean raw and excess returns to zero. These daily returns start to accrue with the first trade when the stock market opens on the day that follows the calculation of the put-call parity violation.

Table 6: Synthetic portfolio returns

				Daily raw returns			Daily excess return		
Portfolio	Criterion	Avrg. num. of stocks		Mean	St. Dev	p-value	Mean	St. Dev.	p-value
(1)	$R > 0$	88.4	pre-ban	0.0013	0.026	0.61	0.0028	0.011	0.18
			ban	−0.013	0.037	0.15	0.0015	0.009	0.49
			post-ban	−0.0002	0.054	0.98	0.0036	0.017	0.26
			total	−0.0018	0.042	0.66	0.0029	0.014	0.07
(2)	$R > Q_{50}$	57.2	pre-ban	0.0021	0.027	0.47	0.0036	0.012	0.15
			ban	−0.011	0.039	0.3	0.0038	0.012	0.3
			post-ban	0.0004	0.052	0.95	0.0042	0.018	0.15
			total	−0.0008	0.041	0.83	0.0039	0.015	0.02
(3)	$R > Q_{90}$	10.8	pre-ban	0.0037	0.03	0.33	0.0052	0.019	0.11
			ban	−0.02	0.064	0.23	-0.0053	0.042	0.6
			post-ban	0.0038	0.06	0.69	-0.0076	0.036	0.13
			total	−0.0003	0.051	0.95	0.0045	0.031	0.13
(4)	$R < 0$	24.5	pre-ban	-0.0011	0.031	0.76	0.00038	0.016	0.90
			ban	-0.013	0.055	0.28	0.0017	0.025	0.74
			post-ban	-0.0022	0.064	0.81	0.0015	0.032	0.74
			total	-0.0037	0.051	0.46	0.0011	0.025	0.64
(5)	$R < Q_{50}$	55.8	pre-ban	−0.0003	0.028	0.9	0.0011	0.012	0.6
			ban	−0.016	0.041	0.08	-0.0014	0.011	0.63
			post-ban	−0.0013	0.058	0.88	0.0025	0.025	0.56
			total	−0.0035	0.045	0.44	0.0013	0.018	0.52
(6)	$R < Q_{10}$	10.7	pre-ban	−0.0001	0.044	0.98	0.0013	0.028	0.74
			ban	−0.018	0.062	0.26	-0.0035	0.036	0.71
			post-ban	−0.0056	0.072	0.63	-0.0017	0.043	0.81
			total	−0.0056	0.06	0.36	-0.0008	0.036	0.83

This table presents the statistical properties of six alternative synthetic portfolios formed based on the end-of-day put-call parity violation that match one of the following criteria: (1) stocks with positive put-call parity violation, (2) stocks with put-call parity violation larger than the median violation of that day, (3) stocks with put-call parity violation larger than the 90% quantile of the violation, (4)

stocks with negative violation, (5) stocks with put-call parity violation smaller than the median violation, and (6) stocks with put-call parity violation smaller than the 10% quantile of the violation. The put-call parity violation is measured for medium-term ATM options pairs for the firms added on the ban list on September 19. These portfolios are equally weighted and rebalanced each day from August 1 to November 28, 2008. The table presents the average daily portfolio raw return and the average daily return in excess of the industry return for the pre-ban, the ban and the post-ban periods as well as for the entire sample period. It also reports their corresponding standard deviations and p-values, which test the equality of the mean raw and excess returns to zero. The daily returns of the synthetic portfolios are calculated from the end-of-day synthetic stock price S_t^* implied by the put-call parity relation for the medium-term ATM options.

Table 7: Panel regressions of return predictability

Model: $r = c + a_1 \cdot R + a_2 \cdot (\mathbf{1}_{R>0} \cdot R) + a_3 \cdot (\mathbf{1}_{\{R \in D_d, R<0\}} \cdot R) + a_4 \cdot (\mathbf{1}_{\{R \in D_d, R>0\}} \cdot R) + \epsilon$

Panel A: Coefficient estimates

	c	a_1	a_2	a_3	a_4
Method 1: Generalized least squares					
	0.002	0.018	−0.037	−0.093	−0.134
	(0.00)	(0.6)	(0.38)	(0.23)	(0.00)
Method 2: One-way fixed effects with robust standard errors					
	0.0013	−0.135	0.121	0.182	−0.211
	(0.04)	(0.19)	(0.29)	(0.33)	(0.00)
Method 3: One-way fixed effects with bootstraped standard errors					
	0.0013	−0.135	0.121	0.182	−0.211
	(0.07)	(0.26)	(0.34)	(0.34)	(0.00)

Panel B: Hypothesis testing

Test	Statistic	p-value
Method 1: GLS estimate		
$a_1 + a_2 = 0$	1.01	0.31
$a_1 + a_3 = 0$	1.1	0.29
$a_1 + a_2 + a_4 = 0$	21.78	0.00
Method 2: One-way fixed effects with robust standard errors		
$a_1 + a_2 = 0$	0.18	0.67
$a_1 + a_3 = 0$	0.07	0.79
$a_1 + a_2 + a_4 = 0$	9.55	0.00
Method 3: One-way fixed effects with bootstraped standard errors		
$a_1 + a_2 = 0$	0.16	0.69
$a_1 + a_3 = 0$	0.08	0.78
$a_1 + a_2 + a_4 = 0$	8.91	0.00

This table reports the results of the panel regression analysis. The dependent variable is the daily stock excess return r and the independent variables are the put-call parity violation measure R calculated on the previous day and three dummy variables that account for positive violations, negative violations during the ban period and positive violations during the ban period. The model is estimated using three different methods. The first applies a generalized least squares estimation with a groupwise correction for heteroskedasticity and an AR(1) correction for autocorrelation. The second uses a one-way fixed firm effects estimation with robust standard errors, while the third applies a one-way fixed firm effects estimation with bootstraped standard errors. Panel A reports the estimated coefficients and the p-values of the t-statistics in parentheses. Panel B presents the test statistics and the corresponding p-values of three combined restriction tests of the model parameters. These test statistics have an asymptotic $\chi^2(1)$ distribution under the null hypotheses.

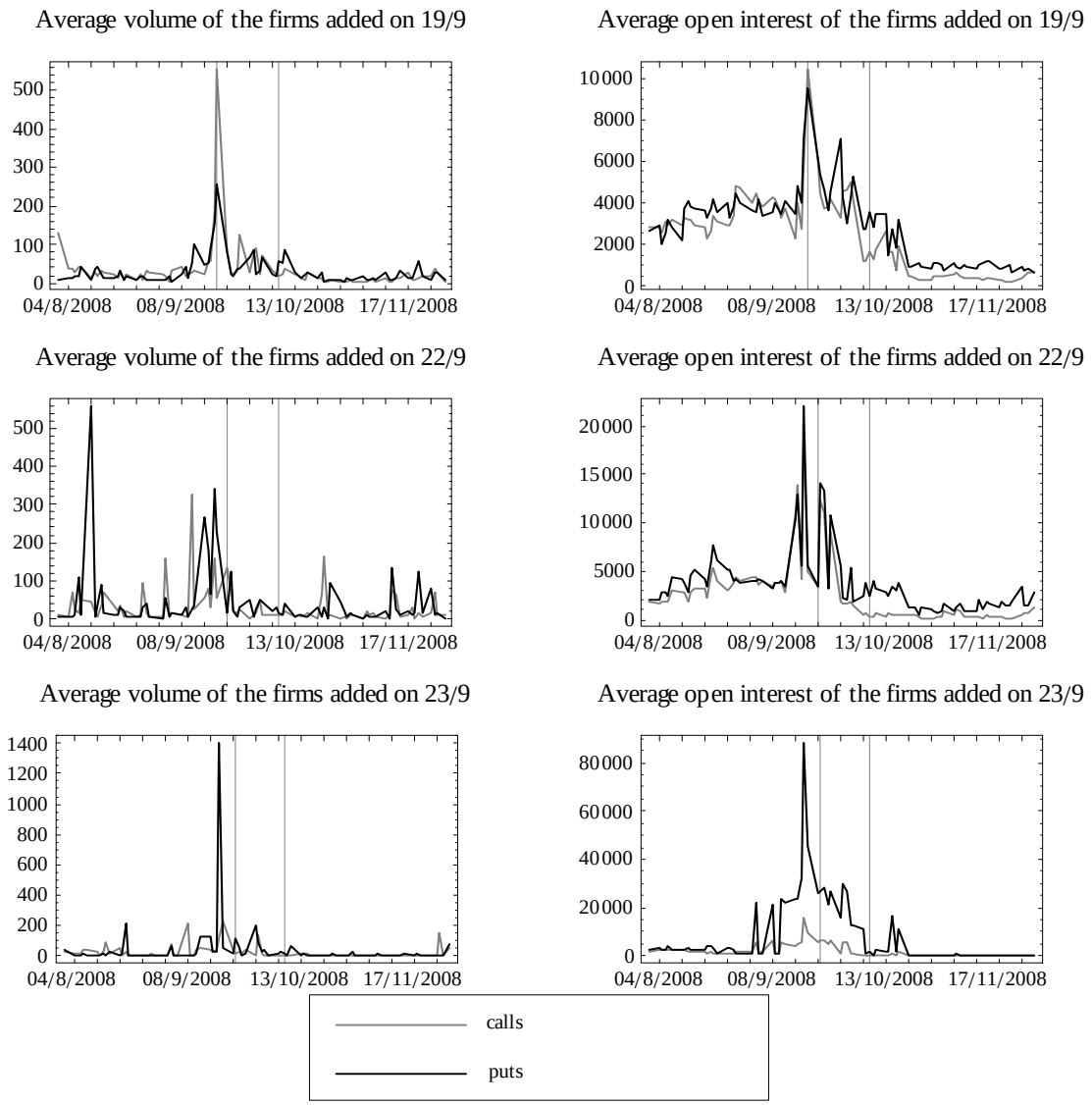


Figure 1: Daily average volume and open interest for medium-term ATM calls and puts for different inclusion dates on the shorting ban list. The vertical lines in the graphs indicate the applicable short sale ban period for each firm category.

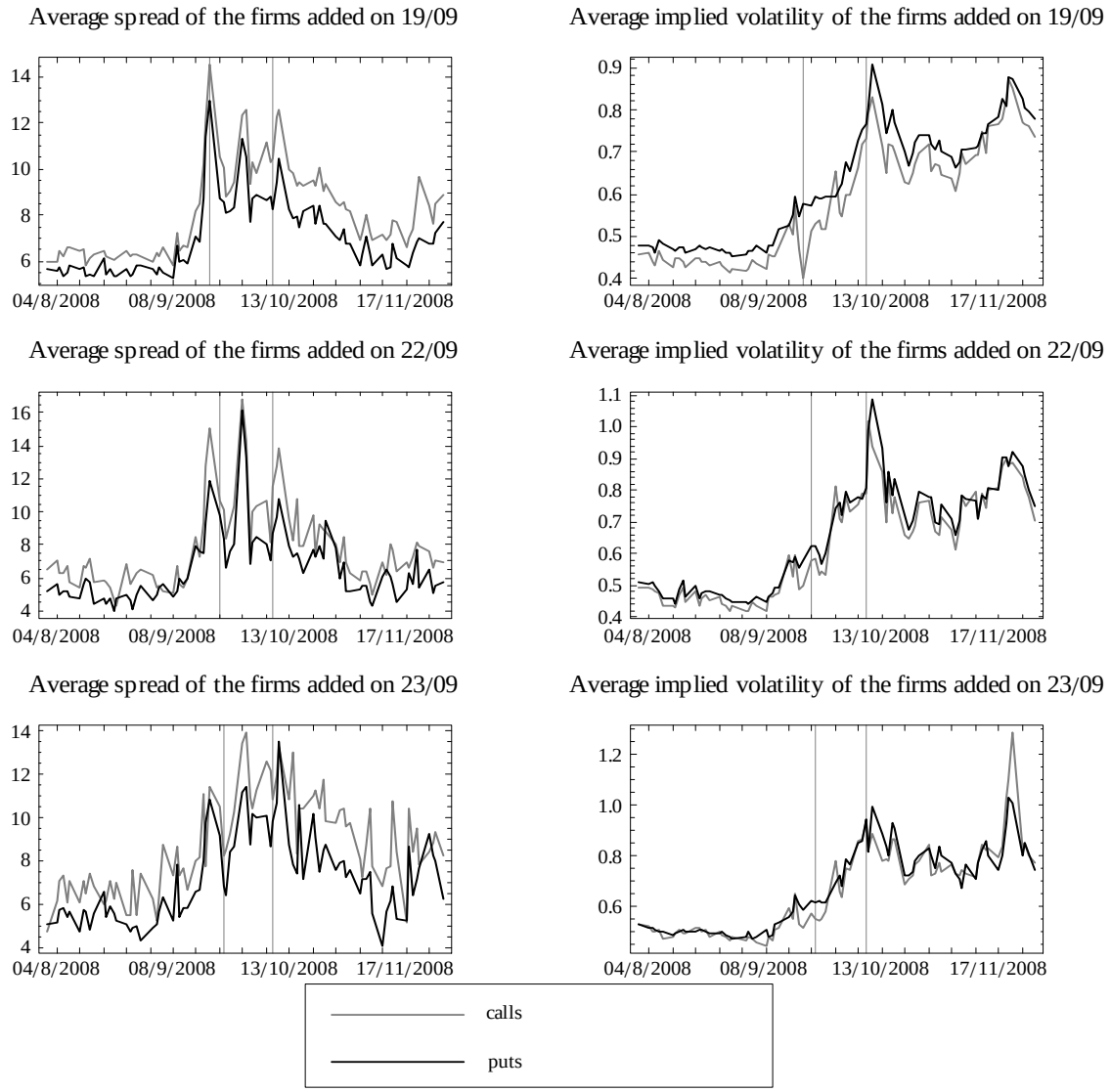


Figure 2: Daily average bid-ask spread and implied volatility for medium-term ATM calls and puts for different inclusion dates on the shorting ban list. The vertical lines in the graphs indicate the applicable short sale ban period for each firm category.

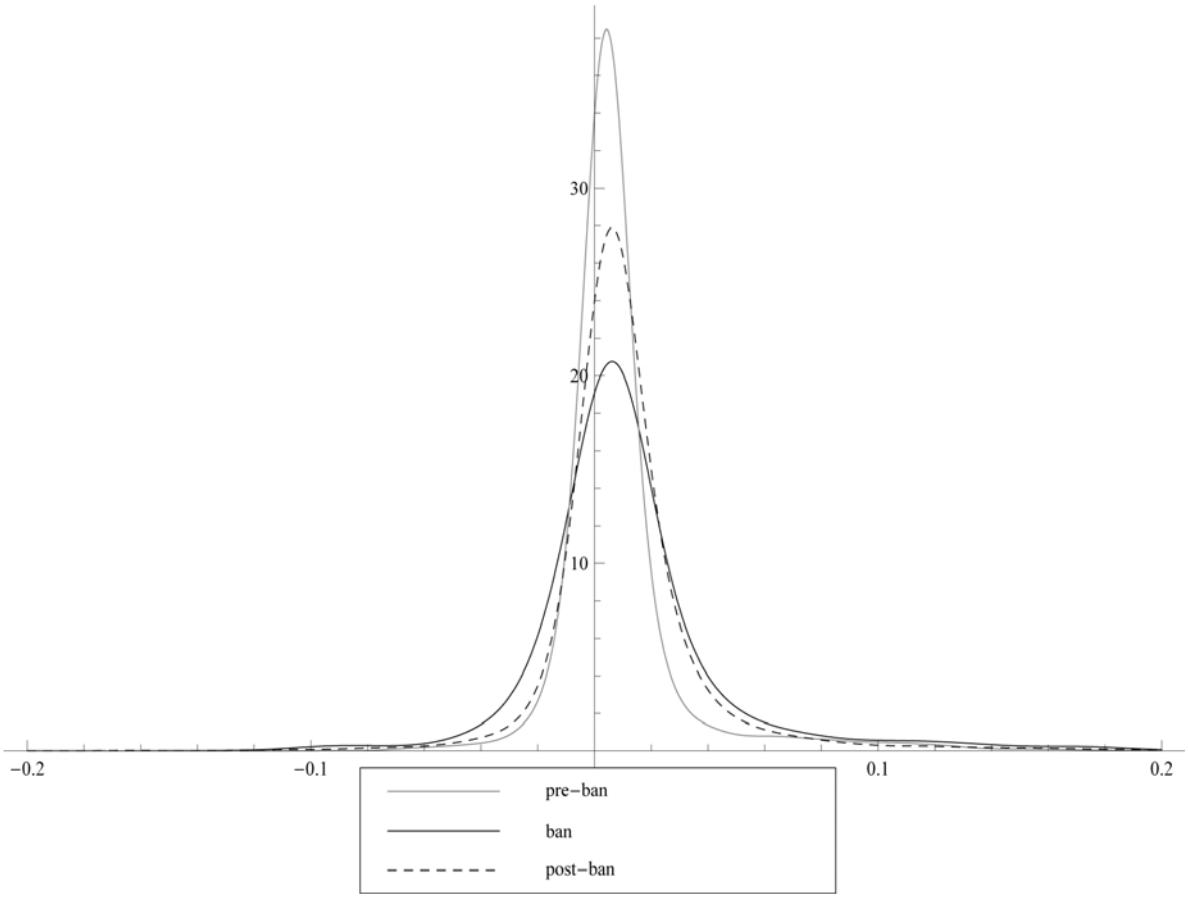


Figure 3: Empirical distribution of the put-call parity violation measure R before, during and after the shorting ban period for the full sample of option pairs

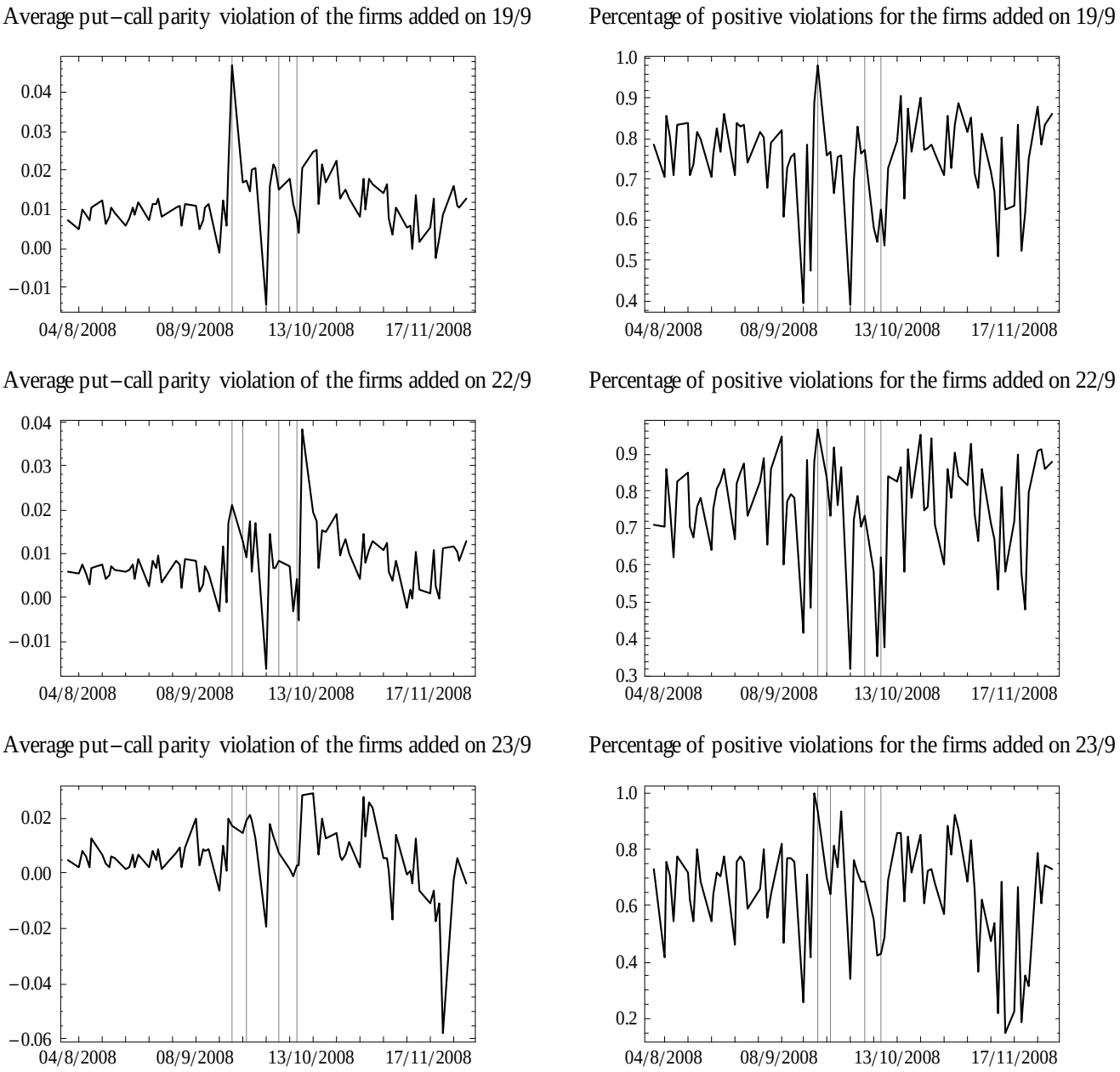


Figure 4: Daily average put-call parity violation and percentage of positive violations for medium-term ATM calls and puts for different inclusion dates on the shorting ban list. The top two graphs include vertical lines indicating September 19 October 3 and October 8. The bottom four graphs include a fourth verical line indicating the date on which the corresponding firms were included on the ban list, September 22 or 23.

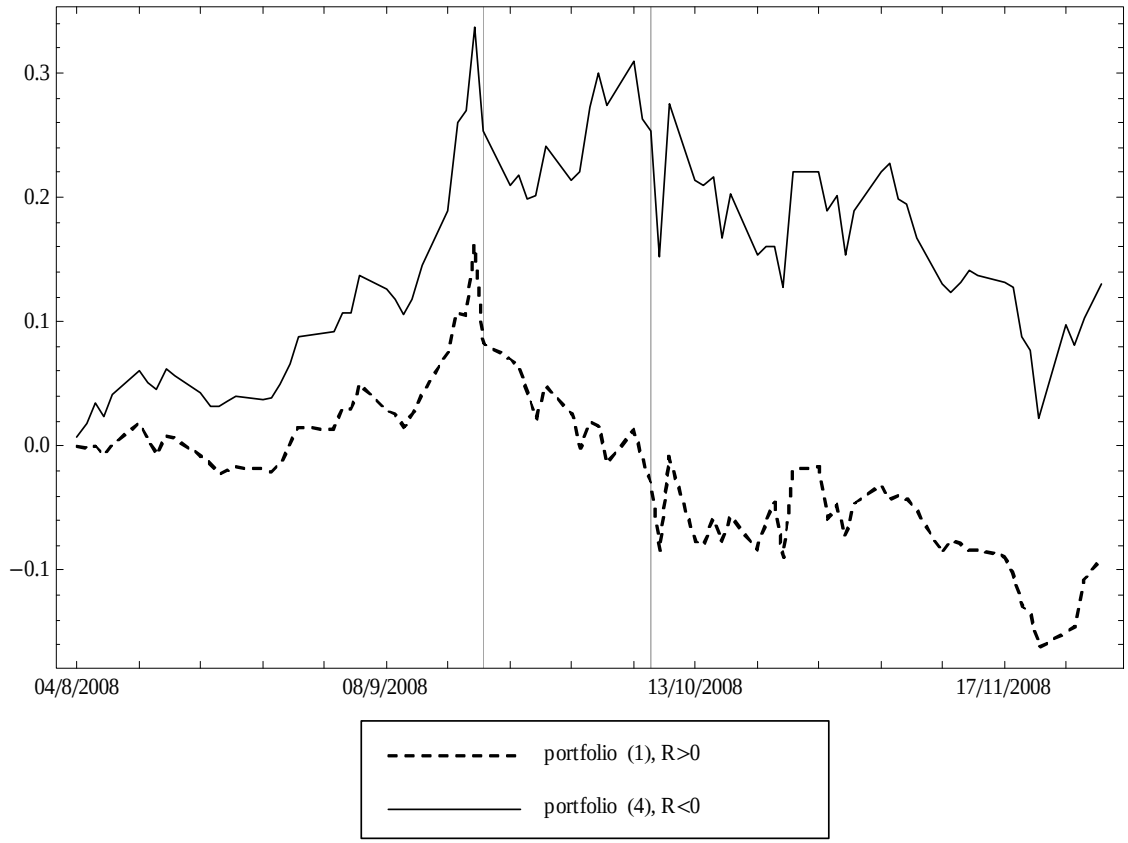


Figure 5: Cumulative portfolio excess returns, August 2008-November 2008. The vertical lines in the graph indicate the applicable short sale ban period (September 19 to October 8).