THE 2008 SHORT SALE BAN: DID WE SELL PRICE DISCOVERY SHORT?

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ABSTRACT

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This dissertation investigates the impact of a short sale ban on the stock market and the options market and the interrelation between the two markets during the US financial crisis of 2008. The first essay focuses on the impact of the short sale ban on financial stocks between September 18, 2008 and October 8, 2008. I examine how daily returns responded to the ban. Non-banned firms with similar sizes and standard deviations of past stock returns as the banned firms served as a control group. An event study shows significant positive cumulative abnormal returns which might indicate that the banned firms were overvalued during the short sale ban. Cross-sectional multivariate regression analysis suggests that the driving force of stock overvaluation was the market's inability to allow operation of differing beliefs.

The second essay investigates the response of the options market to the short sale ban. Only stocks on which options are traded are selected from among banned and control firms. I use put-call parity to examine whether there is a price discrepancy between implied stock prices and actual stock prices before and after the short sale ban. The results show a significant difference between actual stock prices and implied stock prices for banned firms and

control firms during and after the short sale ban, although determinants of the discrepancy are inconclusive.

The third essay links the options market with the stock market to examine information propagation. I use a vector error correction model to examine the lead-lag relation between prices in stock and options markets. There are two different approaches to investigate the price discovery process: (1) Hasbrouck's (1995) information share model and (2) Gonzalo and Granger's (1995) permanent-transitory model. The results indicate that stock and options markets for banned firms are interconnected through a common factor, but both two decomposition methods show that the stock market dominates in the price discovery process.

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CHAPTER 1

INTRODUCTION, MOTIVATION AND HYPOTHESES

1.1 Introduction and motivation

Recently, short selling activities in the stock market have drawn enormous attention from academicians, practitioners and law makers. In the view of academicians, short selling activity is generally believed to help financial markets correct short-term deviations of stock prices from fundamental values. If there are short sale constraints, then market participants have limited access to short sales. According to modern portfolio theory, the efficient frontier with short sale constraints will be a subset of the efficient frontier when there are no short sale constraints. Therefore, there is an academic interest in empirical examination of whether short sale constraints are impediments to achieving a perfect[1] and complete market.

Boehmer, Jones and Zhang (2008) find that about 75% of all short sales are executed by institutions, while individuals represent less than 2%, and about 23% of short sales come from New York Stock Exchange (henceforth, NYSE) member firms such as specialists. Diether, Werner and Lee (2009) document that short sales represent, on average, 23.9% of NYSE and 31.3% of Nasdaq reported share volume for short-term trading. Given the costs of short selling, they postulate reasonably that most short sales transactions come from institutional traders. A growing literature shows a consensus that short sellers are informed (Figlewski (1981); Brent, Morse and Stice (1990); Senchack and Starks (1993)). As many institutions are prevented from shorting, institutions that do use short selling as part of their strategies tend to be more sophisticated, or capable of discerning and exploiting price discrepancies. Dechow, Hutton, Meulbroek and Sloan (2001) document that short sellers take positions in the stock of firms with

[1] A perfect market is referred to a market without any friction in terms of transaction cost, informational cost and tax effect.

inferior ratios of fundamentals to market values. This result suggests that increased short-selling activities predict negative future abnormal returns after controlling for other variables. That is, they short sell growth firms, which turn out to be underperforming firms in the future. Assuming that short sellers trade following past returns and that they can foresee future negative abnormal returns for a long position, one might argue that short selling makes the market more informative.

Between September 18 and October 8, 2008, United State financial stocks were subject to a complete short sale ban. If there is no opportunity for short sale, some informed traders or sophisticated traders were forced to sit out. As a result, some of the information in stock prices was transmitted. Whether or not stock prices still reflected fundamental values is the empirical question that this study attempts to tackle. The research contributes generally to the literature on short sale constraints on stock prices. The results are consistent with past conclusions that a complete short sale ban does bias the stock prices upward. An event study focused on the short sale ban period indicates persistent cumulative abnormal returns during that time.

Researchers have documented that short sales are associated with lower future volatility, suggesting that short sales facilitate the flow of information. Varian (1985) considers an Arrow-Debreu model with agents who have different subjective probability in a complete market, i.e., no restrictions on short sales. He concludes that a wider dispersion of beliefs will be associated with reduced asset prices. How would divergence of expectations change during a short sale ban? How would a change in divergence of expectations affect stock prices? Analysis of set of variables proxying for divergence of opinion indicates that a widened divergence of expectations is present during the short sale ban. My empirical results show that a greater divergence of opinion is associated with lower future abnormal returns. This result is consistent with Miller's (1977) conclusion that stocks tend to be overvalued when there are both short sale constraints and a divergence of opinion.

My second contribution is to investigate whether there is a significant difference between observed stock prices and implied stock prices derived from the option pricing model under a certain type of short sale prohibition. Imposition of the short sale ban in 2008 allows me to investigate the impact of the event on the options market. Theoretically, investors can form a synthetic short position on stock by writing a call, buying a put and borrowing an amount of money at the level of the strike price. This strategy is free from short sale constraints. If there is a contagion effect from the stock market to the options market, however, the synthetic stock prices might not necessarily converge to the observed stock prices. This framework allows direct tests of whether the short sale ban impacted the options market.

The third contribution of this study is analysis of the interaction between stock and options markets. Other research documents that options markets can predict crash in financial markets[2]. I examine this issue in the setting of a short sale ban. Would a short sale ban alleviate the pressure of a financial crash through the options market? This is a regulatory question that has concerned market participants and law makers. My study therefore evaluates the efficacy of policies with respect to a short sale ban.

1.2 Hypotheses

The first essay (chapter 3) focuses on the effect of a short sale ban on the stock market. Three hypotheses are summarized as follows:

- $H1_0$: There is no significant price change for firms subject to a short sale ban before and after a ban. More specifically, a financial stock will not experience positive abnormal returns during the period of a short sale ban compared to other firms of similar size and risk.

[2] Bates (1991) examines an out of money American put option using a jump-diffusion model and finds that the options market could have predicted the crash of 1987 two months earlier . Rappoport and White (1994) view broker's loans as options and estimate implied volatility using the Black-Scholes (1973) Model. Their result suggests that the crash of 1929 could have been predicted by the broker's loan markets months earlier. Fung (2007) examines the predictive power of the options market for the crash of 1997 in the Hong Kong stock market. He finds that implied volatility is a good leading indicator of actual volatility in the stock market.

I create a set of proxies for the divergence of opinion and analyze its relation to stock returns under imposition of a short sale ban. Two hypotheses are related to the experimental design:

- $H2_0$: There are no significant changes in financial stock returns associated with changes in divergence of opinion.

- $H3_0$: Changes in the degree of divergence of opinion, on average, are the same for both option listed financial stocks and non-option listed financial stocks.

Hypothesis three ($H3_0$) extends Miller's (1977) theory to emphasize the function of the options market. If the options market provides a particular channel for pessimistic investors, the stock market should be able to indirectly absorb the unfavorable information disclosed by the options market. Therefore, it is likely that change in the degree of divergence of opinion will help reduce the overvaluation effect of stocks through trades in the options market.

The second essay (chapter 4) focuses on financial stocks with tradable options. It has been documented that derivatives markets are fairly efficient with only a few exceptions in the options market.[3] Those exceptions are due to distortion in the market such as increasing difficulties of short sales. Therefore, a critical analysis is to measure the ability of the options market to adjust put or call prices responding to the short sale ban. One way to answer this question directly is to test put-call parity. A fourth hypothesis is described as follows:

- $H4_0$: The number and sizes of put-call parity violations, on average, remains the same before and after the short sale ban, regardless of time to maturity or level of moneyness.

The liquidity theory and behavioral finance would lead us to expect that there is an increase in violations of put-call parity when time to maturity is longer.

[3] These exceptions are documented by Manaster and Rendleman (1982), Ofek, Richardson and Whitelaw (2004) and Nilsson (2008).

The third essay (chapter 5) investigates the dynamic relation between the stock and options markets from January 2007 through December 2008. I combine the findings from the first two essays and address the primary question: How does the price discovery process actually work when a policy shock starts in one market? Poclicy on the uptick rule and the short sale ban can be regarded as shocks starting in the stock market. A vector error correction model (VECM) is adopted to examine the dynamic movement between the two markets. An error correction term in the VECM serves to show a price adjustment. The model lets us decompose the error correction term in order to investigate the components of information. Two information decomposition approaches, information share (IS) and permanent-transitory models, are used to analyze the contributions of each market to information disclosure.

CHAPTER 2

LITERATURE REVIEW

I first discuss previous literature closely related to my study. I describe the financial theories regarding short sale constraints and empirical evidence on the impact of short sale constraints on the stock market and on the options market. The last part of the literature review discusses the literature on dynamic interaction between the stock and derivatives markets.

2.1 Short sale constraints and the stock market

2.1.1 Short sale constraints, market efficiency and stock returns

Findings on the impact of short sale constraints on stock prices are diverse. One school of thought asserts that the market will slowly adjust stock prices to an equilibrium, assuming that rational market participants will respond fully to information available in the markets. Diamond and Verrecchia (1987) propose a theoretical asset pricing model including short sale constraints. The assumption is that rational investors adjust their expectations and take short sale constraints into account. Meanwhile, risk-neutral market makers adjust the bid-ask spread in order to prevent any informed trader from exploiting price differences. The assumption of homogeneous expectations implies that investors hold identical proportions of the total issue of all risky securities and risk-averse investors will take only long positions in each security, even when there is an option to short. Under these assumptions, Diamond and Verrecchia argue that short selling activity does not play a role in the standard capital asset pricing model. Therefore, the homogeneous expectations model with restricted short selling gives exactly the same conclusion as one with unlimited short selling, as long as investors are risk averse or risk neutral.

Miller (1977) argues that this is not attainable for non-homogeneous expectations under short sale constraints because the price of a security is misestimated when public opinion is only partly revealed in the markets. A sufficient amount of short selling could increase the trading volume of the security outstanding until its price is forced down to the average valuation across all investors. Miller concludes that short sale constraints are impediments to the achievement of market efficiency because a security price will not reflect its intrinsic value derived from the standard asset pricing model if there is a growing divergence of opinion.

There is research related to both these theoretical frameworks. Senchack and Starks (1993) used an event study to analyze the reaction of 2,419 US stocks to the release of short interests by the *Wall Street Journal* each month between 1980 and 1986. They test the hypothesis of Diamond and Verrechia (1987) that the release of short sale volumes would have a significant effect on the price adjustment process. They find short sales are perceived as bad news by the market and would drive down stock prices. Aitken Frino, McCorry and Swan (1998) examine the impact of short selling on Australian stocks with real time disclosure of short interest information. The intraday data surrounding the disclosure of short interests enable them to investigate the impact of short selling on stock returns. Their findings provide consistent evidence again that short selling says bad news to the market. Markets can adjust security prices downward efficiently with instantaneous disclosure. They also conclude that the price discovery process will be slowed down by a non-contemporary information release. A good example is the NYSE, which discloses short interests only once a month.

Boehme, Danielsen and Sorescu (2006) empirically study the interaction between short sale constraints and divergence of opinion on stock returns. They create a unitary short sales constraint proxy based on relative short interests and availability of option-traded stock. They also create a unitary dispersion proxy using a weighted average of idiosyncratic risk (sigma) and the turnover rate. Their findings are consistent with Miller's theory; that is, when there are short sale constraints and heterogeneous beliefs, stocks will be overpriced, which will result in lower future returns. Chang, Cheng and Yu (2007) use a unique set of firms that are removed from the list of short sale constraints. They find that cumulative abnormal returns for those firms drop and become significantly negative after the firms are removed from the constraint list. Furthermore, they find greater overvaluation due to short sale constraints for firms with more divergence of opinion, which is consistent with Miller's hypothesis. Bris, Goetzmann and Zhu (2007) investigate the impact of imposing and removing short sale constraints in different countries. Their research suggests that stock markets that allow for short sales are more efficient. They also document that, from the standpoint of regulators, short sale constraints can be policy tools to reduce panic while during economic crisis. Nevertheless, their result implies that allowing short sales helps markets incorporate negative impacts.

2.1.2 Impact of options market on the stock market under short sale constraints

The traditional viewpoint suggests that an optioned stock is less constrained because of lower transaction cost. Therefore, investors can choose to buy a put or write a call if there are constraints imposed on short sales in the underlying asset market. According to the price discovery mechanism that the options market provides, one should expect a more transparent and efficient market for optioned stocks. Conrad (1989) finds that the variance of stock returns declines after the introduction of options. Kumar, Sarin and Shastri (1998) document that optioned stocks suffer less from adverse selection problems and have greater market depth. Senchack and Starks (1993) separate stocks into optioned stocks and non-optioned stocks. Their research result suggests that more short interests are induced with the presence of tradable options. Danielsen and Sorescu (2001) document the impact of the introduction of options on the underlying asset under short sale constraints before and after 1981. The results are mixed. The introduction of options had a significantly negative impact on stock prices for years after 1981 but a significantly positive impact before 1981. They also find that short interests are positively associated with negative cumulative abnormal returns after 1981, which supports the notion of an upward bias in stock prices under short sale constraints. Overall, their model shows that asset prices decline and the short interest level increases as constraints on short sales are reduced, because the listing of publicly traded options effectively facilitates short sales.

Bates (1991) investigates whether the 1987 stock market crash could have been predicted through the options market. He shows that out-of-the-money puts became unusually expensive during the year preceding the crash. Whether the introduction of or the existence of an options market will have a detrimental effect on the underlying asset market is an empirical question. My examination adds to the literature and sheds light on the impact of the options market on the underlying asset market.

2.2 Short sale constraints and the options market

The put-call parity model (hereafter PCP) demonstrates an arbitrage-free equilibrium between derivatives and the underlying asset markets. When the PCP model holds, call and put options are fairly priced. Investors can replicate a long or short stock position in the derivatives markets without taking on extra risk. The perfect case occurs only when there are no frictions in the market. That is, there is zero transaction cost, costless information is available and short selling is allowed. Klemkosky and Resnick (1979); Finucane (1991); Bates (1991); Nisbet (1992); Ofek, Richardson and Whitelaw (2004); Puttonen (1993); Kamara and Miller (1995); Ackert and Tian (2001); Nilsson (2008) examine the PCP model under different types of market constraints such as transaction costs and shorting restrictions. The results are mixed.

Klemkosky and Resnick (1979) modify a Stoll's model (1969, 1973) by taking into account dividend payouts on American registered options. They establish an inequality model for detecting violations of the PCP model. Their result indicates that the PCP model holds in general, with a few exceptions due to overpriced call options. Nisbet (1992) expands the PCP model by including transaction costs. Given the difficulty of short selling in the London options market, her empirical results are consistent with previous work that markets are efficient, and exploitable opportunities are eroded by transaction costs. The options market efficiency hypothesis is further favored by Kamara and Miller (1995) who investigates only European options. They conclude that violation of the PCP model in some cases can contribute to liquidity risk for which riskless hedging strategy is no longer attainable. Ackert and Tian (2001) investigate the PCP model by studying the relation between the Standard & Poor's (S&P) 500 index and S&P Depository Receipts (SPDR). They find that the introduction of SPDRs does not significantly increase violations of the PCP model under the imposition of short sale constraints and transaction costs.

Ofek, Richardson and Whitelaw (2004) use rebate rate spreads to examine the PCP relation in the presence of short sale constraints. They explicitly calculate implied stock prices using the PCP model, taking into account the early exercise premium. They find that violations of PCP are asymmetric in the direction of short sale constraints, with the extent strongly related to the costs and difficulty of short selling. They conclude that this result is in line with the theory of limited arbitrage which says that in a market where investors have differences of opinion, overly optimistic investors will bid prices up, but rational investors cannot bid prices down due to the short sale constraints(Shleifer and Vishny, (1997)). Therefore, stock prices drift away from fundamental values. Nilsson (2008) further discusses the impact of a complete short sale ban on stock and option markets using Swedish market data. He finds that short sale constraints increase deviations from PCP in the direction corresponding to a short position in the stock, while no such increase can be detected for deviations from PCP where a long position in the underlying stock is required. Nilsson concludes that mispricing of a stock is not the only reason for deviation from PCP, which can be attributed partly to the mispricing of derivatives.

Other research discusses the disparity between observed stock prices and implied stock prices using the Black-Scholes (1973) model. Manaster and Rendleman (1982) (MR hereafter) estimate implied stock prices utilizing that model. Forming stock portfolios based on the differences between observed stock prices and implied stock prices, they analyze the future performance of various portfolios. They reject the hypothesis that implied stock prices provide no information on the future movements of observed stock prices. Bhattacharya (1987) uses transaction-by-transaction data to examine the relation between implied stock prices from the Black-Scholes model and observed stock prices. His approach is free from the problems of discrete information arrival and non-synchronicity of the transactions. To test whether there are arbitrage opportunities based on differences between implied stock prices and observed prices, Bhattacharya implements trading strategies based on ex ante and ex post execution. He concludes that information embedded in option prices is not immediately reflected in stock prices, and that more information assimilation in the stock market occurs overnight than at other times. If not, losses incurred by intra-day trading strategies should, on average, equal the stock bid-ask spread and the return on overnight strategies should be lower than the Center for Research in Security Prices (CRSP) close-to-close return. This result is inconclusive as to whether arbitrage opportunities persist when considering search costs, bid-ask spreads and other market frictions.

2.3 Price discovery and the dynamic relation between the stock and options markets

Hasbrouck (1995) develops an econometric model to determine the price discovery process for one single security traded in different markets. He defines one single security as securities that may be technically distinct, but that are closely linked by short-term equilibrium. According to this definition, a stock and a call option on that stock can be considered one security. Therefore, the implied stock price based on the option transaction may be meaningfully compared to the actual stock prices.

Taking off from the idea of one security in different markets, it makes sense to ask how each market contributes to the price discovery process of one security. For instance, a strand of literature uses a lead-lag relation to disentangle the price discovery process between stock and options markets. Manaster and Rendleman (1982) compare implied stock prices derived from the Black-Scholes option pricing model with actual stock closing prices. They form five portfolios ranked by the differences between implied and actual stock prices. The results, ex ante and ex post, indicate that the options market leads the stock market by a day. Stephan and Whaley (1990) (SW hereafter) contend that MR's approach suffers from problems of non-synchronous transactions. They use intra-day data to avoid the problem, and adopt a multivariate time series analysis approach to directly investigate the relation between the stock and the options markets. Their result, contrary to MR's finding, is that the stock market leads the options market by 15 minutes.

Diltz and Kim (1996) (hereafter DK) reconcile the controdiction between MR and SW for the lead-lag relation between the stock and the options markets. They investigate the interaction between observed stock prices and implied stock prices derived from the Black-Scholes option pricing model using a vector error correction model. Their analysis is free from non-synchronized transaction and bid-ask bias problems. The result is consistent with MR, that the options market leads the stock market in the short run.

Other authors produce mixed results on the impact of the options market on its underlying asset market. Conrad (1989); Senchack and Starks (1993); Kumar, Sarin and Shastri (1998); Bollen (1998) contend that the introduction of options enhances the transparency of the stock market, reduces adverse selection and narrows the bid-ask spread, therefore increasing market liquidity and market depth. Danielsen, Van Ness and Warr (2007), however, suggest that improving liquidity is one of the selection criteria in the option listing decision. They find that a stock's bid-ask spreads narrow significantly before options for that stock are listed.

There is a more direct way to examine the dynamic relation between the stock and the options markets; that is, one can measure the contribution of revealing the information in each market. Hasbrouck (1995) establishes a vector moving average (VMA) model to depict how the information flow is impounded in a single security traded on different exchanges. Gonzalo and Granger (1995) use permanent-transitory approach to separate the common trend from transitory shocks. This methodology allows one to focus on either long term behavior or short-run phenomena such as business cycles of the economic system. A number of studies have been carried out using these two methodologies.

There are only a handful of studies related to derivatives and spot markets, Examples are Chakravarty, Gulen and Mayhew (2002); Baillie, Booth and Tse (2002); Hsieh, Lee and Yuan (2008); and Cabrera, Wang and Yang (2009). The results are somewhat mixed. Hsieh, Lee and Yuan (2008) support the transaction cost hypothesis that markets with lower transaction costs such as the futures market contribute higher information share. Cabrera, Wang and Yang (2009) analyze the foreign exchange rate in three different markets including regular futures, E-mini futures and the interdealer spot market. Their result suggests that the spot market leads the price discovery process. Overall, most authors agree that the options market contributes to information disclosure.

CHAPTER 3

SHORT SALE BAN, DIVERGENCE OF OPINION AND STOCK RETURNS

3.1 Introduction

On July 3, 2007, the Security and Exchange Commission (SEC) officially announced the abolition of the uptick rule. Investors could go short without any restriction. Then, during late 2007 and continuing through 2008, the US economy suffered worsening financial turmoil. The financial markets, especially the stock market, witnessed some historic swings. Dow Jones Industrial Average dropped for more than 700 points on a single day in September, 2008. There are different theories regarding the cause of the market crash. A few practitioners claim that because the uptick rule is aimed at stabilizing the financial market, its elimination aggravated the financial crisis. Opponents suggest that the weak economy and debt crises themselves are at the root of the 2007-2008 financial crises, and removal of uptick rule had nothing to do with the meltdown, despite increasing volatility[4]. Each argument has its supporting theory and empirical evidence. It is still a debate on whether the market should abandon any forms of short sale constraints.

By early 2008, the US stock market suffered a huge drop in major indices such as the Dow Jones industrial Average and the S&P 500. The financial industry faced a meltdown that threatened to paralyze the entire US economic system. Lehman brothers filed for bankruptcy. Merrill-Lynch was acquired by Bank of American. Rumors dominated the market, and investors

[4] In a *Wall Street Journal* article, Zuckerman (2008) reports two groups of investor with different perspectives on removal of uptick rules. People who are against the changes argue that "traders are in hog heaven---- they keep banging and banging a stock [down] …." They also said "the increased volatility caused investors to want higher returns, so there will be a higher cost of capital for companies, putting our market at a competitive disadvantage." Opponents contend that "there were ways around uptick rules, such as using option strategies and exchange-traded funds or simply violating it and pay a small fine."

lost their confidence in certain financial firms. The SEC decided to conduct a series of investigations, which led to a ban on short sales of 23 financial firms[5]. Eventually, the SEC prohibited investors from "naked" short selling financial stocks on September 19, 2008.

This unique period allows us to investigate the effectiveness of policy change, despite the multiple factors entering into this whole financial mess. My goal is to examine the impact of policy change on a particular industry under the particular circumstances of the financial crisis.

The intension is to test theories and to discover whether stocks were severely mispriced due to imposition of the short sale ban. Asquith and Meulbroek (1996) have documented that short sellers are able to identify securities with subsequent low returns. Therefore, short selling activity is regarded as a contrarian strategy that plays an important role in keeping the price of stocks in line with fundamentals. Thus, a ban on short sales might cause the market to be temporarily out of equilibrium.

First of all, I hypothesize that imposition of short sale ban caused the banned firms to be overpriced and resulted in positive abnormal returns during the period. The second hypothesis tests whether divergence of opinion affects the extent of overpricing in stocks. Finally, a third test tries to link the degree of divergence of opinion with the options market. I postulate that stocks that have listed options should be better able to respond to favorable or unfavorable news in the market than non-optioned firms, so the options market's mere presence results in a more consistent belief in firm value. Figlewski and Webb (1993) investigate 342 stocks of which 196 are option-traded stocks. Their examination of relation between option prices and short interests yields evidence that the presence of options helps mitigate the effect of short sale constraints in the stock market and makes a market more efficient and complete.

I separate the sample firms into the four categories: banned firms with options, banned firms without options, non-banned firms with options and non-banned firms without options. The

[5] Following Regulation SHO, the SEC issued emergency orders to prohibit "naked" short sales for the 23 firms on July 15, 2008. Naked short selling describes a short sale where the sellers

aim is to find a set of control firms with similar market capitalization and similar degrees of divergence of opinion before imposition of the short sale ban. I believe this methodology will provide more rigorous empirical results, as it enables investigation of the impact of the short sale ban on banned firms from different perspectives. For example, a pairwise test can be conducted between banned and non-banned firms under the category of option firms[6].

The tests indicate no significant difference in firm variables such as trading volume, market size, return variability, turnover ratios and short interest for banned and control firms before the short sale ban was imposed. Nevertheless, there were significant positive cumulative returns for the banned firms during the period of the short sales prohibition. I further examine whether the difference in returns is compensation for bearing extra risk. Cumulative returns sorted on pre-estimated beta suggest that banned firms earned higher returns than control firms at the same level of risk (beta).

Univariate analysis and regression analysis of cumulative returns show that overvaluation of the banned stocks was likely the consequence of an increase in the divergence of opinion and the short sale ban in the market. In a distinction from other short sale ban research, this study uses regression analysis with an interaction term to see how the restriction affects the price. The compounding effect of the short sale ban on the divergence of opinion was strongly and significantly positive during the ban period and negative after the removal of the short sale ban.

One contribution of this paper is that I split the sample into optioned and non-optioned firms for both banned and control firms. The approach is motivated by the SEC order regarding options market makers. The SEC was determined to prevent fraudulent activities from driving market prices downward. According to an amendment to the short sale ban order, bona fide options market makers were exempt from the short sale ban on those covered securities,

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do not borrow or arrange to borrow the securities to deliver to the buyers within the three-day window of settlement.

but the SEC required the options market makers to take care to guard against market manipulation through trading in the option markets. This regulation should have effectively prevented the options market makers from engaging in buying a call or writing a put with certain counterparties. [7] The function of price discovery provided by the options market was likely severely dampened. One should expect the transaction behavior for option-traded stocks to be different from that of non-optioned stocks. Yet, univariate and regression analysis both show that returns are negatively associated with the presence of options during the ban period, indicating that the options market seems to facilitate information flow and provide liquidity as well.

3.2 Sample selection and methodology

I describe the sample selection process, sample data in section 3.2.1 and methodology in 3.2.2.

3.2.1 Sample selection and description

The sample firms are all in the financial industry. According to the Security and Exchange Commission emergency order on September 18, 2008, there were a total of 799 financial firms named in the short sale ban. I collect daily data from January 2007 through December 2008 for the event study. Daily stock prices, trading volume and outstanding shares are collected from Center in Research of Security Prices (CRSP). Financial analysts' earnings forecasts are collected from the IBES summary database. Short interests are provided by shortsqueeze.com. In the financial turmoil, some financial firms either declared bankruptcy or were acquired by other firms. When there are not complete daily return data, I exclude some

[6] Autore, Billingsley and Kovacs (2009) and Boehmer, Jones and Zhang (2008) split their samples only into banned and non-banned firms.

[7] The amendment regarding the bona fide option market makers is stated as follows: "the requirement of this order should not apply to any person that is a market maker ….However, if a customer or counterparty position in a derivative security based on a covered security is established after 12:01 a.m. E.D.T. on September 22, 2008, a market maker may not effect a short sale in the covered security if the market maker knows that the customer or the counterparty transaction will result in the customer or counterparty establishing or increasing an economic net short position."

firms from the event study. The final sample is 724 in total. Options are traded on 198 of those firms in 2008.

I also select a set of non-banned firms not on the short sale ban list. They are of similar size and represent similar levels of divergence of opinion before the short sale ban. Market value of equity at the end of 2007 and standard deviation of raw daily returns computed from an estimation window (-120, -31 days) prior to the short sale ban are the proxy for firm size and divergence of opinion, respectively. I do not require a one-to-one match between the two sample groups. Therefore, 544 matched firms are selected. Panel A of Table B.1 gives the descriptive statistics. The insignificant t-statistics both for mean difference (Diff) in market value of equity and the standard deviation of raw daily returns [SIGMA(raw)] indicate that the matching process serves well to pick out control firms with similar firm size and return variability.

I also use the dispersion of financial analyst earnings forecast [SIGMA(fa)] as a proxy for divergence of opinion. Only firms with more than three financial analysts following are included. This results in 204 banned firms and 196 control firms. The t-statistic of -1.55 on the mean difference (Diff) in SIGMA(fa) between banned and control firms is not significantly different from zero, indicating a consistent result as well as SIGMA(raw). The mean difference in daily raw returns before the short sale ban is significantly different from zero. Turnover ratios for banned firms and control firms do not differ significantly.

Panel B of Table B.1 further splits the sample into optioned and non-optioned firms for both banned and control groups. Optioned firms tend to have higher turnover ratios (1.56% vs. 0.27% for banned firms and 1.24% vs. 0.41% for control firms), indicating that optioned stocks are much more active than non-optioned stocks. I also see that optioned stocks are larger stocks ($8123.06 million vs. $584.36 million for banned firms, and $9376.51 vs. $423.73 million for control firms), which is consistent with findings elsewhere (Kumar, Sarin and Shastri (1998); Danielsen, Van Ness and Warr (2007)). Another difference is that the daily raw returns of optioned firms are significantly lower than returns of non-optioned firms among the banned firms.

Before examining whether the short sale ban impacted on stock returns, it is worth to look at some firm variables. Number of trades, trading volume and turnover ratio are estimated to examine whether there was any change in pre-, during and post-short sale ban period. (The pre-ban period is 90 days prior to September 18, 2008. The during-period is September 18, 2008 through October 7, 2008, and post-period is October 8, 2008, through December 31, 2008.) To test whether the selected variables change significantly for the banned firms compared to the control firms, one needs to take into account the fact that there is likely to be significant serial correlation and heterogeneity problems due to industry effect and the cluster effects of the single event. To resolve this issue, I establish a time series regression of cross-sectional average with Newey-West standard errors based on lag of 20 days for each of the selected firm variables as follows. I first compute the daily cross-sectional average of each variable. Second, I run a time series regression to test for changes over time for each subperiod using a dummy variable equal to one in event period. This dummy variable captures the difference for the selected firm variables in the pre-, during- and post-short sale ban periods. Finally, I run a time series regression of the daily cross-sectional average of differences in each selected firm variable for control and banned firms using the Newey-West adjustment procedure on the intercept and a dummy variable taking the value of one for the event period and zero for the pre- or post-period. The firm dummy variable to capture the difference between control and banned firms over time is labeled as Dif-Dif in the tables.

Table B.2 reports the regression results. Panel A shows changes in firm variables before and during the short sale ban period. The number of trades, trading volume and turnover ratio of control firms increased significantly over time during the short sale ban. Only trading volume changed positively for banned firms in the same period. The Diff - Diff column indicates that during the short sale ban, trading volume for banned firms increased significantly more than for control firms, and number of trades decreased significantly for banned firms. Panel B of Table B.2 presents changes in firm variables over time after the short sale ban was imposed. There are no statistically significant changes after elimination of the short sale ban except for a decline in trading volume for banned firms. The Diff - Diff column, however, suggests that lift of the short sale ban did have an impact on the banned firms in that trading volume and turnover ratio increased significantly in the post-ban period.

The change in short interest activity over time is also of note. Information on short interest is released to the public every two weeks. In Table B.3, I compare the difference of several short interest-related variables for banned and control firms before and after the short sale ban. Apparently, shorting activities for both groups were discouraged. Although the descriptive statistics show no significant difference in relative short interest scaled by shares outstanding whatever the sub-period. It is interesting to note that control firms have more insider and institutional ownership than the banned firms.

3.2.2 Methodology

3.2.2.1 Impact of the short sale ban announcement on stock returns

Results for the use of proxies for short demand are mixed[8]. Figlewski and Webb (1993), for example, use short interest as a proxy for short demand to predict future returns. In this study, the social environment provides a natural laboratory to investigate the issues with no need for proxies. The 2008 short sale ban is a predeterministic factor. Intuitively, I use two different approaches to examine the impact of the short sale ban on stock returns. First, I run the a pooled regression of daily raw returns on different dummy variables:

$$R_{i,t} = a + a_1 \times MPOSED + a_2 \times IMPOSED \times BANNED + a_{3.} \times REMOVED + a_4 \times REMOVED \times BANNED + \varepsilon_{i,t} \quad (3.1)$$

[8] Jones and Lamont (2002) contend that using short interests as a proxy for short demand is problematic because short interest is the intersection of supply and demand. The short demand might be negatively correlated with short interest in some cases. They argue that the result in Figlewski and Webb (1933) is clear.

where *IMPOSED* equals one if t is during the short sale ban window and zero otherwise; *BANNED* equals one if firms are banned from shorting and zero otherwise; *REMOVE*D equals one if t is after the lifting of the short sale ban and zero otherwise. The regression standard error is calculated using a cluster regression model including firm and time effects.

Second, I calculate cumulative raw returns (CRRs) for different event windows such as (-1, 0), (0, 19), (0, 60) and (20, 60)[9]. I conduct a paired t-test of cross-sectional CRRs for banned firms and control firms. I also use an event study to examine the impact of imposition of the short sale ban on financial firms. An estimation window of 90 days is chosen to estimate the beta coefficient using the market model in equation (3.2)[10]. The event windows to examine the impact of imposition of the short sale ban are (-1, 0), (0, 19), (0, 60) and (20, 60).

Abnormal returns and cumulative abnormal returns during the event window are computed using equation (3.4) and equation (3.5);

(3.2) $$R_{i,t} = \alpha + \beta R_{m,t} + \varepsilon_{i,t}$$

(3.3) $$\varepsilon_{i,t} \sim iid(0, \sigma_{\varepsilon})$$

(3.4) $$AR_{i,t} = R_{i,t} - (\hat{\alpha} - \hat{\beta} R_{m,t})$$

(3.5) $$CAR_{i,t} = \sum_{t=-d}^{D} AR_t$$

where $R_{i,t}$ is the daily rate of return for individual stock; $R_{m,t}$ is the market rate of returns estimated by the value-weighted index daily return from the CRSP database; $AR_{i,t}$ is the abnormal returns during the event window for a particular stock; $CAR_{i,t}$ is the cumulative abnormal returns for a stock during the event window selected.

[9] An event window of (-1, 0) is one day preceding short sale ban announcement and up to the announcement date. (0, 19) is the period of the short sale ban. (0, 60) is the 60 days after the short sale ban announcement. (20, 60) is the period right after the short sale ban removal announcement date.

[10] When estimation window of 150 days and 70 days are used to estimate the beta coefficient and the abnormal returns, the results are quantitatively similar.

3.2.2.2 Cross-sectional regression analysis of cumulative returns on divergence of opinion

According to Miller's (1977) theory, coexistence of a short sale constraint and high levels of divergence of opinion is likely to induce overvaluation in stock prices. Therefore, I test the hypothesis if the degree of divergence of opinion is associated with stock returns. Other authors have discussed the measures of divergence of opinion and how they relate to price changes. Peterson and Peterson (1982) document a positive relation between return volatility and the dispersion of IBES forecasts, which supports volatility as an opinion divergence measure.

Shalen (1993) builds a rational expectations model to explain that excess volume and excess price variability can be proxies for dispersion of expectations. The theoretical results suggest that divergence of expectations contributes to a positive correlation between trading volume and contemporaneous and future absolute price changes. Harris and Raviv (1993) propose a speculative trading model based on differences of opinion among traders (not on private information). They argue that speculative trading stems from disagreement among traders over the relation between an announcement and the ultimate performance of the assets in question. They conclude that disagreement will induce excess trading volume and therefore result in absolute price changes as well[11].

I construct several variables as proxies for divergence of opinion before the short sale ban period. Following Chang, Cheng and Yu (2007) and Boehme, Danielsen and Sorescu (2006), the first measure of divergence of opinion is *SIGMA(raw),* the standard deviation of daily raw returns within an estimation window (-97, -7). The second measure, *SIGMA(ar)*, is the standard deviation of abnormal returns for the same estimation window. The third measure, *SIGMA(tr)*, is trading volume scaled by shares outstanding during the same estimation window. The last measure, *SIGMA(fa)*, is the standard deviation of financial analyst earnings forecasts as of the end of July 2008.

One of my main questions is whether the ability to trade in the option market helps reduce the asymmetry of price adjustment. Previous research provides mixed results regarding the effect of an option introduction on stock prices. It seems helpful to analyze the relation between the options market and the underlying asset market in the event of the short sale ban.

According to the SEC short sale ban list, 240 of 799 financial stocks had listed options. To maintain comparability, I select control firms with the same market capitalization and return variability as criteria. I then obtain a subset of 168 non-financial firms with traded options and 376 non-financial stocks without traded option as control firms.

Research has documented that introduction of the options market makes the underlying assets less volatile because of the reduction of asymmetrical information. Investors who seek alternatives to sell banned stocks short are enabled to do this in the options markets, so unfavorable opinion can be revealed. Other researchers conclude that option are redundant and do not improve the liquidity of the stock market. My third hypothesis states that the presence of options for a stock has a significant effect on the speed of the price adjustment process in the underlying asset market when there is a short sale ban.

Pessimistic investors are forced to stay out of the stock market if there is a ban on shorting stocks. They can choose the options market to continue their short strategy by writing a call or buying a put. The counterparty, i.e., the options market makers, however, comply with the SEC order and may not be the counterparty of such a position if the transactions would result in their customer establishing or increasing an economic net short position.

One might wonder whether the options market can provide liquidity and improve price discovery. Therefore, I test whether the options market can play a role in helping improve market efficiency.

The regression model to analyze the relation between cumulative abnormal returns and divergence of opinion is:

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[11] Harris and Raviv (1993, p477) summarize a branch of literature regarding the notion that

$$CAR_{i,t} = a + b_1 \times DO_{i,t-1} + b_2 \times DO_{i,t-1} \times BANNED + b_3 \times SIZE_i + b_4 \times OPTION + b_5 \times OPTION \times BANNED + B \times CONTROL + \varepsilon_{i,t} , \quad (3.6)$$

where t is the event windows (-1, 0), (0, 14), (0, 60) and (20, 60); $CAR_{i,t}$ is the cumulative abnormal return for different event windows; $DO_{i,t-1}$ is the set of proxy variables for divergence of opinion; *BANNED* variable is one for banned firms and zero for control firms; *SIZE* is the natural logarithm of market capital; *OPTION* takes a value of one for matching option-traded firms, and zero otherwise; *B* is a matrix of coefficient for included control variables; *CONTROL* is a matrix of control variables including change in relative short interest, days to cover (the total short interests scaled by average trading volume), institutional ownership scaled by shares outstanding, insider ownership scaled by shares outstanding, alpha90 estimated by the market model from 90 days prior to the short sale ban event, and the interaction term of each control variable with banned variable; $\varepsilon_{i,t}$ is the error term following iid $(0,\sigma_\varepsilon^2)$.

3.3 Empirical results

3.3.1 Changes in stock return around imposition and removal of the short sale ban

If Miller's (1977) theory is correct, that is, that there is a short sales constraint where higher level of divergence of opinion in the stock market, the stock returns should reflect positively to the imposition of a short sale ban upon its announcement. Hence, I first examine whether banned firms are more overvalued than non-banned firms.

Table B.4 reports the behavior of average daily raw returns around the short sale ban event according to equation (3.1). I first test the entire sample dividing into banned and control firms. The banned column of Panel A.1 reports average returns for banned stocks during the event window of 0.24% ($=a + a_1 + a_2$) which is 1.05 percentage point higher than the average returns of the control stocks (-0.81%). The diff column shows a statistically significant difference (a_2) in average returns during the short sale ban for banned and control firms.

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trading is induced by differences of beliefs.

Panel A.2 shows results after the removal of the short sale ban. The *Diff* column shows an insignificant difference of -0.46% for average returns. Conrad (1989); Senchack and Starks (1993) and Danielsen and Sorescu (2001) provide evidences that the introduction of options not only reduces constraints imposed on the underlying asset markets but also stimulates short interest. The interplay between markets will essentially alleviate the severity of the overvaluation of stocks.

To investigate whether the inclusion of options does help facilitate the price adjustment process, I run equation (3.6) separately for optioned and non-optioned firms. The results are in panel B and C. The regression results might suggest that the source of differences in average returns between banned and control firms comes from the inclusion of option. The *Diff* column of Panel C.1 indicates that the average returns of non-optioned banned firms are significantly higher (0.88%, with a t statistic of 3.57) than returns of non-optioned control firms. This research seems to confirm previous research.

The Cumulative raw returns (CRRs) in different event windows are used to examine the impact of the short sale ban on banned and control firms. The first graph of figure A.1 display the CRR(-1, 60) for the banned and control firms. On average, firms during this period performed poorly, while prices declined. It is interesting to see that CRRs during the short sale ban were much higher for banned firms than control firms, suggesting that the rise in stock prices is likely due to the restriction on shorting.

The second graph shows an even more dramatic difference in abnormal returns for banned and control firms. CAR(-1, 60) increase to about 20% before the removal of the short sale ban for the banned firms. CAR(-1, 60) of control firms fall below 10% during the short sale ban and continue to decline after its elimination.

Table B.5 shows pairwise t-statistics of cross-sectional CRRs for event windows of (-1, 0), (0, 19), (0, 60) and (20, 60). The *Diff* column in Panel A shows a strong overvaluation of banned stocks in all event windows, indicating that the prices of banned stocks only partially reflected the information in the market due to the short sale restriction. The *Diff* column in Panel B suggests that CRRs increased before the announcement date but dropped sharply afterward for optioned firms. Panels C and D provide evidence that the availability of options will have a greater impact on price adjustment if there is no short sale constraint.

I next conduct an event study using the market model to investigate the impact of the short sale ban on all the sample firms. I use an estimation window of 90 days with minimum of 45 days required to estimate the beta coefficient. I compute abnormal returns (hereafter ARs) and cumulative abnormal returns (hereafter CARs) for different event windows.

Panel A of Table B.6 reveals a result consistent with the CRR results. The *Diff* column in Panel A suggests that the difference in average CARs is strong and significant for each event window. As in figure A.1, CARs for banned firms are positive and increase during the short sale ban period but the pattern is different for control firms.

Splitting the sample into option and non-optioned firms, the story is very different. Optioned firms have much higher CARs than non-optioned firms during the short sale ban period; the result is especially strong for the banned optioned firms. Senchack and Starks (1993) conclude that abnormal returns will be less negative with an unexpected short interest if firms have tradable options. This argument might make sense for non-banned firms with options but not for banned firms with options.

To investigate whether the overvaluation of banned firms is attributable to an increase in systematic risk, I use the pre-estimated beta from the market model to form four different risk class groups. Modern portfolio theory asserts that securities with the same level of systematic risk should generate the same expected rate of return. According to the efficient market hypothesis, the market will adjust the stock price if disequilibrium occurs. Or according to arbitrage theory, investors will realize an opportunity and adjust stock prices accordingly.

Table B.7 shows patterns of cumulative raw returns and cumulative abnormal returns of different event windows. Whatever the event window, CRRs and CARs of banned and control firms show a very different pattern. For instances, CRR(0, 19) and CAR(0, 19) during the short sale ban period are significantly higher for banned firms with the same levels of beta. Except for quartile 2, the insignificance of difference in CRRs after lifting of the short sale ban appears to be consistent with portfolio theory. It is likely that banned stocks are overvalued because pessimistic investors were not in the markets during the short sale ban period.

3.3.2 Stock prices and divergence of opinion

Miller (1977), and Boehme, Danielsen and Sorescu (2006) and Chang, Cheng and Yu (2007)) have established that a greater divergence of opinion is associated with overvaluation of stocks when there are short sale constraints. To examine the question for my sample period, I construct a set of proxies to represent divergence of opinion. *SIGMA(raw)* is the standard deviation of daily raw returns during the estimation window. Trading volume is another widely accepted proxy for belief divergence. Accordingly, *SIGMA(tr)* represents the ex ante average daily trading volume scaled by outstanding shares over the estimation window. *SIGMA(fa)* is the standard deviation of the consensus financial analyst earnings forecast. The last measure, *SIGMA(ar)*, is the standard deviation of abnormal returns estimated by market model.

Table B.8 provides the correlation matrix for these variables. I see that *SIGMA(raw)* is highly correlated with *SIGMA(ar)*, but not with *SIGMA(fa)* and *SIGMA(tr)*. Thus, *SIGMA(fa)* and *SIGMA(tr)* might help capture different aspects of price variability.

I then sort the CRRs and CARs into quartile groups using those proxies for divergence of opinion. Tables B.9 and B.10 present the results. Panels A and B in both tables consistently show that the CRRs and CARs increased significantly and monotonically with greater dispersion of opinion for banned firms during the short sale ban period. I do not find the same pattern for control firms. That is, without the short sale constraint, changes in opinion may not result in overvaluation of stock prices. A pairwise t-test is conducted to examine the difference in CRRs and CARs for banned and control firms within each quartile. The results (not tabulated here) are consistent with Miller's (1977) overvaluation theory.

Next, I perform a cross-sectional regression analysis to further test the hypothesis that the overvaluation effect of the short sale ban is positively associated with divergence of opinion. That is, the more diverse the opinion, the more the stock prices rose when the short sale ban was imposed. With the same regression, I also test the hypothesis that the availability of options helps facilitate and improve the price discovery process.

The results of equation (3.6) are reported in Table B.11. Panel A shows that *SIGMA(raw)* as a proxy for divergence of opinion predicted the direction of CARs when the short sale ban was imposed on financial stocks. CAR(0, 19) is significantly and positively associated with *SIGMA(raw)* at the 10% significance level during the short sale ban period. The incremental effect of the shorting restriction is also profound. The coefficient of the interaction term of *SIGMA(raw)* with banned variable is 2.14, significant at the 5% level, suggesting that financial stocks might be overvalued.

In the regression of CAR(20, 60), a negative coefficient of -3.24 on the interaction term between *SIGMA(raw)* and the banned variable strongly suggests a downward price adjustment for the financial stocks. This indicates that pessimistic opinions are gradually incorporated into the market after the removal of the short sale ban, which is consistent with the story of overvaluation.

Panel B uses *SIGMA(ar)* as the proxy for differences of opinion. During the ban period, the relation between returns and divergence of opinion is positive but weak for both financial and non-financial firms. Although, prices of financial stocks are adjusted downward significantly more than prices of the non-financial firms for the regression of CAR(20, 60).

Panel C, on the other hand, shows that the financial stocks are overvalued relative to the non-financial stocks by 7.02 percentage point (9.68% - 2.66%) with a 1% increase in *SIGMA(tr)* during the short sale ban. I do not find a similar result using *SIGMA(fa)* as the proxy for divergence of opinion. I postulate this could be the result of the small sample size.

Institutional ownership is negatively associated with CAR(-1, 0) and CAR(20, 60) but not with CAR(0, 19) in Panels A, B and C of Table B.11. Institutional investors are believed to be more sophisticated investors with superior information. They are able to take advantage of over- or undervaluation of stock prices. It is intuitive to find that the institutional ownership declines along with the increase in CARs since stocks might be overvalued. Yet, Boehmer, Jones and Zhang (2008) document that about 75% of all short sales are executed by institutional investors, so a short sale ban should have a negative impact on shorting activities. It is likely that purchases to close short sale positions might offset sales. Therefore, the insignificant relation between CAR(0, 19) and institutional ownership is in line with the Boehmer et al. findings.

The *OPTION* dummy and the interaction term of the *OPTION* dummy with the *BANNED* dummy in Table B.11 allow us to test the efficiency of the options market. Before the short sale ban period, cumulative abnormal returns had declined significantly. The result is consistent with the literature that options serve a discovery function for security prices. The interaction term further emphasizes the impact of the inclusion of options on the financial stocks. It is shown that the greater the overvaluation of financial stocks, the greater the downward price adjustment. Panels A, B and C show significant interaction effects of -0.02%, -0.04% and -0.01% (respectively) for banned stocks with options in CAR(20, 60) window. There is no such significant relationship between either CAR(0, 19) and *OPTION* nor CAR(0, 19) and *OPTION*BANNED,* suggesting that price discovery did not function during the ban period for the banned stocks.

Nonetheless, Table B.11 does indicate a deterioration in price discovery under the short sale constraint but a restoration after its lifting. The possible reason might be that options market makers were dissuaded from short selling financial stocks during the short sale ban.

3.4 Conclusion

The short sale ban beginning on September 19, 2008, provides a unique setting to analyze the effect of the option market for stock prices. I offer three hypotheses: (1) in the presence of heterogeneous beliefs, the short sale ban can cause stock prices to be biased upward temporarily, (2) the more diverse investors beliefs, the more dramatic the overvaluation during the short sale ban period and the more price adjustment after the removal of the restriction, and (3) the listing of options enables better price discovery for stocks.

The empirical results indicate that there are significant positive cumulative abnormal returns during the period between imposition and removal of the short sale ban. This might suggest that the market is temporarily incomplete; investors could not fully implement short selling strategies and therefore could not arbitrage away any price discrepancy consistent with their beliefs. Hence, financial stocks become overpriced during the short sale ban period.

The univariate analysis suggests there is a positive relation between the level of divergence of opinion and the overvaluation of the banned stocks during the short sale ban period. A cross-sectional regression model suggests that cumulative abnormal returns and the level of divergence of opinion are positively related in the short sale ban period but negatively related after its elimination. This is in line with Miller's (1977) theory that short sale constraints and a greater divergence of opinion will result in overvaluation of stock prices. The short sale ban is shown to have had a significant and negative impact on the price discovery process, and thus that it should be viewed as an impediment to market efficiency (or price discovery). Interestingly, inclusion of the options market has a weak effect on helping facilitate information and correct stock prices during the short sale ban period, but price adjustment is strong and significant during the post-ban period.

My findings complement findings elsewhere in the literature and contribute to our understanding of the price impact the short sale ban may have had. This has regulatory implications in that a ban might hinder price discovery and therefore cause the overvaluation of individual stocks.

At this point, I do not completely reveal how the options market contribute to price discovery for stocks, but in a second essay I will continue to focus on the impact of the short sale ban on the options markets. It is of more than academic interest to examine the propagation mechanism whereby the options markets helps underlying assets reflect relevant information under a short sale ban. One direction is to examine the relation between observed stock prices and implied stock prices based on the option pricing model.

CHAPTER 4

SHORT SALE CONSTRAINTS AND PUT-CALL PARITY

4.1 Introduction

This essay examines how the options market reacted to the Security and Exchange Commission short sale ban for hundreds of financial stocks. The restrictions caused several brokerage firms to change their online platform in order to prevent their customers from implementing a short sales strategy[12]. I postulate that this action aggravated financial market completeness and essentially increased the transaction costs for investors. It became more difficult to trade in the options market with possible increases in the spread and other types of transaction costs. Hence, I hypothesize that violations of put-call parity would be severe during the short sale ban period.

The rest of the study is organized as follows. Section 4.2 describes sample selection and methodology. Section 4.3 presents the empirical results. Section 4.4 concludes.

4.2 Data and methodology

4.2.1 Option data and description

Options data are obtained from OptionMetrics database, which includes bid and ask prices of options, open interest, trading volume and expiration date. I choose data from January 2007 through December 31, 2008 for optioned financial stocks and for matching non-banned, non-financial stocks.[13]

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[12] According to a report in the *Wall street Journal* on September 23, 2008, brokerage firms took action in order to comply with the SEC's order on short sale restrictions. They either allowed their customers to exercise put only at expiration or allowed no earlier exercise on a put if it would turn into a short sale position.

[13] I use the same group of matched firms as in chapter 3, selecting control firms with options traded in the market.

Several rules are applied to sample selection. Following Ofek, Richardson and Whitelaw (2004), I apply two grouping procedures. I separate the options data into three groups by level of

moneyness. The at-the-money group is for options data with ln(S/X) ratios ranging from -0.1 to 0.1. The in-the-money group has ln(S/X) ratios greater than 0.1; and the out-of-the-money group has ln(S/X) ratios of less than -0.1. In the second grouping procedure, I separate the options data by the length of time to maturity. The short-term group includes options with time to maturity between 10 days to 91 days. The intermediate-term group includes options with time to maturity between 91 days to 182 days. The long-term group includes options with time to maturity greater than 182 days.

First, I match call options with different times to maturity and level of moneyness. Second, I match call options and put options with same times to maturity and strike prices. If I obtain multiple pairs at the same day for one firm, then I choose the one closest to the middle of the range. For the analysis, I divide the sample into three different groups in accordance with the events: (1) period A is from July 3, 2007, through September 17, 2008, the period after elimination of the uptick rule and before the short sale ban; (2) period B is from September 18, 2008, through October 8, 2008, the period of the short sale ban; and (3) period C is from October 9, 2008, through December 31, 2008, the period after expiration of the short sale ban.

Table B.12 reports descriptive statistics for paired at-the-money options in different time periods. Panels A, B and C show that descriptive statistics of some key variables for short-term, intermediate-term and long-term options. Both call and put volume declined drastically along with times to maturity for both banned and control firms, whatever the event period. Interestingly, there is not a similar pattern for open interest. While open interest for all puts and calls declined along with times to maturity before the short sale ban, during the ban period, open interest grew for intermediate-term options but declined for long-term options for both control and banned firms. Mean values of bid-ask spreads on calls and puts as a percentage of the midpoint of the corresponding option quotes are similar, but values declined along with times to maturity for both groups. The implied volatility for calls and puts is similar, declining with times to maturity as well. The pattern of options trading appears quite consistent before and after the short sale ban imposition period.

Imposition of the short sale ban does impact trading behaviors with respect to time horizon. First of all, option volume and open interest on the puts increase with the time period, regardless of time to maturity, indicating that the short sale ban on financial stocks might have forced investors to change their trading platform from the stock market to the options market. Descriptive statistics for the control firms show the opposite pattern; volume and open interest on put declined during the short sale ban period but increased afterward. Spreads for puts and calls has became wider during the short sales ban period, suggesting a discrepancy between the supply of and demand for options. Investors who want to sell calls might need to ask for a lower price and bid on a higher price if they want to buy a put.

Not surprisingly, the implied volatility of puts and calls grew over the time horizon due to uncertainty in the markets.

4.2.2 Methodology

The put-call parity (PCP) approach requires no volatility input, greatly simplifying the process of recovering the implicit spot price. In addition, unlike conventional approaches, which depend on the joint conditions of market efficiency and the accuracy of the specific option pricing model, the only condition the PCP model requires that the put and the call be priced relatively correctly without giving rise to any arbitrage opportunities. Consequently, the PCP model further alleviates the potential model risks that are inherent in the conventional Black-Scholes option pricing model (Hsieh, Lee, and Yuan, 2008).

Following Ofek, Richardson and Whitelaw (2004) and Nilsson (2008), I investigate the PCP model under the consideration of possible earlier exercise on put options. Unlike Ofek et al., I do not eliminate financial stocks with dividend payments because the majority of financial firms pay out dividends. This makes the analysis more complicated because I need to consider early exercise for both calls and puts. My purpose is to examine whether PCP is violated before and after the short sale ban and how the degree of violations may have changed.

Stoll (1969) specifies the PCP relation for European options under a frictionless market as in equation (4.1):

$$p_t - c_t + S_t - Xe^{-r(T-t)} = 0 \tag{4.1}$$

where *p* is the European put premium, c is the European call premium, *S* is the stock price, *X* is the strike price. *T* - *t* is time to maturity, r is the three-month Treasury bill rate as the proxy for the risk-free interest rate. For stocks with European options, there is no problem implementing equation (4.1) because investors only can exercise at expiration.

Yet, I must deal with American options with dividend payments. Investors who buy an American call option on stocks with dividend payments should exercise only when the present value of the dividend payment at the time of exercise is greater than the difference between the strike price and the present value of the strike price at the time of exercise. Investors who buy an American put option are likely to be exercised earlier as long as the difference between the stock price and the strike price exceed the put premium. Therefore I have to estimate the early exercise premium for puts and calls when analyzing an American options value[14].

Thus, equation (4.1) is not appropriate under short sale constraints, and I must modify it for my test. The modification is described as :

$$P - EEP_p - (C_t - EEP_c) + S_t - Xe^{-r(T-t)} = 0\,, \tag{4.2}$$

where *P* is the observed put price, EEP_p is the early exercise premium for put options, C is the observed call price, and EEP_c is the early exercise premium for call options. I follow Barone-

[14] Merton (1973) responses to Stoll's (1969) and claims that American put options could be exercised any time prior to expiration date as long as the $c < \frac{r \times S}{(1+r)}$. He further argues that the rational premature exercising of puts is not only theoretically possible, but could also be expected to represent a significant fraction of all puts exercised.

Adesi and Whaley's (1987) quadratic approximation approach to estimate EEP. Table B.13 presents the results.

Ofek, Richardson and Whitelaw (2004) and Nilsson (2008) eliminate optioned stocks with dividend payments and therefore calculate the exercise premium for only the puts. I include all financial stocks regardless of dividend payment. Table B.13 shows that the exercise premium on the puts is relatively low, compared with that for the calls. For example, the early exercise premium for intermediate time to maturity puts in the pre-ban period is 0.011% of the stock price, much lower than the 0.178% for calls in the same time period.

I also test whether early exercise premiums on calls and puts are significantly different in different time periods. Table B.13 reports the statistical results. Panel A shows that the early exercise premium on puts dropped significantly from 0.011% (pre-ban) to 0.002% (ban period) for banned firms and 0.0019% (pre-ban) to 0.003% (ban period) for control firms. A similar pattern (from 0.178% to 0.135%) is observed for the calls of the banned firms but not for the control firms. The column labeled *Diff - Diff* indicates that the differences in early exercise premiums for the pre-ban and ban periods differ statistically from one group to another.

Panel B of table B.13 compares early exercise premiums in the ban and post-ban period. The early exercise premium for puts continues to drop regardless of the firm group, but there is a significant rebound on the premium for calls after the short sale ban is expired. The *diff – diff* column shows that the difference in early exercise premiums between the ban and post-ban period is statistically different only for the puts. I then adjust put-call parity condition for these two estimates as in equation (4.2).

I have noted that stock prices might deviate from equilibrium because pessimistic investors are kept away from the stock market under certain market constraints. With the constraints, the stock market is not able to completely reflect different expectations of market participants. Whatever the existences of arbitrage opportunities, it is likely that observed stock prices deviate from implied stock prices. The deviation would be an indication of market inefficiency. Hence, I hypothesize that the extent of PCP violations increases after short the sale ban.

The value of stock options is determined by a replicating portfolio approach, where one goes long on one portfolio and short on another. A complete prohibition on shorting stocks implies that the replication argument will break down. To compare long and short positions on financial stocks, I construct two portfolios using the PCP equations. To create a synthetic long position, I buy a call at the ask price, sell a put at the bid price and lend at the strike price. That is :

$$S^a = -C^a + EEP_c + P^b - EEP_p - Xe^{-r(T-t)} \tag{4.3}$$

where S^a is the purchase price of the stock.

The second portfolio is constructed to create a synthetic short position on the stock. I buy a put at the ask price, sell a call at the bid price and borrow at the strike price. That is :

$$S^b = C^b - EEP_c - P^a + EEP_p + Xe^{-r(T-t)} \tag{4.4}$$

where S^b is the selling price of the stock.

Combining equations (4.3) and (4.4), I establish a range for testing the PCP violation :

$$S^b \le S \le S^a \tag{4.5}$$

If the spot price is between the purchase price and the selling price, I say there is no violation of the PCP.

The tests examine whether there is violation of PCP before and after the short sale ban and whether there are differences in term of the extent of PCP violations. I hypothesize that there will be more violations after the short sale ban as well as greater degree of violations during the period. I am particularly interested in asymmetric changes in lower and upper bound of the range for equation (4.5) because the replication process is relatively difficult for short positions.

4.3 Empirical results

4.3.1 Violation of put-call parity in different periods

I perform an empirical analysis of equation (4.2) for options with different levels of moneyness and time to maturity. Figure A.2 plots the deviation of observed stock prices as a percentage of implied stock prices derived using equation (4.2) over the (-90, 90) day window for at-the-money options with different times to maturity. I call this the deviation ratio. If put-call parity holds over the short sale ban period, we should see the deviation ratio remain stable and trivial for both control and banned firms.

Without considering transaction costs (i.e., the bid-ask spread), there is a relatively large spike for banned firms right after announcement of the short sale ban while the ratio for control firms remains stable. The deviation ratio for both groups fluctuates in terms of frequency and magnitude after the short sale ban announcement, especially for options with longer time to maturity. One interesting finding is that the deviation ratio on banned firms is higher than zero even before the short sale ban policy, suggesting that stock prices might be persistently overvalued.

I then run a pooled regression model of the deviation ratio on a ban window dummy variable and banned stock interactions by exchange using the data for windows (-90, 19) and (-2, 90). The first window allows comparison of the deviation ratio for the pre-ban window (-90, -3) and the ban window (-2, 19). The second window allows comparison of the deviation ratio between the ban window (-2, 19) and the post-ban window (20, 90). The pooled regression is written as :

(4.6) $$DR_{i,t} = a + a_1 * IMPOSED + a_2 * IMPOSED * BANNED + a_3 * REMOVED + a_4 * REMOVED * BANNED + \varepsilon_{i,t}$$

where DR is the deviation ratio, the dummy variable *IMPOSED* equals one if the date falls into the ban imposed window, and zero otherwise; the dummy variable *BANNED* equals one if a given stock is a banned stock, and zero otherwise; the variable *REMOVED* equals one if the date falls into the ban removal window, and zero otherwise.

Table B.14 shows the results for options with different levels of moneyness and time to maturity. Panel A describes the deviation ratio for at-the-money options with long times to maturity. Panel A.1 shows a much higher deviation ratio for the banned firms, and the difference of 2.53% between the two groups is significant with a t-statistic of 3.41, indicating that the short sale ban seems to have had a tremendous impact on financial firms. Panel A.2 shows that after elimination of the short sale ban, deviation ratios for both firm groups rose, which might be partially attributable to the fact that investors in longer time to maturity options are more subject to arbitrage limits or higher liquidity risk.

Panel B of Table B.14 reports deviation ratios for at-the-money options with intermediate times to maturity. The differences in deviation ratios for both groups are significant for both periods, but, deviation is much smaller for both groups after elimination of the short sale ban. Panel C of Table B.14 shows even less of a significant difference in deviation ratios for both firm groups with short time to maturity options.

Next, I examine the frequency of observations with deviation ratio (DR < 0) less than zero, i.e., actual stock prices lower than implied stock prices before, during and after the short sale ban. Following Ofek, Richardson and Whitelaw (2004), I do not impose any theoretical assumption but would expect to see an uniform distribution of deviation ratios over time. In fact, Table B.15 shows the opposite.

Panel A shows far more deviation ratios greater than 0 than less than 0, suggesting a skewed distribution over the sample in the pre-ban and post- ban period for both firm groups. Statistical tests of positive normal approximation to the binomial distribution further suggest that firms with short sale constraints are more likely to experience positive deviation of observed stock price from fundamental price : 73.11% vs. 56.16% for pre-ban period and 65.84% vs. 47.50% for the ban period. Results are similar in the other as well. One thing worth noting is that deviation ratios greater than 0 occurred less often during the ban period for both groups, which seems to be contradictory to the hypothesis that a short sale ban will have a negative impact on the put-call parity.

In a further examination of violation of put-call parity, I include the bid-ask spread to calculate the upper and lower bound of implied stock prices using equations (4.3) and (4.4). Put-call parity is unlikely to be violated if observed stock prices fall in the range described in equation (4.5).

Table B.16 shows the distribution of put-call parity violation over different time periods for banned and control firms. Results here are consistent with those in Table B.15. The distribution of put-call parity violation is asymmetrical; many more observations show stock prices above the upper bound, suggesting that observed stock prices over time are higher than implied stock prices derived from put-call parity except for in-the-money options, which show a different pattern for the violations. Similar to the findings in Table B.15, there are fewer violations during the short sale ban period for both control and banned firms.

Table B.17 reports the distribution of deviation ratios for at-the-money options for 90 days before and after the ban announcement. One can see that the skewness of the violation increases along with time to maturity for banned firms. Medians are 0.56, 1.50, and 2.51, from short to long, suggesting that maturity effect might play a role in violation of put-call parity when there is a restriction on sale of the underlying assets, as there is no dramatic change in the extent of violation for control firms.

This result is consistent with findings in Ofek, Richardson and Whitelaw (2004) that limits to arbitrage cause an asymmetrical shift to the right tail of the distribution for longer time to maturity options. For example, the 1st percentiles of the stock price ratios are relatively stable at -10.25%, -7.42% and -8.07% for short, intermediate and long time to maturity, respectively. The 99th percentile values increase to 13.85%, 14.58% and 23.86% for short, intermediate and long time to maturity, respectively. Although I find the same result for the control firms, the effect is weaker.

4.3.2 Regression analysis: determinants of violation of put-call parity

4.3.2.1. Deviation of put-call parity and the short sale ban

The regression model takes into account firm and time effects in order to mitigate the problem of heterogeneity. T-statistics are recalculated by using estimated clustered standard deviations.

Table B.18 reports a multivariate regression analysis of deviation ratios on the ban dummy variable, post-ban dummy variable, other control variables and the interaction effects of control variables with the firm dummy variable. Examination includes percentage bid and ask spread across calls and puts, daily option volumes averaged across calls and puts, open interest averaged across calls and puts, the ratio of implied volatility on puts over calls, the ratio of open interest on puts over calls, moneyness of the options and time to maturity in years, with the logarithm of daily stock trading volume and daily stock returns as control variables. The first three control variables are treated as proxies for liquidity in the options markets. The next four variables describe the characteristics of the options. I include stock returns and trading volume to control for impact of the stock market on the options market.

Model 1 of Table B.18 reports the regression results without including any dummy variables. The deviation ratio is positively and significantly related to stock trading volume, stock returns, logarithm of stock price to exercise price ratio and time to maturity, but negatively related to average option volume and ratio of implied volatility on puts over that on calls. Average option spread is not significantly associated with the deviation ratio.

Models 2, 3, 4 and 5 show the regression results without including the interaction effect of firm dummy and control variables. The R squared increases from 11% for model 1 to 12% for models 2, 3, and 4, only a slight change, which still indicates event dummy and firm dummy variables should be included in the regression model. The statistical results of models 2, 3, 4, and 5 show that the short sale ban had negative impact on the deviation ratios of non-banned firms but a positive impact on banned firms.

For instance, for model 2 the coefficient on the ban dummy is -0.621 with a t-statistic of -3.49 (significant at 1%) for control firms. Interaction of the ban event dummy with the firm dummy results in a coefficient of 0.847 (= -0.621 + 1.468) for the effect of the short sale ban on the deviation ratio of the banned firms, suggesting that the short sale ban causes a upward deviation ratio for firms subject to short sale restrictions. The interaction effect between the post-ban dummy and the firm dummy is not significant at the 10% level, suggesting that the banned firms behave no differently from the control firms after lifting of the short sale ban. A negative coefficient of -1.12 with a t-statistic of -4.36 on the post-ban dummy suggests that pessimistic investors drove down stock prices after the removal of short sale ban. This eventually brought the actual stock price closer to the implied stock price derived by PCP.

Models 2, 3, 4 and 5 (2.1, 3.1, 4.1 and 5.1) in Table B.18 describe results without (with) the interaction terms between firm dummy and control variables. R squared increases from 12% to 13%, indicating that interaction terms between the firm dummy and control variables add power to explain variation in the deviation ratios.

Stock trading volume and stock returns are positively related to the deviation ratio for both firm groups in all models. The weaker significance of the interaction term of stock trading volume with the firm dummy in models 2 and 5.1 indicates that trading volume contributes less of incremental effect because of the short sale ban. The interaction term of stock returns with the firm dummy is statistically significant in four models (models 2.1, 3.1, 4.1 and 5.1). It is likely that rising stock returns, which doubled for the banned firms due to the short sale constraints, lead to an upward bias in deviation ratios.

Models 3.1 and 4.1 (without including the option spread and its interaction with the firm dummy) show that the conclusion about the impact of the short sale ban on firms remains the same when including the interaction term of firm dummy with relevant control variables. Models 2.1 and 5.1 reveal another aspect of the effect of the short sale ban when the option spread is as included proxy for liquidity. The ban dummy and its interaction with the firm dummy are not effective variables. Perhaps the option spread subsumes the event effect. That is, the option spread may incorporate more information during the short sale ban for both control and banned firms.

If the short sale ban works to prevent potential short sellers from pushing prices farther down, stock prices will be upward biased because of the prohibition of the short sale. The effect is then transmitted to the options market so that the gap between observed and implied stock prices becomes wider during the short sale ban period. Not surprisingly, after the short sale ban is lifted, investors are able to adjust prices downward through either the stock or the options markets[15].

4.3.2.2. Deviation of put-call parity, liquidity and time to maturity

Kamara and Miller (1995) argue that violations of put-call parity reflect a premium for liquidity risk, which is in line with the efficient market theory. They proxy for liquidity risk the conditional variance of daily returns on the S&P 500 scaled by daily stock volume, and by put volume and by call volume. They also include deviations of stock prices to exercise prices as a percentage of exercise prices as an extra proxy for liquidity risk. Their findings suggest that the greater the liquidity risk, the more the violation of put-call parity.

Behavioral theory, proposed by Ofek, Richardson and Whitelaw (2004), suggests that limits to arbitrage cause prices to deviate from fundamental values under short sale constraints. They use the bid-ask spread, trading volume and open interest as proxies for liquidity of options. Their findings suggest that the greater the liquidity in the options market, the higher the deviation ratio, which they regard as evidence of real put-call disparity.

Both arguments try to relate the level of liquidity with violation of PCP under short sale constraints, but their conclusions are the exact opposite. I try to test these two theories for the short sale ban in a specific time period. The interaction term between firm dummy and control variables as proxies for liquidity risk allows us to test the two theories.

First, pooled regression models (models 1, 2, and 5) show that higher spreads are associated with deviation ratios. After including the interaction effect (models 2.1 and 5.1), the negative association drops tremendously for the banned firms (from -2.432 to -0.41 in model 2.1 and from -2.452 to -0.42 in model 5.1) This seems to be in line with the behavioral theory proposed by Ofek, Richardson and Whitelaw (2004).

One thing worth noting is that the interaction term between the firm dummy and spreads is positively related to the deviation ratio, indicating that the market cannot provide enough liquidity for the banned firms during the short sale ban so the deviation ratio is pushed up mostly by the transaction costs and by the risk that investors must assume in a much more illiquid market while overall the behavioral effect dominates, one should be cautious in interpreting the results. The presence of a significant and negative relation between option spread and the deviation ratio for control firms is a puzzle as control firms are not restricted from short selling either in the stock or the options markets.

Second, the relation between option volume and the deviation ratio is significantly negative (a t-statistic of -4.65 significant at the 1% level) without including interaction terms (model 3). This is in line with the traditional view that higher option volume facilitates the flow of information and reduces liquidity risk. The relation between option volume and the deviation ratio becomes insignificant when we includ the interaction term in model 3.1. The relation between open interest and the deviation ratio is not significant.

Figlewski and Webb (1993) test the hypothesis that the difference between the implied volatility of puts and calls should be positively associated with short interest. This hypothesis assumes that the options market facilitates information flow and induces more short interest in the stock markets. Nilsson (2008) argues that the asymmetric implied volatility between calls and puts can be treated as evidence that short sale constraints are present in the stock market.

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[15] The first essay suggests that options market might lost the function of price discovery during the short sale ban.

Therefore, an indirect approach to test whether the options market delivers a price discovery function is examination of the relation between the ratio of implied volatility of puts over calls and the deviation ratio. A high ratio of implied volatility should be associated with a lower deviation ratio if the options market is still an alternative to get around the short sale constraint.

My finding suggests the relation between relative implied volatility and the deviation ration is negative and significant at the 1% level in all models in Table B.18. The interaction term between relative implied volatility and the firm dummy is not statistically significant in any model. Hence, the higher relative implied volatility could be a result of investors using the options markets as a means to implement short strategies regardless of whether they are allowed to short sell in the stock market.

In addition, Kamara and Miller (1995) and Ofek, Richardson and Whitelaw (2004) both find that time to maturity is positively related to the deviation ratio. In my work, the conclusion is different for control and banned firms when including interaction terms. For instance, the coefficient of time to expiration is negative at the 5% level for control firms, suggesting that the longer the time to maturity, the lower the deviation ratio. Yet, time to maturity is significantly and positively related to the deviation ratio for banned firms, showing that the cost of arbitrage increases with a longer time to maturity.

One reasonable explanation is that put writers are reluctant to enter long-term contracts when they perceive that downward prices for those banned firms are more likely after the short sale ban is lifted. They might suffer from margin calls if they do so. Therefore, there is lower trading volume or open interest and higher spreads for long-term puts, which might cause a higher deviation ratio.

4.4 Summary

This study take a new tack in examining the effect of a short sale ban by separating sample firms into banned firms with options and non-banned firms with options. The process allows one to analyze the relation between the stock and the options markets under a short sale prohibition. Put-call parity is used to investigate whether there is discrepancy between actual and implied stock prices when a short sale ban is imposed for certain group of firms.

First, univariate analysis indicates that deviation ratios for banned firms respond relatively negatively to the short sale ban. That is, their deviation ratios increase significantly more than those for control firms during the short sale ban and drop after removal. Because higher deviation ratio implies that actual stock prices are higher than the fundamental values of the stock, my finding is consistent with Miller's (1973) argument that stock subject to short sale constraints is overvalued.

Second, multivariate regression analysis allows examination of the determinants of put-call disparity. When I include control variables, regression results remain consistent with the initial conclusion that this short sale ban was an impediment to market efficiency. I must note that it is still inconclusive whether the deviation from fundamental values stems from liquidity risk or investors' misconceptions.

Finally, the longer the time to maturity of options contracts, the higher the deviation ratio for firms subject to the short sale ban. Moreover, higher relative implied volatility suggests that the options market serves the function of price discovery when short sales are forbidden from the stock market.

CHAPTER 5

SHORT SALE CONSTRAINTS AND PRICE DISCOVERY IN THE STOCK AND OPTIONS MARKETS

5.1 Introduction

In previous chapters, I have discussed the impact of short sales on the stock and options markets separately. In a framework of general equilibrium, though, no market is isolated from the overall financial market. I believe that because all financial markets are highly integrated, the stock and options markets have a close relationship. Enactment of several regulations makes it possible to examine how the options market interacts with the underlying asset market. Analysis of a set of banned and non-banned stocks with tradable options enables a test of whether there is correlation between the stock and the options markets and how an information propagation mechanism between them works.

This study differs from previous research (Manaster and Rendleman (1982); Stephan and Whaley (1990); Diltz and Kim (1995)) in that I do not use a model-dependent approach to estimate the implied stock price, but rather I use the implied stock price derived from put-call parity as described in equation (4.2) in Chapter 4. My study is similar in spirit to Puttonen's (1993), which is a study of relation among the stock index, stock option index and stock futures index for Finland markets under the impossibility of short sales in stock market. The empirical result suggests that the options and futures markets lead the stock market over the long run.

To my knowledge so far, my study is the first empirical investigation of interaction between the options market and the stock market under the short sale ban during the financial crisis of 2008.

The rest of the study is organized as follows. Section 5.2 describes methodology. Section 5.3 presents the empirical results. Section 5.4 concludes.

5.2 Methodology

There is a growing consensus that most financial data are not stationary. Thus, before a model is specified, I test for the stationarity of time series data. I use the augmented Dickey-Fuller test, Philips-Perron test and the Zivot-Andrews unit root test with structural breaks to do the unit root test. The notion that stock prices implied by options trading should not deviate far from observed stock prices implies that there is a cointegrating relation. Therefore, I test for a cointegrating relation between two time series.

DK (1996) test the cointegrating relation between actual and implied prices of stocks and fail to reject the hypothesis that both time series are cointegrated. If time series data are cointegrated, then it is reasonable to test for a long-run and short-run equilibrium for both markets. Through this relation, I can examine the contribution of price discovery from each market and the error correction process.

5.2.1 Unit Root Test

5.2.1.1 Dickey-Fuller unit root test

Consider a simple AR(1) model $P_t = \gamma P_{t-1} + \varepsilon_t$,where P_t is the security price, γ is the slope coefficient, t is the time index, and ε is the white noise innovations. Under the null hypothesis that a unit root is present, i.e. $\gamma = 1$, a $DF_r = T(\hat{\gamma} - 1)$ statistic is calculated, with results evaluated according to the critical value derived by Dickey and Fuller. Depending on whether there is a drift or time trend in the model, the Dickey-Fuller statistic table offers three different versions for the critical values.

5.2.1.2 Augmented Dickey-Fuller Test

The augmented Dickey-Fuller test is an extension that will accommodate some forms of serial correlation. The test can be carried out using the model,

$P_t = u + \beta t + \gamma P_{t-1} + \gamma_1 \Delta P_{t-1} + ... + \gamma_p \Delta P_{t-p} + \varepsilon_t$. The random walk form is obtained by imposing u = 0 and β = 0; the random walk with drift has β = 0; and the trend stationary model leaves both parameters free. The test statistic is $DF_t = \frac{\hat{\gamma} - 1}{Est.Std.Error(\hat{\gamma})}$.

The advantage of this formulation is that it can accommodate higher-order autoregressive processes in ε_t, but an alternative formulation may prove convenient. Subtracting P_{t-1} from both sides of the equation, I obtain :

$$\Delta P_{t-1} = u + \gamma^* P_{t-1} + \sum_{j=1}^{p-1} \phi_j \Delta P_{t-j} + \varepsilon_t,$$

where $\phi_j = -\sum_{k=j+1}^{p} \gamma_k, and, \gamma^* = \left(\sum_{i=1} p\gamma_i \right) - 1$. The unit root test is carried out as before by testing the null hypothesis γ^* = 0 against γ^* < 0. The t-test, DF_t, may be used. The lag length, *p*, remains to be determined. I use Akaike information criteria (AIC) to determine the lag length of *p*.

5.2.1.3 Philips-Perron unit root test

Philips and Perron (1988) propose a different test for detecting the presence of a unit root in more general time series models. Their test is similar to augmented Dickey-Fuller tests, but they incorporate an automatic correction to allow for autocorrelated residuals. The test regression model is written as $\Delta y_t = \beta' D_t + \pi y_{t-1} + \mu_t$, where μ_t is I(0) and maybe heteroskedastic . After a complicated construction, they establish a set of Z-statistics such as Z_π, Z_t to test for unit roots under different conditions. Under the null hypothesis of $\pi = 0$, the Phillips-Perron Z_π, Z_t statistics have the same asymptotic distributions as the augmented Dickey-Fuller t-statistic and normalized bias statistics.

5.2.1.4 Zivot-Andrews unit root test with structural break

It is of interest to examine whether there may be a structural break during our time period of data. Zivot and Andrews (1992) provide a different approach to test for unit roots when taking into account structural change. They assume that they do not know exactly when a breakpoint occurs. To test the null hypothesis in a unit root process with drift that excludes any structural change against the alternative hypothesis of a unit root process with drift that includes any structural changes, the unit root equation, $P_t = u + \beta t + \theta DU_t + \gamma DT_t + \alpha P_{t-1} + \sum_{j=1}^{i} c_j \Delta P_{t-j} + \varepsilon_t$ is estimated for each possible break date, $T_{pB,}$ and the statistic $t(\lambda) = \frac{\hat{\alpha} - 1}{Est..Std..Error(\hat{\alpha})}$. The minimum t-statistic among all the t-statistics generated by all possible break dates, T_{PB} corresponds to the date a structural change occurred.

5.2.2 Cointegration test

An (n X 1) vector time series y_t is said to be cointegrated if each of the series taken individually is I(1), that is, non-stationary with a unit root, while some linear combination of the series $a'y_t$ is stationary, or I(0), for some non-zero (n X 1) vector *a.* Cointegration means that although many developments can cause permanent changes in the individual elements of y_t, there is some long-run equilibrium relation linking the individual components, represented by the linear combination $a'y_t$. For instance, in the financial markets, arbitrage between stocks and options implies that the actual stock prices will be connected to theoretical stock prices. Diltz and Kim (1996) perform a cointegration test between actual and implied stock prices, they find all cases fail to reject the null hypothesis of cointegration, suggesting there is a permanent long-run relation between the two time series data.

I use the Johansen methodology (1988, 1991, 1992a, 1992b,1994) to test whether there is a cointegrating relation between observed stock prices and implied stock prices derived using the put-call parity model. The Johansen methodology is based on a vector autoregressive (VAR) model of order p given by equation (5.1)

$$(5.1) \qquad P_t = u + A_1 P_{t-1} + ... + A_p P_{t-p} + \varepsilon_t , ,$$

where P_t is an n X 1 vector of variables that are integrated of order one, i.e., I(1), and ε_t is an n X 1 vector of innovations.

This VAR can be written as :

$$(5.2) \qquad \Delta P_t = u + \prod P_{t-1} + \sum_{i=1}^{p-1} \Gamma_i \Delta P_{t-i} + \varepsilon_t$$

where $\prod = \sum_{i=1}^{p} A_i - I$, and $\Gamma_i = -\sum_{j=i+1}^{p} A_j$

If the coefficient matrix $\prod$ has reduced rank r < n , then there are n X r matrices α and β each with rank *r* such that $\prod = \alpha\beta'$ and $\beta' P_t$ is stationary. *r* is the number of cointegrating relation. The elements of α are known as adjustment parameters in the vector error correction model, and each column of β is a cointegrating vector. It can be shown that for a given *r*, the maximum likelihood estimator of β defines the combination of P_{t-1} that yields the *r* highest canonical correlation of ΔP_t with P_{t-1} after correcting for lagged differences and deterministic variables when present.

Johansen proposes two different likelihood ratio tests of the significance of these canonical correlations and thereby the reduced rank of the $\prod$ matrix: the trace test and the maximum eigenvalue test shown in equations (5.3) and (5.4) :

$$(5.3) \qquad J_{trace} = -T \sum_{i=r+1}^{n} \ln(1 - \hat{\lambda})$$

$$(5.4) \qquad J_{\max} = -T \ln(1 - \hat{\lambda}_{r+1})$$

where *T* is the sample size and $\hat{\lambda}_i$ is the *i*th highest canonical correlation. The trace test tests the null hypothesis of *r* cointegrating vectors against the alternative hypothesis of *n* cointegrating vectors. The maximum eigenvalue test tests the null hypothesis of r cointegrating vectors against the alternative hypothesis of $r + 1$ cointegrating vectors.

5.2.3 Price discovery: A VECM approach

A vector error correction model (VECM) is conducted to simultaneously examine the relation between actual underlying asset prices and implied stock prices derived from put-call parity in the long run and the short run. My particularly focus is the long-term and short-term relation between the stock and the options markets when financial markets have undergone turmoil and several different financial althernatives have taken place, including removal of the uptick rule, a temporary short sale ban.

I interpret the policy changes as shocks from one financial market to the other, and examine how information propagation mechanism works across the two markets. If the stock and the options markets are highly related and cointegrated, then there is either a bilateral information flow or a lead-lag relation in the two markets. To examine the relation properly, there are two widely accepted approaches to investigate the mechanics of price discovery: Hasbrouck's (1995) information share (IS) model and Gonzalo and Granger's (1995) permanent-transitory (PT) model.

Although they are based on the same model, i.e., vector error correction model, Hasbrouck's (1995) information share (IS) model and Gonzalo and Granger's (1995) permanent-transitory (PT) have different definitions of price discovery. Hasbrouck defines price discovery as the variance of innovation from the common factor. Gonzalo and Granger focus on the error correction process, i.e., the long-run equilibrium. They estimate the contribution of each market to the common factor in terms of correcting market disequilibrium.

5.2.3.1 Information share model (IS)

Stock and Watson's (1988) common trends representation of the vector error correction model is as follows :

$$p_t = p_0 + \psi(\sum_{i=1}^{t} \varepsilon_i) + \Psi(L)\varepsilon_t \quad (5.6)$$

where p_0 is a constant n-vector and $\Psi(L)$ is a matrix polynomial in the lag operator. The first term on the right-hand side of equation (5.6) is a vector of initial values that may reflect non-stochastic differences between price variables. The second term is the product of a scalar random walk and a unit vector, which captures the random walk component that is common to all prices. The third component is a zero-mean covariance stationary process.

Hasbrouck (1995) proposes that it is possible to decompose the variance of the common trends representation of equation (5.6), which includes a single random walk term that is common to all prices. He argues that the increment $\psi\varepsilon_t$ is the component of the price change that is permanently impounded into the security prices and is presumably due to new information. The variance term of this term is $\psi\Omega\psi'$. Then he further posits that the portion of the variance explained by each market is the IS of market *j*. The IS measures the portion of a subset of the market's information that is impounded into prices by different markets trading the same underlying security.

The IS is described as follows:

$$IS_j = \frac{\psi^2 \Omega_{jj}}{\psi\Omega\psi'} \quad (5.7)$$

where ψ_j is the *j*th element of ψ. Normalization ensures that the information shares sum to unity.

If price innovations are correlated across markets, Ω will not be diagonal, and equation (5.7) will not be appropriate to estimate the information share. Therefore, the original variance structure is modified by imposing *F*, which is a Cholesky factorization and a lower triangular matrix such that $\Omega = FF'$. The modification takes the following form:

$$IS_j = \frac{([\psi F]_j)^2}{\psi \Omega \psi'} \tag{5.8}$$

where $[\psi F]_j$ is the *j*th element of the row matrix ψF. The factorization imposes a hierarchy that maximizes the information share for the first price and minimizes the information share for the last price. By permuting the order of the market prices, equation (5.8) will provide an upper and a lower bound for the information share of each market.

5.2.3.2 Permanent-transitory model (PT)

Gonzalo and Granger (1995) raise an important question of how to estimate the common factor, which might be an unobserved factor and yet the driving force that results in cointegration. They argue it matters for us to recover this common factor because (1) economists or policy makers are usually interested in the long-run behavior of a large macroeconomic system, and (2) decomposition allows us to study how different information is conveyed through different components and (3) a study of common factors will allow us to investigate how they are related to other variables.

Let X_t be a (p X 1) vector of I(1) time series with mean 0, and assume that the rank of cointegration is *r* , it follows that the vector of X_t has an ECM representation:

$$\Delta X_t = \underset{pXr}{\gamma} \underset{rXp}{\alpha'} X_{t-1} + \sum_{i=1}^{\infty} \Gamma_i \Delta X_{t-i} + \varepsilon_t \tag{5.9}$$

where $\Delta = I - L$, with *L* the lag operator.

Gonzalo and Granger further say that the elements of *X* can be explained in terms of a smaller number (p - r) of I(1) variables, f_t, called common factors plus some I(0) components:

$$X_t = A_1 f_t + \tilde{X}_t, \tag{5.10}$$

where X is a (p x 1) vector, A is a (p x k) vector, f_t is a (k x p) vector and $\tilde{X}$ is a (p x 1) vector with I(0) process. Two conditions are imposed:

(i) f_t is an exact linear function of the current value of X_t,

(5.11) $$\underset{k\times 1}{f_t} = \underset{k\times p}{B_1} \underset{p\times 1}{X_t}$$

(ii) The transitory component, $\tilde{X}$, has no permanent effect on X_t such that

(5.12) $$\tilde{X}_t = A_2 z_t,$$

where $z_t = \alpha' X_t$

These conditions make it possible to identify the common factor and also make the common efficient prices f_t observable. More conveniently, Gonzalo-Granger decomposition can be carried out using equation (5.10) and the B_1 matrix can be estimated, as the Johansen procedure takes care of the unit root and cointegration. B_1 becomes a natural measure of the contribution to price discovery of market *j*. The higher the weight, the greater the contribution of the market to the information impounding process.

5.3 Empirical results

5.3.1 Unit root tests and cointegration tests

5.3.1.1 Unit root tests

The first objective is to test whether the price series for both banned and non-banned firms are stationary. I do not test the hypothesis for each individual firm but rather use value-weighted prices of the firms. Therefore there are four value-weighted price series, on actual stock price and implied stock price for banned firms and non-banned firms.

Table B.19 reports the results of unit root tests using augmented Dickey-Fuller Z(ADF), Philips-Perron and Zivot-Andrews (ZA) test for both actual and implied stock price series from January 1, 2007, through December 31, 2008. I use the Akaike information criterion (AIC) to determine the number of lags for each model.

The ADF and Philip-Perron tests both suggest that the null hypothesis of a unit root cannot be rejected at the 10% significance level for the time series of actual and implied prices of banned firms regardless of time to maturity and moneyness. The ZA test, however, indicates that the hypothesis of a unit root is rejected at the significance level of 10% for most of the price series of the banned groups, suggesting that inclusion of the short sale ban is critical to determine whether the series is stationary or not, although this is weak significance[16].

The unit root hypothesis is rejected for all the price series of the non-banned firms regardless of time to maturity and moneyness. Overall, I conclude that the price series of banned firms are I(1).

5.3.1.2 Cointegration tests

Another objective is to test whether there is a common factor present between the stock and option markets so that any divergence of actual and implied stock prices will not last over the long run. That is, is there an invisible hand that aligns the two markets even though the price series is non-stationary? To check whether there is a cointegrating relation between stock and options markets, I perform Johansen rank test for the banned firms. Since the price series of non-banned firms is stationary, they are not included in the test.

Part A of Table B.20 reports the results of a Johansen rank test for the price series of the banned firms with different times to maturity and levels of moneyness (at lags of 3 for all series). All the trace statistics of all price series are higher than the critical value at a significance level of 1%, indicating rejection of the null hypothesis that there is no cointegrating vector between actual and implied stock prices. The second trace statistics of all the price series are less than the critical value at the 10% significance level, indicating that the null hypothesis of one cointegrating vectors cannot be rejected.

[16] The result from the Zivot-Andrews test shows there is a structural change in most of the price series, and it occurs around the time of the short sale ban. Some series have a break on the first day of the short sale ban, some at the end of the ban.

5.3.2 Empirical results for vector error correction model

The starting point is the same for both the information share model and permanent-transitory model to assess the contribution of price discovery in the two financial markets. Model development is based on a vector error correction model.

The Johansen rank test indicates that there is one common factor between the options and stocks of banned firms. Therefore, I construct a vector error correction model as follows:

$$\Delta p_t^{option} = a_0^{option} + \alpha^{option}(\gamma^{option} p_{t-1}^{option} + \gamma^{option} p_{t-1}^{stock}) + \sum_{i=1}^{3} \Gamma_i^{option} \Delta p_{t-i}^{option} + \sum_{i}^{3} \Gamma_i^{stock} \Delta p_{t-i}^{stock} + \varepsilon_t^{option}$$

$$\Delta p_t^{stock} = a_0^{stock} + \alpha^{stock}(\gamma^{stock} p_{t-1}^{stock} + \gamma^{stock} p_{t-1}^{stock}) + \sum_{i=1}^{3} \Gamma_i^{stock} \Delta p_{t-i}^{stock} + \sum_{i}^{3} \Gamma_i^{stock} \Delta p_{t-i}^{stock} + \varepsilon_t^{stock}$$

where Δ is the first difference operator; a_0^j is the constant term for *j*, where *j* = option, stock; α^j measures the extent of the *j*th market response to a deviation from the equilibrium relation, also known as the cointegrating vector, and γ^j is the common factor weight contributed by the *j*th market. Following the Johansen rank procedure, I estimate the γ and α coefficients of the equations without imposing any restriction on the γ matrix.[17]

Table B.21 shows the normalized coefficient of the cointegrating vector for the two price series (implied stock price and actual stock price) of the banned firms with different times to maturity and levels of moneyness. The estimates of alphas on actual stock price show a relatively low coefficient regardless of time to maturity and level of moneyness, suggesting that the stock market might not respond to deviation in the equilibrium relation. On the other hand, the estimates of alphas are higher in the option equation, indicating that the options market is likely to respond significantly to adjustment of the equilibrium relation. For instance, the alphas estimates are 0.995 and 0.098 for intermediate term at-the-money options and stock equations.

[17] I test for the hypothesis that one or more variables should not enter the cointegrating vector, and the likelihood ratio fails to reject the null hypothesis for both of the price series. Therefore, I do not impose any restrictions on the cointegrating vector.

5.3.3 Empirical results for information share (IS) and permanent-transitory (PT) models

It is straightforward to ask further how the two financial markets contribute individually to the price discovery of underlying assets. I use information share (IS) and permanent-transitory (PT) model to answer this question. As I have noted, although IS and PT models are derived from Stock and Watson's (1988) common trends representation, the decompositions take place in a different manner. Are the estimations equivalent to each other? How do we reconcile the two models if the results differ?

Baillie et al. (2002) and de Jong (2002) compare the results of IS and PT models using calibration and real-world data to investigate this issue. They conclude that as long as the error terms of the VECM equations are not correlated, the conclusions from IS and PT models will be consistent regardless of the order of permutation in the Cholesky factorization.

The correlation between two prices series reported in Table B.22 can be as high as 99%. According to Hansbrouck (1995), upper and lower bounds of information shares can be constructed by placing the price series in different orders on a Cholesky factorization. As the numbers are quite different, I then further calculate the midpoint of the information share for each market.

Panels A and B of Table B.23 document the results for the information share model with actual stock prices ordered in the first place and second place of the Cholesky matrix, respectively. For instance, the upper and lower bounds of information share provided by the stock market to the options market are (95%, 21%), (99%, 7%), (98%, 51%), (91%, 2%) and (93%, 38%) for intermediate-term ATM, intermediate-term ITM, intermediate-term OTM, short-term ATM and long-term ATM options.

I follow Baillie et al. (2002) in using the midpoint of the upper and lower bounds as a unique measure of the price discovery contribution. Therefore, Panel C presents the average estimation of the daily information share contribution from each market. The results show that the stock market is the primary provider of price discovery in all cases except for short-term at-the-money options.

Gonzalo and Granger (1995), however, assert that only the permanent factor has an impact on a price series in the long run. They are interested in finding the common factor and decomposing it to see how each market contributes to the error correction process. Assuming cointegrating relation between the stock and the options markets, the error correction term is considered to align the two prices so that the price will not deviate from the fundamental value in the long run.

Following Gonzalo and Granger (1995), I then model the common factor as a linear combination of the two price series and estimate the eigenvalue vector of the permanent component for the model. The results after normalization are shown in table B.24[18]. Without considering any correlation between the two markets, the PT model suggests that the stock market strongly dominates the error correction term in all cases. For example, on average, the stock market contributes 91% to formation of the common factor component in the case of intermediate term at-the-money options. Although factor weight estimates from the PT model might be overestimated, the results are consistent with that of the IS model.

Although there is no cointegrating relation between the two price series for non-banned firms, the Granger causality test results shown in Panel B of Table B.20 based on the VAR model also consistently suggest that we can reject the null hypothesis that the stock market does not granger-cause the options market in three out of five cases. Therefore, the stock market still dominates price discovery for non-banned firms.

[18] The PT model does not impose any restrictions to prevent a negative sign for the common factor weight, and the size of the weights is actually the main concern here. So I calculate the weight of each price series in the common factor model by dividing the absolute value of the coefficient on price series *j* by the sum of the coefficients of the two price series, *j* = implied, actual price series.

5.4 Summary

The literature provides mixed results regarding the lead-lag relation between spot and derivatives markets. I contribute to this literature by investigating the price discovery process in the stock and the options markets under current financial situation turbulence and imposition of regulatory rules. I use information share and permanent-transitory models to estimate the contribution to price discovery from each market.

Unit root tests are used to examine whether the price series is stationary. The primary results suggest that price series of banned firms are not stationary and therefore an I(1) process is present. The price series for control firms are stationary, however. This result might be time-specific and must be interpreted cautiously. The focus is on the banned firms in the cointegration test and vector error correction model analysis.

Johansen rank tests suggest there is one cointegrating relation between stock and options markets for banned firms, and a VECM further concludes that the stock market is likely to have led the options market during the financial crisis period. IS and PT models results are consistent with the conclusion of the VECM that the stock market contributes the most to the price discovery.

CHAPTER 6

SUMMARY AND CONCLUSION

Before the meltdown of Wall Street in 2008, the removal of the long-standing uptick rule symbolized that the deregulation of US stock markets had reached a milestone. Market players were able to participate fully in the stock market regardless of their expectations of the market. With the collapse of some financial institutions and fragility in the banking system came some government intervention in order to prevent a financial market crash. A short sale ban was one of the regulations adopted worldwide during this period, and there has been some thought of restoring the uptick rule.

There are different opinions and considerable debate regarding this matter. Some observers are concerned with ethics and social justice. Others are more concerned with market efficiency. This dissertation examines the subject from the viewpoint of market efficiency. In three separate but related essays I examine the issue through the stock market, the options market and the interrelationship of the two financial markets.

In the first essay (chapter 3), I investigate the impact of the short sale ban on stock prices and the relation among stock returns, the short sale ban and divergence of opinion. I construct a unique group of control firms that are similar to "banned firms" (firms that could not be shorted) in size and degree of divergence of opinion. Several groups of stocks with options traded are created to further analyze the impact of the short sale ban in different ways. An event study shows significant positive cumulative abnormal stock returns which might indicate overvaluation for the banned firms during the short sale ban. Cross-sectional multivariate regression analysis suggests that the market's inability to allow different beliefs is the driving force behind stock overvaluation.

The second essay (chapter 4) focuses primarily on market efficiency and put-call parity, using optioned firms from the first essay. Implied prices for each stock over the sample period are derived based on put-call parity. Optioned stocks are grouped in times to maturity and levels of moneyness in order to examine the individual impacts of the short sale ban. I find a significant difference between actual and implied stock prices for banned and control firms during and after the short sale ban, although determinants of the discrepancy are inconclusive.

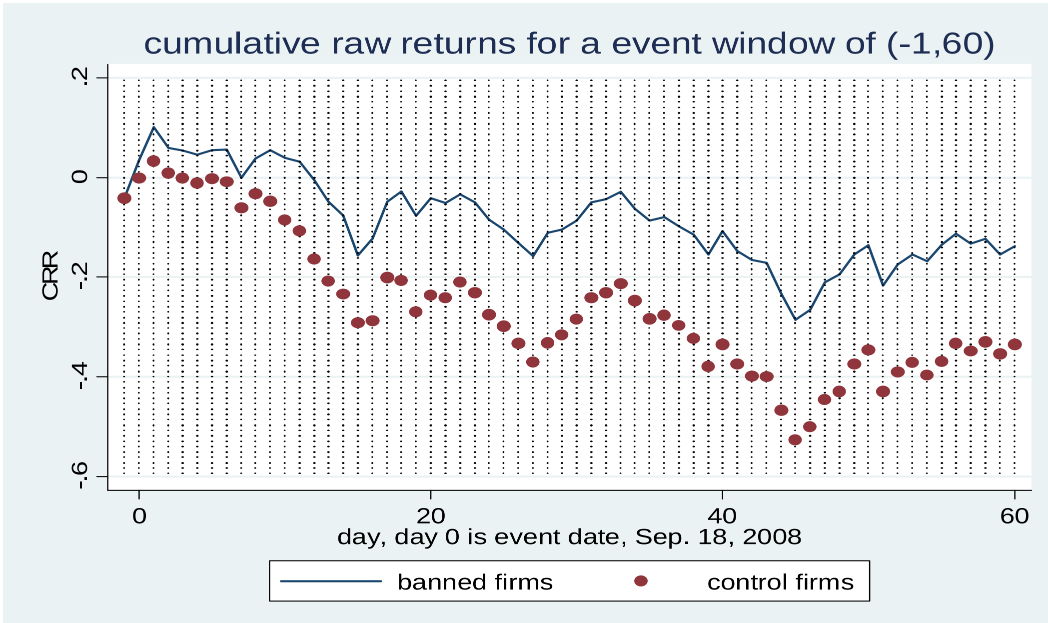
Finally, the third essay (chapter 5) examines the dynamic relation between stock and options markets between January 2007 and December 2008. The main objective is to decompose the process of price formation and figure out the contribution of each market to price discovery of the underlying assets. A vector error correction model is applied to measure interrelationship of the price series over the period. The result indicates that stock and options markets for banned firms are interconnected through a common factor. Two different decomposition methods show that the stock market dominates in the price discovery process.

Overall, I have shed some light on the impact of short sale constraints in market efficiency and the relation between stocks and options. The overall impact of the short sale ban was quite negative in terms of market efficiency. Although the chaos seems under control in the short run, we know market eventually adjust according to investors' expectations once any ban is lifted. Therefore, imposition of a rule is likely to be counter-productive when market participants hold fast to their beliefs and bet against the market.

Other striking evidence has to do with the cointegrating relation between stocks and options. An individual market might seem to behave randomly but jointly the two markets (stock and options) actually help financial markets to achieve equilibrium in the long run even at times of financial crash.

APPENDIX A

FIGURES



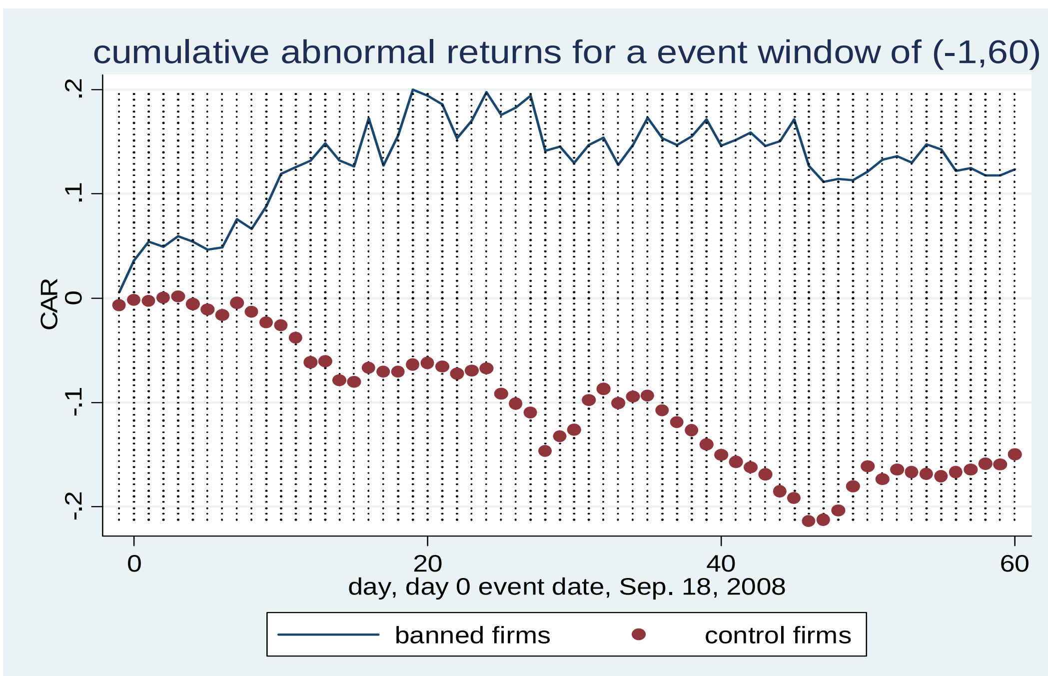


Figure A.1: Comparison of returns around the short sale ban announcement for banned and control firms.

First graph is cumulative raw returns calculated from the event window of (-1, 60) for banned firms and control firms. Second graph is cumulative abnormal returns calculated from the event window of (-1, 60) for banned firms and control firms. The market model is used to calculate abnormal returns. Weighted value returns from all CRSP firms as the market rate of returns.

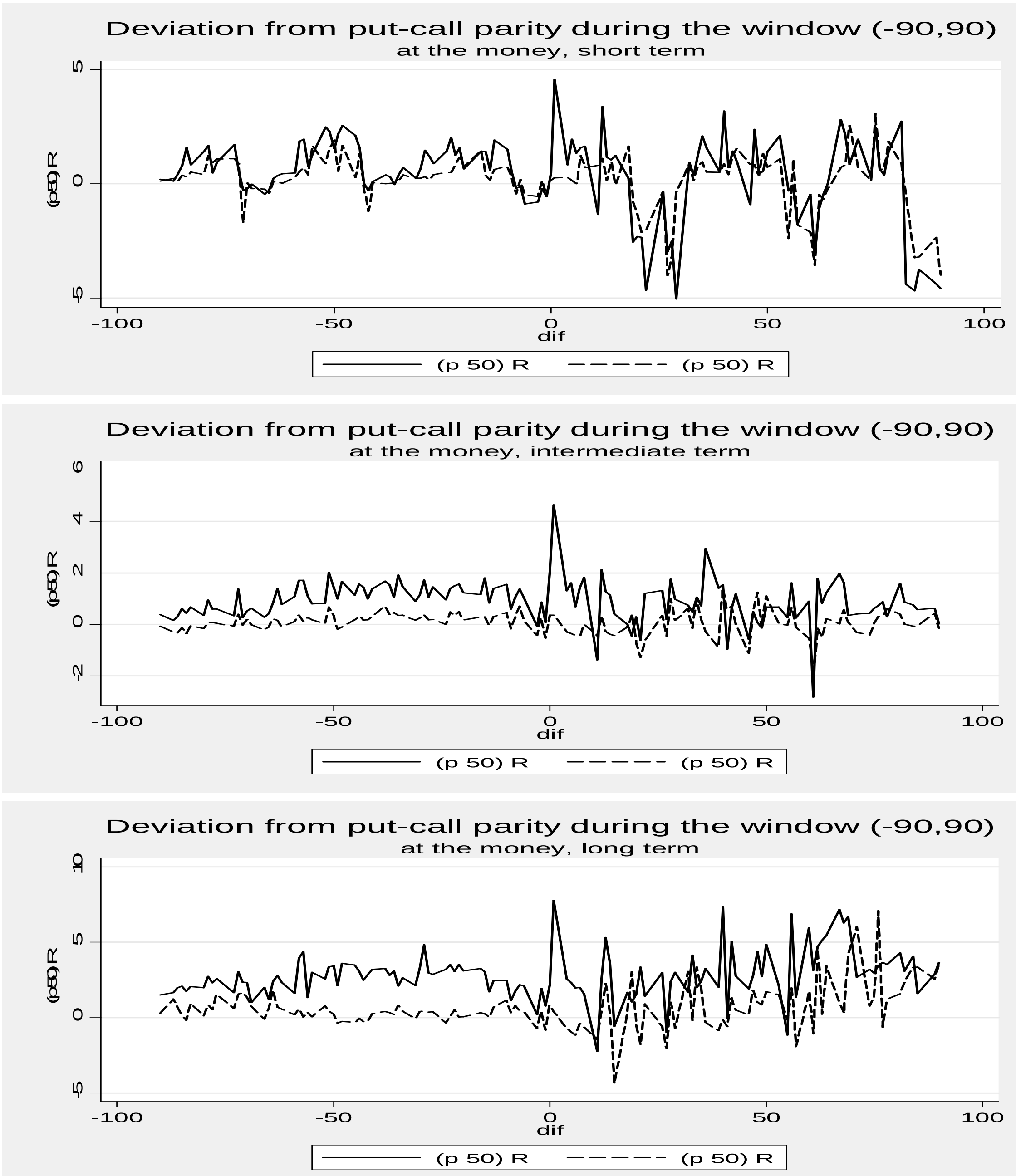


Figure A.2: Deviation from put-call parity during the window (-90, 90).
Median deviation of observed stock prices from implied stock prices as a percentage of the implied stock price for at-the-money option pairs at different times to maturity. The solid line represents banned firms; the dashed line represents control firms.

APPENDIX B

TABLES

Table B.1

Firm Characteristics before the short sale ban

The banned financial firms are matched with control firms on the basis of two firm characteristics: market value of equity as of the end of 2007 and standard deviation of daily raw returns for a 90-day window ending 30 days prior to the short sale ban. The standard deviation of analyst earnings forecast is calculated for the forecasts disclosed at the end of July 2008. Turnover ratio is the average of daily trading volume scaled by share outstanding for the 90-day estimation window ending 30 days preceding the short sale ban. Obs is the number of observation for each firm variable. Diff is the difference in firm characteristics between two firm groups. Numbers in parentheses in Panel B are the numbers of observation within each group. *, ** and *** indicate 10%, 5% and 1% level of significance.

Panel A: difference in firm characteristics between banned and control firms

	Obs	Banned firms	Obs	Control firms	Diff(control - banned)
Market value of equity (in millions of dollar)	724	2646.049	544	3188.561	542.5118
t-statistic					0.6967
Returns (%)	724	-0.0865	544	0.01708	0.10357
t-statistic					5.6383***
Standard deviation of daily return(%)	724	3.94157	544	3.78434	-0.15724
t-statistic					-1.2568
Standard deviation of analysts forecast (%)	204	7.48529	196	4.92857	-2.55672
t-statistic					-1.5468
Turnover ratio	724	0.006226	544	0.0066432	.000417
t-statistic					0.9000
Standard deviation of turnover ratio	724	0.005261	544	0.0054625	.0002018
t-statistic					0.5345

Table B.1 (continued)

Panel B: difference in firm characteristics between optioned and non-optioned firms within each firm group

	Banned			Control		
	Optioned	Non-optioned	Diff(non-optioned - Optioned)	Optioned	Non-optioned	Diff(Non-optioned - optioned)
	8123.055	584.3629		9376.507	423.7342	
Market value of equity (in millions of dollar)	(198)	(526)	-7538.69	(168)	(376)	-8952.773
t-statistic			-5.4302***			-4.5185***
	-0.104	-0.04		0.02458	0.01373	
Return(%)	(198)	(526)	0.064	(168)	(376)	-0.01085
t-statistic			2.4788***			-0.4036
	4.207	3.842		2.87447	4.19088	
Standard deviation of daily return(%)	(198)	(526)	-0.365	(168)	(376)	1.31641
t-statistic			-1.8611*			7.9809***
	12.973	4.4275		6.42857	3.62857	
Standard deviation of analysts forecast(%)	(73)	(131)	-8.545	(91)	(105)	-2.800
t-statistic			-2.4831**			-1.4638
	1.5606	0.2695		1.24165	0.40637	
Turnover ratio(%)	(198)	(526)	-1.291	(168)	(376)	-0.83528
t-statistic			-15.524***			-12.9328***
	1.0563	0.3265		0.76018	0.45066	
Standard deviation of turnover ratio (%)	(198)	(526)	-0.73	(168)	(274)	-0.30952
t-statistic			-8.7875***			-6.0269***

Table B.2

Changes in sample characteristics around the short sale ban period

Time series regression of cross-sectional average with Newey-West standard errors for firm characteristic variables on an intercept term (not reported) and event dummy variable. The event dummy variable equals one from September 18, 2008, to October 7, 2008, and zero otherwise. The Diff variable reports the coefficient of the event dummy variable for the banned and the control firms. The Diff – Diff column reports the event dummy variable coefficient from a time series regression of the difference between banned and control firms for each variable on an intercept (not reported) and the event dummy variable. *, ** and *** indicate 10%, 5% and 1% level of significance. Numbers of lags up to 20 days to is used to compute the Newey-West standard errors.

	Banned			Control			
	Pre	Ban	Diff	Pre	Ban	Dif	Dif- Diff
Panel A: Pre- and Ban period							
Number of trades	1345.27	1191.52	-153.75	2219.42	2470.39	250.96**	-180.62**
Trading volume (in thousands of shares)	1799.89	2741.87	941.98***	822.27	1052.36	230.09***	1088.86***
Turnover ratio (%)	0.677%	0.724%	0.047%	0.677%	0.819%	0.142%***	0.009%
	Banned			**Control**			
	Ban	Post	Diff	Ban	Post	Diff	Diff - Diff
Panel B: Post- and Ban period							
Number of trades	1191.52	1286.59	-95.07	2470.39	2257.13	213.25	-77.85
Trading volume (in thousands of shares)	2741.87	1875.57	866.30***	1052.36	1032.10	20.27	1095.88***
Turnover ratio (%) %	0.724%	0.596%	0.128%	0.819%	0.766%	0.054%	0.166%***

Table B.3

Short interest related variables before, during and after the short sale ban event

Short interest is average total shares sold short. Relative short interest is defined as short interest scaled by outstanding shares. Insider holding is the ownership of insiders scaled by shares outstanding. Institutional holding is the ownership of institution s scaled by share s outstanding. Diff is the average difference of the particular variable between control firms and banned firms. *, ** and *** indicate the 10%, 5%, and 1% level of significance.

		9/10/2008			9/25/2008			10/9/2008			10/28/2008		
		Banned	Control	Diff	Banned	Control	Diff	Banned	Control	Diff	Banned	Control	Diff
Short interest	in shares	6418648	3516916	-2901732	4537435	3090074	-1447361	3907619	2844188	-1063431	3840526	2699065	-1141460
t-statistic				-2.86***			-2.28**			-2.00**			-2.11**
Relative short interest	%	5.1697	4.7203	-0.449	4.37112	4.32140	-0.050	3.70823	3.86328	0.155	3.5049	3.5559	0.051
t-statistic				-1.10			-0.14			0.49			0.17
Insider holding	%	21.034	23.651	2.617	21.7048	24.2655	2.561	21.8743	24.7582	2.884	21.951	25.571	3.620
t-statistic				2.16**			2.07**			2.32**			2.87***
Institutional holding	%	36.089	45.290	9.201	35.9138	44.9708	9.057	35.7087	45.2973	9.589	35.824	44.322	8.498
t-statistic				5.22***			5.06			5.38***			4.78***

Table B.4
Average returns around the short sale ban event date

The pooled regression of daily raw return on an announcement window dummy variable and banned stocks interaction by exchanging for window (-90, 19) and window (-2, 90); $R_{i,t} = a + a_1 \cdot IMPOSED + a_2 \cdot IMPOSED\ BANNED + a_3 \cdot REMOVED + a_4 \cdot REMOVED\ BANNED + \varepsilon_{i,t}$, *IMPOSED* equals one if the date falls into the ban imposed window, and zero otherwise. Dummy variable *BANNED* equals one if a given stock is a banned stock, and zero otherwise. *REMOVED* equals one if the date falls into the ban removal window, and zero otherwise. In Panel A.1, the banned column reports average returns for banned stocks during the announcement window, $a + a_1 + a_2$; the control column reports the same measures for control stocks, $a + a_1$; and the Diff column reports the difference between the two, a_2. In Panel A.2, the banned column reports average returns for banned stocks during the ban removal window, $a + a_3 + a_4$; the control column reports the same measures for control stocks, $a + a_4$; and the Diff column reports the difference between the two, a_4. Regression standard errors are calculated using a cluster regression model including firm and time effects. *, ** and *** indicate the significance level of 10%, 5% and 1%.

Panel A: Entire samples

	Panel A.1: Ban imposed period			Panel A.2: Ban removed period		
	Banned	Control	Diff	Banned	Control	Diff
Average daily return (t - 2, t + 19)	0.241	-0.806	1.047			
t-statistic			2.54**			
Average daily return (t + 17, t +21)				-3.306	-2.850	-0.456
t-statistic						-0.5

Panel B: Optioned firms

	Panel B.1: Ban imposed period			Panel B.2: Ban removed period		
	Banned	Control	Diff	Banned	Control	Diff
Average daily return (t - 2, t + 19)	0.292	-1.150	1.442			
t-statistic			1.36			
Average daily return (t + 17, t + 21)				-4.587	-2.520	-2.067
t-statistic						-0.87

Table B.4 (continued)

	Panel C: Non-optioned firms					
	Panel C.1: Ban imposed period			Panel C.2: Ban removed period		
	banned	control	Diff	Banned	control	diff
Average daily return (t - 2, t + 19)	0.224	-0.653	0.877			
t-statistic			3.57***			
Average daily return (t + 17, t + 21)				-2.823	-2.996	0.173
t-statistic						0.30

Table B.5

Average cumulative raw return for different event windows

Columns 1 and 2 of panel A reports the average cumulative raw returns for banned and control firms individually in different event window. Column 3 of Panel A reports the difference in cumulative raw returns between banned and control firms. Columns 1 and 2 of Panel B report the average cumulative raw returns for optioned and non-optioned firms in different event window, respectively. Column 3 of Panel B reports the difference in cumulative raw returns between optioned and non-optioned firms. Column 3 of Panel C reports the difference in cumulative raw returns between optioned and non-optioned firms within the banned group. Column 3 of Panel D reports the difference in cumulative raw returns between optioned and non-optioned firms within the control group. *, ** and *** indicate a 10%, 5% and 1% level of significance.

	Panel A			Panel B		
	Banned firms	Control firms	Diff	Optioned firms	Non-optioned firms	Diff
CRR(-1, 0)	3.54%	-0.17%	-3.71%***	4.42%	0.95%	-3.48%
t-statistic			-6.6578			-4.9681***
CRR(0, 19)	-0.84%	-16.59%	-15.75%***	-9.89%	-6.80%	3.09%**
t-statistic			-11.7859			2.0141
CRR(0, 60)	-9.66%	-29.39%	-19.73%***	-20.45%	-17.19%	3.26%
t-statistic			-8.8238			1.3239
CRR(20, 60)	-8.12%	-12.31%	-4.19%**	-10.57%	-9.55%	1.02%
t-statistic			-2.1009			0.5077
Average number of firms	724	544		366	905	

Table B.5 (continued)

	Panel C			Panel D		
	Banned			Control firms		
	Optioned firms	Non-optioned firms	Diff	Optioned firms	Non-optioned firms	Diff
CRR(-1,0)	7.22%	2.16%	-5.06%***	1.13%	-0.75%	-1.87%
t-statistic			-4.53			-2.7932***
CRR(0,19)	-1.23%	-0.69%	0.54%	-20.06%	-15.02%	5.04%
t-statistic			0.2457			2.8327***
CRR(0,60)	-10.73%	-9.25%	1.48%	-31.88%	-28.25%	3.62%
t-statistic			0.4546			1.0259
CRR(20,60)	-9.04%	-7.77%	1.27%	-12.36%	-12.29%	0.07%
t-statistic			0.493			0.0217
Average number of firms	198	526		168	376	

Table B.6

Average cumulative abnormal Returns for different event windows

Columns 1 and 2 of panel A reports the average cumulative abnormal returns for banned and control firms individually in different event window. Column 3 of Panel A reports the difference in cumulative abnormal returns between banned and control firms. Columns 1 and 2 of Panel B report the average cumulative abnormal returns for optioned and non-optioned firms in different event window, respectively. Column 3 of Panel B reports the difference in cumulative abnormal returns between optioned and non-optioned firms. Column 3 of Panel C reports the difference in cumulative abnormal returns between optioned and non-optioned firms within the banned group. Column 3 of Panel D reports the difference in cumulative abnormal returns between optioned and non-optioned firms within the control group. *, ** and *** indicate a 10%, 5% and 1% level of significance.

	Panel A: entire samples			Panel B: Optioned vs. non-optioned firms		
	Banned firms	Control firms	Diff	Optioned firms	Non-optioned firms	Diff
CAR(-1,0)	3.59%	-0.17%	-3.76%***	4.38%	1.00%	-3.40%***
t-statistic			-6.7066			-4.801
CAR(0,19)	14.22%	-5.41%	-19.63%***	12.11%	3.22%	-8.89%***
t-statistic			-12.9405			-4.6368
CAR(0,60)	11.77%	-14.45%	-26.22%***	8.15%	-2.62%	-10.78%***
t-statistic			-10.0655			-3.4847
CAR(20,60)	-1.91%	-8.58%	-6.67%***	-3.82%	-5.17%	-1.35%
t-statistic			-3.1179			-0.6166
Average number of firms	721	542		365	898	

Table B.6 (continued)

	Panel C: banned			Panel D: control firms		
	optioned firms	Non-optioned firms	Dif	optioned firms	Non-optioned firms	Dif
CAR(-1,0)	7.15%	2.25%	-4.90%***	1.14%	-0.76%	-1.90%***
t-statistic			-4.3408			-2.8142
CAR(0,19)	25.15%	10.09%	-15.06%***	-3.19%	-6.41%	-3.22%*
t-statistic			-5.2621			-1.8355
CAR(0,60)	22.70%	7.59%	-15.11%***	-8.95%	-16.97%	-8.02%**
t-statistic			-3.3556			-2.16
CAR(20,60)	-1.80%	-1.95%	-0.16%	-6.20%	-9.67%	-3.47%
t-statistic			-0.0535			-1.0192
Average number of firms	197	524		168	374	

Table B.7

Cumulative returns sorted by pre-estimated beta for banned firms and control firms

Panel A reports the pattern of cumulative raw returns of different event window for banned firms and control firms. Panel B report the pattern of cumulative abnormal returns of different event window for banned firms and control firms. The pre-estimated beta is the cross-sectional average of the beta coefficient measured using the market model during the estimation window of 90 days. The cumulative raw returns are calculated by summing individual stock daily returns. Cumulative abnormal returns are computed by summing the abnormal returns estimated using market model. Diff is the difference in cumulative returns between the banned firms and control firms within the same beta group. *, ** and *** indicate a 10%, 5% and 1% level of significance.

Panel A: Cumulative raw returns sorted by pre-estimated beta

	CRR(0, 19)			CRR(20, 60)		
Pre-estimated Beta	Banned	Control	Diff	Banned	Control	Diff
1	0.075%	-9.773%	-9.848%*** (-2.6068)	-11.541%	-10.252%	1.288% (0.3005)
2	-4.769%	-15.800%	-11.032%*** (-5.9913)	-6.953%	-16.344%	-9.391%** (-2.3117)
3	-1.775%	-17.823%	-16.048%*** (-7.5431)	-3.567%	-8.225%	-4.658% (-1.5993_
4	1.605%	-25.390%	-26.995%*** (-8.6955)	-8.851%	-15.640%	-6.788% (-1.5335)

Panel B: Cumulative abnormal return sorted by preestimated beta

	CAR(0, 19)			CAR(20, 60)		
	Banned	Control	Diff	Banned	Control	Diff
1	0.270%	-11.467%	-11.737%*** (-2.9976)	-7.247%	-10.426%	-3.179% (-0.6608)
2	3.363%	-7.644%	-11.007%*** (-5.9328)	-2.139%	-12.712%	-10.573%** (-2.4837)
3	13.989%	-2.231%	-16.220%*** (-5.9328)	0.907%	-4.581%	-5.488%* (-1.8140)
4	32.865%	1.308%	-31.557%*** (-8.2980)	0.791%	-6.043%	-6.834% (-1.4508)

Table B.8
Correlation matrix

Spearman rank correlation matrix for proxies of divergence of opinion. *SIGMA(raw)* is the standard deviation of daily raw returns within an estimation window (-97, -7). *SIGMA(ar)* is the standard deviation of abnormal returns for the same estimation window. *SIGMA(tr)* is trading volume scaled by shares outstanding during the same estimation window. *SIGMA(fa)* is the standard deviation of financial analyst earnings forecasts as of the end of July 2008.

	SIGMA(raw)	SIGMA(tr)	SIGMA(fa)	SIGMA(ar)
SIGMA(raw)	1.0000			
SIGMA(tr)	0.2737	1.0000		
SIGMA(fa)	0.2519	0.2069	1.0000	
SIGMA(ar)	0.9248	0.1875	0.2209	1.0000

Table B.9

Cumulative raw returns for banned and control firms with high and low dispersion of opinion

I report the average CRR (cumulative raw returns) for different event windows within quantile of dispersion of opinion. Panel A uses the standard deviation of raw returns 90 days preceding the short sale ban event as the proxy for divergence of opinion. Panel B measure the dispersion of opinion using standard deviation of turnover ratio 90 days preceding the short sale ban event. Panel C measures the dispersion of opinion by calculating the standard deviation of analyst earnings forecast one quarter preceding the short sale ban event. Panel D reports the distribution of cumulative raw returns sorted by SIZE quantiles. Panel E reports the distribution of cumulative raw returns sorted by short interest quantiles. CRR(-1, 0) is the cumulative raw returns from one day prior to the event to the event date (09/18/2008). CRR(0, 19) is the cumulative raw returns for the event window (0, 19). Diff (1 - 4) is the difference of CRRs. *, ** and *** indicate 10%, 5% and 1% level of significance.

	banned firm					control firms				
	Obs	CRR(-1, 0)	CRR(0, 19)	CRR(0, 60)	CRR(20, 60)	Obs	CRR(-1, 0)	CRR(0, 19)	CRR(0, 60)	CRR(20, 60)
Panel A: Standard deviation of raw returns										
1	175	0.114%	-5.282%	-8.679%	-3.308%	159	0.483%	-12.517%	-21.404%	-8.645%
2	180	2.463%	-5.442%	-12.999%	-7.612%	137	-0.689%	-17.176%	-31.549%	-14.380%
3	204	2.574%	-2.138%	-9.674%	-7.664%	113	0.284%	-21.014%	-42.865%	-22.000%
4	182	8.666%	9.090%	-7.056%	-13.365%	135	-0.783%	-17.067%	-24.962%	-5.927%
Diff (1 - 4)		-0.08552	-0.14373	-0.01623	0.100572		1.266	4.550	3.558	-2.717
t-statistic		-5.8043***	-3.9931***	-0.3573	2.9039***		1.4072	1.5286	0.6884	-0.5464
Panel B: Standard deviation of abnormal returns (%)										
1	165	1.143%	-5.895%	-9.292%	-3.222%	150	-0.174%	-13.323%	-23.466%	-10.052%
2	184	2.434%	-4.006%	-11.467%	-7.712%	132	1.008%	-16.506%	-29.026%	-12.324%
3	182	3.489%	-1.803%	-10.214%	-8.223%	134	-0.313%	-19.341%	-40.412%	-20.716%
4	189	6.809%	7.801%	-7.59%	-12.622%	127	-1.175%	-17.614%	-24.920%	-5.548%
Dif(1 - 4)		-5.666	-13.696	-1.932	9.400		1.001	4.291	1.454	-4.504%
t-statistic		-3.798***	-3.944***	-0.453	2.8623***		1.062	1.3934	0.2779	-0.8934

Table B.9 (continued)

	Obs	CRR(-1, 0)	CRR(0, 19)	CRR(0, 60)	CRR(20, 60)	Obs	CRR(-1, 0)	CRR(0, 19)	CRR(0, 60)	CRR(20, 60)
Panel C: Standard deviation of turnover ratio										
1	220	-0.148%	-0.786%	-8.308%	-5.696%	96	-1.447%	-15.390%	-24.671%	-9.310%
2	174	2.673%	-2.809%	-10.818%	-8.138%	143	-1.501%	-15.893%	-27.535%	-11.119%
3	153	4.003%	-4.740%	-12.329%	-7.358%	164	0.583%	-14.837%	-27.550%	-10.941%
4	176	8.628%	4.502%	-7.752%	-11.885%	141	1.183%	-20.226%	-36.827%	-17.171%
Dif (1-4)		-8.776%	-5.288%	-0.556%	6.189%		-2.630%	4.836%	12.156%	7.861%
t-statistic		-7.2819***	-1.6454*	-0.1409	2.1654**		-2.563**	1.8395*	2.0119*	1.3717
Panel D: Standard deviation of analyst earnings forecasts										
1	62	2.227%	-3.476%	-14.858%	-11.621%	38	-1.407%	-17.979%	-30.120%	-12.141%
2	51	6.377%	-2.764%	-10.648%	-7.745%	49	-0.274%	-18.951%	-27.872%	-7.681%
3	43	4.578%	-4.294%	-11.217%	-4.938%	57	0.286%	-14.245%	-29.159%	-15.255%
4	48	8.964%	13.099%	-1.141%	-14.223%	52	3.240%	-20.881%	-41.296%	-22.432%
Dif (1-4)		-6.737%	-16.574%	-13.717%	2.603%		-4.647%	2.902%	11.176%	10.291%
t-statistic		-3.350***	-2.528**	-1.558	0.448		-2.570**	0.670	1.304	1.284

Table B.9 (continued)

	Obs	CRR(-1, 0)	CRR(0, 19)	CRR(0, 60)	CRR(20, 60)	Obs	CRR(-1, 0)	CRR(0, 19)	CRR(0, 60)	CRR(20, 60)
Panel E: Size										
1	179	-0.978%	3.032%	-5.305%	-6.192%	133	-2.477%	-13.220%	-20.029%	-4.429%
2	183	1.962%	-2.980%	-16.959%	-13.992%	129	-1.543%	-15.227%	-32.358%	-17.861%
3	178	8.238%	-0.727%	-7.887%	-6.769%	134	2.559%	-17.625%	-33.938%	-16.052%
4	169	5.271%	-2.055%	-8.283%	-6.098%	143	0.802%	-19.534%	-29.665%	-9.989%
Dif (1-4)		-6.249%	5.087%	2.978%	-0.094%		-3.279%	6.314%	9.636%	5.560%
t-statistic		-5.295***	1.489	0.754	-0.031		-3.944***	2.168**	1.940*	1.181
Panel F: Relative short interest										
1	192	-0.377%	1.410%	-7.240%	-6.770%	121	-2.787%	-15.209%	-22.480%	-0.070161
2	167	1.680%	-4.683%	-14.086%	-8.724%	146	-1.805%	-17.579%	-34.552%	-0.15661
3	167	5.606%	-1.852%	-12.599%	-10.588%	146	1.070%	-17.671%	-29.422%	-0.111085
4	191	7.449%	1.292%	-6.083%	-7.360%	122	2.787%	-15.479%	-30.218%	-0.152208
Dif(1-4)		-7.826%	0.118%	-1.156%	0.590%		-5.575%	0.270%	7.738%	8.205%
t-statistic		-6.3405***	0.0372	-0.3078	0.2025		-5.4683***	0.1158	1.5358	1.6764*

Table B.10

Cumulative abnormal returns for banned and control firms with high and low dispersion of opinion

Panel A measure the divergence of opinion using the standard deviation of raw return 90 days preceding the short sale ban event. Panel B measures the divergence of opinion using the standard deviation of abnormal return estimated 90 days prior to the short sale ban. Panel C measures the divergence of opinion using the standard deviation of turnover ratio 90 days preceding the short sale ban event. Panel D measures the divergence of opinion by calculating the standard deviation of analyst earnings forecast one quarter preceding the short sale ban. Pane E reports the distribution of cumulative abnormal returns sorted by SIZE quantiles. Panel F reports the distribution of cumulative abnormal returns sorted by short interest quantiles. CRR(-1, 0) is cumulative raw returns from one day prior to the event to the event date (09/18/2008). CRR(0, 19) calculate the cumulative abnormal returns for the event window (0, 19). Diff(1 - 4) is the difference of CARs. *, ** and *** indicate 10%, 5% and 1% level of significance.

	banned firm					control firms				
	obs	CAR(-1,0)	CAR(0,19)	CAR(0,60)	CAR(20,60)	obs	CAR(-1,0)	CAR(0,19)	CAR(0,60)	CAR(20,60)
Panel A: Standard deviation of raw returns										
1	156	0.061%	2.716%	1.386%	-1.225%	159	0.446%	-2.961%	-9.027%	-6.073%
2	179	2.419%	9.038%	5.785%	-3.283%	137	-0.782%	-5.483%	-17.228%	-11.816%
3	203	2.738%	13.459%	13.638%	-0.254%	113	0.330%	-6.983%	-22.558%	-15.579%
4	182	8.716%	30.090%	24.663%	-2.990%	134	-0.676%	-6.866%	-10.832%	-1.988%
Dif (1 - 4)		-8.655%	-27.374%	-23.277%	1.765%		1.122%	3.905%	1.805%	-4.086%
t-statistic		-5.800***	-6.440***	-3.927***	0.459		1.252	1.286	0.316	-0.771
Panel B: Standard deviation of abnormal returns										
1	165	1.023%	6.265%	4.976%	-1.228%	150	-0.264%	-2.370%	-10.439%	-8.107%
2	184	2.393%	11.560%	9.036%	-2.883%	132	0.952%	-3.735%	-12.670%	-8.810%
3	182	3.535%	13.197%	11.720%	-1.572%	134	-0.265%	-7.758%	-23.035%	-15.184%
4	189	7.048%	24.840%	20.570%	-1.861%	127	-1.101%	-8.232%	-11.764%	-1.476%
Dif (1 - 4)		-6.025%	-18.574%	-15.595%	0.633%		0.836%	5.862%	1.325%	-6.631%
t-statistic		-4.0198***	-4.465***	-2.7446***	0.1705		0.8975	1.8919*	0.221	-1.1983
Panel C: Standard deviation of turnover ratio										
1	218	-0.050%	4.297%	0.755%	-1.714%	97	-1.346%	-9.448%	-15.261%	-5.808%
2	174	2.763%	11.049%	10.511%	-0.837%	142	-1.553%	-7.107%	-16.382%	-8.874%
3	153	3.888%	13.661%	10.678%	-3.076%	163	0.587%	-1.992%	-11.273%	-7.548%
4	175	8.685%	30.170%	27.979%	-2.193%	141	1.179%	-4.790%	-15.573%	-11.471%
Dif (1-4)		-8.735%	-25.872%	-27.224%	0.479%		-2.525%	-4.658%	0.312%	5.662%
t-statistic		-7.1313***	-6.8965***	-5.2234***	0.1455		-2.4733**	-1.7312*	0.0479	0.9237

Table B.10 (continued)

	obs	CAR(-1,0)	CAR(0,19)	CAR(0,60)	CAR(20,60)	obs	CAR(-1,0)	CAR(0,19)	CAR(0,60)	CAR(20,60)
Panel D: Standard deviation of analyst earnings forecast (SIGMA(fa))										
1	62	2.300%	9.747%	4.706%	-5.230%	38	-1.485%	-9.230%	-19.824%	-10.594%
2	51	6.418%	19.798%	20.951%	1.134%	49	-0.313%	-5.677%	-10.251%	-3.945%
3	43	4.633%	17.419%	19.999%	3.653%	57	0.190%	-2.291%	-14.992%	-12.516%
4	48	8.999%	43.409%	40.139%	-2.614%	52	3.326%	-1.315%	-14.023%	-14.465%
Dif (1 - 4)		-6.698%	-33.662%	-35.433%	-2.616%		-4.810%	-7.914%	-5.801%	3.871%
t-statistic		-3.316***	-4.142***	-2.790**	-0.382		-2.635**	-1.840*	-0.693	0.496
Panel E: Size										
1	179	-0.793%	6.592%	3.638%	-1.055%	132	-2.346%	-8.890%	-12.074%	-0.838%
2	183	2.122%	5.929%	-1.424%	-7.395%	129	-1.633%	-8.177%	-25.384%	-17.725%
3	178	8.101%	22.992%	21.254%	-1.411%	134	2.447%	-0.915%	-12.946%	-12.021%
4	168	5.193%	22.657%	24.073%	1.337%	143	0.825%	-3.709%	-7.500%	-3.821%
Dif (1 - 4)		-5.987%	-16.065%	-20.435%	-2.391%		-3.171%	-5.181%	-4.574%	2.983%
t-statistic		-5.016***	-4.0717***	-3.8983***	-0.7154		-3.8672***	-1.7399*	-0.855	0.5958
Panel F: Short interest										
1	191	-0.239%	9.223%	7.268%	-0.433%	121	-2.678%	-9.980%	-12.819%	-2.554%
2	167	1.799%	8.413%	4.907%	-3.171%	145	-1.750%	-6.550%	-19.522%	-11.675%
3	166	5.477%	17.821%	11.871%	-5.516%	146	0.991%	-3.799%	-12.459%	-8.091%
4	190	7.505%	21.819%	22.405%	0.576%	122	2.720%	-1.304%	-12.319%	-11.377%
Dif(1 - 4)		-7.744%	-12.595%	-15.137%	-1.009%		-5.398%	-8.676%	-0.499%	8.823%
t-statistic		-6.2118***	-3.3965***	-3.1369***	-0.3354		-5.3361***	-3.6507***	-0.0899	1.6777*

Table B.11

Regression of CARs on divergence of opinion and other control variables

Panels A , B, C and D measure the dispersion of opinion using *SIGMA(raw)*, *SIGMA(ar), SIGMA(tr)* and *SIGMA(fa),* respectively. *SIGMA(raw)* is the standard deviation of raw returns from 90-day prior to the short sale ban announcement. *SIGMA(ar)* is the standard deviation of the abnormal returns based on market model from the 90-day estimation window prior to the short sale ban announcement. SIGMA(tr) is the standard deviation of the turnover ratio from 90-day prior to the short sale ban. *SIGMA(fa)* is the standard deviation of analyst earnings forecast as of the 7/31/2008. Relative short interest is the total short interest scaled by shares outstanding. Days to cover is the total short interest scaled by average trading volume. Dummy variable *BANNED* is equal to one if the corresponding firm is banned from shorting, and zero otherwise. Institutional ownership is shares held by institutional organization scaled by shares outstanding. Insider ownership is shares held by insiders scaled by shares outstanding. Alpha is the intercept term estimated from the market model for a 90- day estimation window prior to short sale ban announcement date. Dummy variable *OPTION* is equal to one if the corresponding firm is optioned stock. *, ** and *** indicate 10%, 5% and 1% level of significance. T-statistic is in parentheses.

Explanatory variables	CAR(-1,0)	CAR(0, 19)	CAR(20, 60)
Panel A : Standard deviation of raw returns			
ln(market capitalization)	0.01593	0.02959	0.03687
	(6.17)***	(4.45)***	(3.65)***
SIGMA(raw)	0.23399	1.60578	3.2749
	(1.33)	(1.72)*	(2.30)**
SIGMA(raw)*BANNED	0.6565	2.14266	-3.23699
	(2.22)**	(2.01)**	(-2.28)**
change in relative short interest	-1.56818	-0.39416	0.13451
	(-5.00)***	-0.49	0.05
change in rsi*BANNED	-0.37293	-2.95953	-3.47647
	-0.78	(2.58)**	-1.08
DTC (days to cover)	0.00123	0.00187	-0.00168
	(3.70)***	(2.07)**	-0.58
days to cover *BANNED	0.00027	0.00236	0.00211
	0.38	1.47	0.7
institutional ownership	-0.04394	0.00308	-0.41088
	(-2.59)***	0.07	(-4.99)***
institutional ownership *BANNED	-0.04511	0.02976	0.31324
	(-1.90)*	0.64	(3.29)***
insider ownership	-0.02183	-0.10962	-0.06526
	(-1.03)	-1.47	-0.6
insider ownership *BANNED	-0.02152	0.09207	0.02207
	-0.84	1.09	0.19
alpha90	-1.98919	-15.79747	-42.0658
	-1.49	-1.53	(-5.64)***
alpha90*BANNED	-0.58739	-2.68742	7.88917
	-0.26	-0.24	0.8
Table 3.11(continued)			
OPTION	-0.04442	-0.07235	0.118

Table B.11(continued)

	(-3.80)***	(-2.27)**	(2.04)**
OPTION * BANNED	0.02494	0.04693	-0.13999
	1.47	1.23	(-2.16)**
Observations	1025	1024	1011
R-squared	0.25	0.33	0.16

Table B.11 (continued)

Panel B: Standard deviation of abnormal returns			
Explanatory variables	CAR(-1, 0)	CAR(0, 19)	CAR(20, 60)
ln(market capitalization)	0.0168	0.03039	0.04185
	(6.25)***	(4.47)***	(4.38)***
SIGMA(ar)	0.29102	1.48725	4.21466
	1.39	1.36	(2.80)***
SIGMA(ar)*BANNED	0.57739	1.67165	-4.05459
	(1.97)**	1.46	(-2.69)***
change in relative short interest	-1.55977	-0.38074	-0.29557
	(-4.95)***	-0.48	-0.11
change in rsi*BANNED	-0.39891	-3.16879	-3.09917
	-0.83	(-2.72)***	-0.97
DTC (day to cover)	0.00127	0.00204	-0.00195
	(3.80)***	(2.35)**	-0.67
days to cover *BANNED	0.00029	0.00244	0.00239
	0.4	1.49	0.8
institutional ownership	-0.0466	-0.01398	-0.42581
	(-2.76)***	-0.31	(-5.20)***
institutional ownership *BANNED	-0.03965	0.05535	0.33159
	(-1.69)*	1.15	(3.52)***
insider ownership	-0.0242	0.11904	-0.10697
	-1.15	1.58	-0.96
insider ownership *BANNED	-0.01936	0.1044	0.08199
	-0.74	-1.2	0.7
alpha90	-1.96639	-15.42658	-41.15911
	-1.47	-1.51	(-5.50)***
alpha90*BANNED	-0.38503	-1.80769	6.32634
	-0.17	-0.16	0.64
OPTION	-0.04604	-0.07249	0.11591
	(-3.90)***	(-2.27)**	(2.01)**
OPTION * BANNED	0.02701	0.05523	-0.14895
	1.57	1.41	(-2.28)**
Observations	1025	1024	1011
R-squared	0.25	0.32	0.16

Table B.11 (continued)

Panel C: Standard deviation of turnover ratio			
Explanatory variables	CAR(-1, 0)	CAR(0, 19)	CAR(20, 60)
ln(market capitalization	0.01246	0.0147	0.02859
	(4.72)***	(1.82)*	(2.68)***
SIGMA(tr)	-0.22666	-2.66363	2.9577
	-0.32	-1.24	0.95
SIGMA(tr)*BANNED	1.55647	9.68151	-1.56644
	1.21	(2.71)***	-0.39
change in relative short interest	-1.65204	-0.72958	0.56527
	(-5.33)***	-0.96	-0.2
change in rsi*BANNED	-0.37296	-2.8148	-3.54252
	-0.74	(-2.42)**	-1.07
DTC (days to cover)	0.00119	0.00174	-0.00067
	(3.52)***	(2.02)**	-0.21
days to cover *BANNED	0.00042	0.00288	0.00094
	0.58	(1.76)*	0.28
institutional ownership	-0.06331	-0.05055	-0.35535
	(-3.81)***	-1.03	(-4.81)***
institutional ownership *BANNED	-0.03239	0.03814	0.21736
	-1.46	0.76	(2.60)***
insider ownership	-0.04607	-0.16522	0.10941
	(-2.48)**	(-3.38)***	1.15
insider ownership *BANNED	0.01402	0.17897	-0.21957
	0.69	(3.44)***	(-2.33)**
alpha90	-1.63404	-14.66806	-40.72153
	-1.22	-1.36	(-5.32)***
alpha90*BANNED	-0.44724	-1.72827	8.07124
	-0.19	-0.14	0.82
OPTION	-0.03438	-0.03619	0.11343
	(-2.90)***	-1.12	(1.93)*
OPTION * BANNED	0.02299	0.04449	-0.1204
	1.33	1.12	(-1.89)*
Observations	1025	1024	1011
R-squared	0.23	0.29	0.14

Table B.11 (continued)

Panel D: Standard deviation of financial analyst forecast			
Explanatory variables	CAR(-1,0)	CAR(0,19)	CAR(20,60)
ln(market capitalization	0.01095	0.0247	0.04817
	(2.93)***	(2.98)***	(2.94)***
SIGMA(fa)	0.20253	-0.12489	0.03404
	(1.96)*	-0.51	-0.12
SIGMA(fa)*BANNED	-0.22094	0.47894	-0.00946
	(2.02)**	-1.38	-0.03
change in relative short interest	-1.5567	0.24944	2.87618
	(3.12)***	-0.19	-0.72
change in rsi*BANNED	-1.06382	-6.14306	-8.03063
	-1.43	(2.55)**	-1.63
DTC (days to cover)	0.00425	0.00629	-0.00224
	(2.96)***	(1.93)*	-0.5
days to cover *BANNED	0	0.00392	0.00325
	0	-0.77	-0.52
institutional ownership	-0.11998	-0.14985	-0.25437
	(3.81)***	(2.08)**	(2.12)**
institutional ownership *BANNED	-0.02288	0.03982	0.13783
	-0.66	-0.53	-1.09
insider ownership	-0.11056	-0.33173	-0.10359
	(3.23)***	(3.17)***	-0.55
insider ownership *BANNED	0.03115	0.22509	-0.0978
	-0.76	(1.86)*	-0.57
alpha90	-1.12463	-4.81576	-21.05894
	-0.55	-0.89	(1.93)*
alpha90*BANNED	-3.9281	-31.02038	-16.68904
	-0.95	(2.50)**	-1.1
OPTION	-0.01835	-0.05509	-0.02211
	-1.01	-1.38	-0.24
OPTION * BANNED	0.02846	0.00715	-0.07261
	-1.08	-0.11	-0.65
Observations	315	315	316
R-squared	0.36	0.41	0.16

Table B.12: Sample description for at-the-money options at different times to maturity

Mean statistics of some major variables regarding option transactions for both banned firms and control firms over July 3, 2007 through December 31, 2008. The pre-ban period is July 3, 2007, through September 17, 2008, starting after removal of the uptick rule to the date before the short sale ban was imposed. The short sale ban is from September 18, 2008, through October 7, 2008. The post-ban period is from October 8, 2008, through December 31, 2008. Control firms are unbanned firms matched with banned firms under several conditions. Deviation ratio (DR) is the percentage deviation of actual stock prices from implied stock prices derived from put-call parity. Spread(%) is the percentage spread between ask and bid price of call (or put).

		Pre-ban		Ban period		Post-ban	
		Banned firms	Control firms	Banned firms	Control firms	Banned firms	Control firms
Panel A: short-term	DR=ln(s0/sm)x100	0 936232	0.8145856	2.03681	1.136838	0.3517075	0.4334745
	DR <0 (%)	39.38	42.01	38.77	42.86	44.36	44.06
	DR >0 (%)	60.62	57.99	61.23	57.14	55.64	55.94
	Call volume	380.5479	271.7187	544.4437	142.1625	590.6516	353.841
	Put volume	265.1988	136.1527	299.8185	131.336	497.1551	267.2153
	Call open interest	2239.245	1986.198	2715.754	949.5038	2853.504	1898.598
	Put open interest	2394.475	1683.241	2108.891	1355.445	3909.509	2377.152
	Spread(%) of call	.3099867	0.2564175	.5209617	0.3670724	.1814131	0.1669392
	Spread(%) of put	.2906489	0.269492	.4543605	0.3280128	.1992815	0.1728697
	Implied volatility of call	.4579602	.4335993	.8278454	.6430949	1.02732	.8652229
	Implied volatility of put	.4795599	.4496466	.8729971	.6577349	2.745555	1.947994
	# of firms per date	154.8831	138.2479	138.3764	128.3997	79.88719	64.81114
	#of obs. per firm	287.9401	285.0838	12.78998	13.38404	47.98521	47.90241
Panel B: intermediat e-term	DR=ln(s0/sm)x100	1.08183	.5115028	2.401508	.3125579	.901045	.2121316
	DR <0 (%)	34.92	48.37	36.67	52.42	37.33	47.69
	DR >0 (%)	65.08	51.64	63.33	47.58	62.67	52.31
	Call volume	88.95202	67.93198	205.7719	42.55748	177.7333	115.4449
	Put volume	85.82295	47.48391	137.6353	47.82863	210.0245	111.845
	Call open interest	1693.841	1487.923	3841.084	1403.428	2112.823	1464.114
	Put open interest	2024.214	1409.786	2873.275	1943.339	3025.861	1700.18
	Spread(%) of call	.1552066	.1243152	.4079108	.228509	.1046906	.0976653
	Spread(%) of put	.1488924	.1248847	.3499865	.2172637	.0846173	.0896605
	Implied volatility of call	.4320787	.4203847	.6135866	.5408863	.8992554	.7699031
	Implied volatility of put	.4458661	.4301253	.6944904	.5663783	.9584237	.8080329
	# of firms per date	142.3483	126.6952	124.4092	113.859	30.07743	26.45156
	#of obs. per firm	267.8495	263.7909	10.62745	10.69631	31.0503	33.462
Panel C: long-term	DR=ln(s0/sm)X100	3.264336	1.827698	3.138033	0.4425692	3.701986	1.769062
	DR <0 (%)	26.62	40.12	35.01	55.16	27.81	41.10
	DR >0 (%)	73.38	59.88	64.99	44.84	72.19	58.90
	call volume	54.17226	32.4287	71.51463	8.073413	108.0939	46.8883
	Put volume	47.79958	21.78631	41.54022	12.5754	151.4098	68.73551
	Call open interest	1200.434	1029.489	1557.32	335.5615	1885.353	760.9568
	Put open interest	1604.548	1085.207	1777.944	536.1081	3823.973	979.2666
	Spread(%) of call	.1304809	.1090625	.37249	.2777276	.1131976	.1161629
	Spread(%) of put	.1371878	.1225395	.3135351	.2520782	.0861215	.0992681
	Implied volatility of call	.4177038	.4069812	.563574	.500964	.7954745	.6954954
	Implied volatility of put	.4233185	.4129981	.6134049	.5253944	.8574888	.7384992
	# of firms per date	110.3502	103.6115	94.62157	87.02778	21.31308	18.63962
	#of obs. per firm	247.87	258.0426	10.5064	11.12103	37.8011	36.20337

Table B.13: Change in sample characteristics around the short sale ban period

Time series regressions of cross-sectional averages with Newey-West standard errors for option characteristic variables on an intercept term (not reported) and event dummy variable. The event dummy variable equals one from September 18, 2008, through October 8, 2008, and zero otherwise. The Diff variable is the coefficient of the event dummy variable for the banned and the control firms. The Diff - Diff column reports the difference between banned and control firms for each variable on an intercept (not reported) and the event dummy variable. *, ** and *** indicate 10%, 5% and 1% level of significance. Lags up to 20 days are used to compute the Newey-West standard errors.

At the money option with intermediate time to maturity

Panel A: Pre-ban period vs. ban period

	Banned			Control			
	Pre	Ban period	Diff(ban - pre)	Pre	Ban period	Diff (ban – pre)	Diff - Diff(ban-control)
Volume_call	100.91	284.25	183.34***	59.88	54.35	-5.53	188.87***
Volume_put	91.82	162.18	70.36***	36.02	81.44	45.42*	24.94
EEP_call (ratio)	0.178	0.135	-0.043***	0.032	0.034	0.002	-0.045***
EEP_put (ratio)	0.011	0.002	-0.009***	0.019	0.003	-0.016***	0.007***
Spread_call (%)	0.16	0.36	0.19***	0.13	0.20	0.07***	0.13***
Spread_put(%)	0.15	0.31	0.16***	0.13	0.19	0.06***	0.10***
Implied volatility_call	0.53	0.67	0.14**	0.48	0.60	0.12***	0.03
Implied volatility_put	0.55	0.74	0.19***	0.47	0.58	0.11***	0.07***

Panel B: Ban period vs. post-ban period

	Banned			Control			
	Ban period	Post	Diff(ban - post)	Ban period	Post	Diff(ban - post)	Diff - Diff(ban-control)
Volume_call	284.25	175.29	108.97**	54.35	110.89	-56.54***	165.50***
Volume_put	162.18	211.15	-48.97*	81.44	107.87	-26.42	-22.54
EEP_call (ratio)	0.135	0.154	-0.019**	0.03	0.058	-0.025***	0.006
EEP_put(ratio)	0.002	0.001	0.001**	0.003	0.002	0.001***	-0.001***
Spread_call (%)	0.36	0.10	0.26***	0.20	0.09	0.11***	0.15***
Spread_put(%)	0.31	0.08	0.22***	0.19	0.09	0.10***	0.12***
Implied volatility_call	0.67	0.91	-0.24***	0.58	0.78	-0.21***	-0.04
Implied volatility_put	0.74	0.97	-0.23***	0.60	0.82	-0.22***	0.00

Table B.14: Deviation of put-call parity around the short sale ban event

Pooled regression of the deviation ratio (DR) on a ban window dummy variable and banned stock interactions by exchange using data from windows (-90, 19) and (-2, 90). The first window compares the DR between the pre-ban window (-90,-3) and the ban window (-2,19). The second window compare the DR between the ban window (-2,19) and the post-ban window (20,90):

$$DR_{i,t} = a + a_1 \cdot IMPOSED + a_2 \cdot IMPOSED \cdot BANNED + a_3 \cdot REMOVED + a_4 \cdot REMOVED \cdot BANNED + \varepsilon_{i,t},$$

The dummy variable *IMPOSED* equals one if the date falls into the ban imposed window, and zero otherwise. The dummy variable *BANNED* equals one if a given stock is banned stock, and zero otherwise. The variable *REMOVED* equal s one if the date falls into the ban removal window, and zero otherwise. In panel A.1 , the banned column reports the average DR for banned stocks during the banned window, $a + a_1 + a_2$; the control column reports the same measures for control stocks, $a + a_1$; and the Diff column reports the difference between the two, a_2. In Panel A.2, the banned column reports DR for banned stocks during the ban removal window, $a + a_3 + a_4$; the control column reports the same measures for control stocks, $a + a_4$; and the Diff column reports the difference between the two, a_4. The regression standard error is calculated using a cluster regression model including firm and time effects. *, ** and *** indicate the significance level of 10%, 5% and 1%.

panel A: at-the-money options with long time to maturity	Panel A.1: Ban imposed period			Panel A.2: Ban removed period		
	Banned	Control	Diff	Banned	Control	Diff
DR (%) in (t - 2, t + 19)	3.23	0.70	2.53***			
t-statistic			3.41			
DR (%) (t + 20, 90)				3.68	1.93	1.76**
t-statistic						2.05
Panel B: at-the-money options with intermediate time to maturity						
	Panel B.1: Ban imposed period			Panel B.2: Ban removed period		
	banned	control	diff	banned	control	diff
DR (%) in (t - 2, t + 19)	2.32	0.32	2.01***			
t-statistic			4.18			
DR (%) (t + 20, 90)				0.96	0.22	0.74**
t-statistic						2.37
Panel C: at-the-money options with short time to maturity	Panel C.1 Ban imposed period			Panel C.2: Ban removed period		
	banned	control	diff	banned	control	diff
DR (%) in (t - 2, t + 19)	1.90	1.21	0.69*			
t-statistic			1.67			
DR (%) (t + 20, 90)				0.43	0.41	0.02
t-statistic						0.07

Table B.14(continued)

Panel D: out-of-the money with intermediate time to maturity	Panel D.1 : Ban imposed period			Panel D.2: Ban removed period		
	banned	control	diff	banned	control	diff
DR (%) in (t - 2, t + 19)	21.56	12.94	8.62***			
t-statistic			3.62			
DR (%) (t + 20, 90)				22.20713	9.07556	13.13157***
t-statistic						4.63

Panel E: in the money with intermediate time to maturity	Panel E.1: Ban imposed period			Panel E.2: Ban removed period		
	banned	control	diff	banned	control	diff
DR (%) in (t - 2, t + 19)	-1.04	-1.46	0.42			
t-statistic			1.2			
DR (%) (t + 20, 90)				-2.81	-1.93	-0.88*
t-statistic						-1.66

Table B.15: Put-call parity around short sale ban event

Percentage of Deviation ratio (DR) = ln(observed prices/implied prices derived by put-call parity) less than or greater than 0 for banned and control firms in different time periods. The time horizon of 90 days before and 90 days after the short sale ban is split into pre-ban, ban and post-ban periods. I test the distribution of DR with different times to maturity and levels of moneyness. The statistical tests of positive DR use DeMoivre-Laplace normal approximation to the binomial distribution. p-values of the statistic are presented.

panel A: at the money option with long time to maturity

	Banned firms			Control firms		
	Pre-ban	Ban period	Post-ban	Pre-ban	Ban period	Post-ban
DR < 0 (%)	26.89%	34.16%	28.34%	43.84%	52.50%	20.81%
DR > 0 (%)	73.11%	65.84%	71.66%	56.16%	47.50%	79.19%
test (p-value)						
Pro(DR > 0) = 0.5	0.00	0.00	0.00	0.00	0.95	0.00

Panel B: at the money option with intermediate time to maturity

	Banned firms			control firms		
	Pre-ban	Ban period	Post-ban	Pre-ban	Ban period	Post-ban
DR < 0 (%)	30.29%	36.64%	37.60%	45.10%	51.33%	48.85%
DR > 0 (%)	69.71%	63.36%	62.40%	54.90%	48.67%	51.15%
test (p-value)						
Pro(DR > 0) = 0.5	0.00	0.00	0.00	0.00	0.85	0.23

Panel C: at the money option with short time to maturity

	Banned firms			control firms		
	Pre-ban	Ban period	Post-ban	Pre-ban	Ban period	Post-ban
DR < 0 (%)	34.59%	40.37%	43.34%	39.06%	42.64%	29.29%
DR > 0 (%)	65.41%	59.63%	56.66%	60.94%	57.36%	70.71%
test (p-value)						
Pro(DR > 0) = 0.5	0.00	0.00	0.00	0.00	0.00	0.00

Table B.15(continued)

Panel D: out of the money with intermediate time to maturity						
	Banned firms			control firms		
	Pre-ban	ban period	post ban	Pre-ban	ban period	post ban
DR < 0 (%)	11.62%	19.14%	24.19%	24.50%	29.81%	33.04%
DR > 0 (%)	88.38%	80.86%	75.81%	75.50%	70.19%	66.96%
test (p-value)						
Pro(DR > 0) = 0.5	0.00	0.00	0.00	0.00	0.00	0.00

Panel E: in the money with intermediate time to maturity						
	Banned firms			control firms		
	Pre-ban	ban period	post ban	Pre-ban	ban period	post ban
DR < 0 (%)	59.00%	62.15%	67.24%	68.39%	71.77%	46.36%
DR > 0 (%)	41.00%	37.85%	32.76%	31.61%	28.23%	53.64%
test (p-value)						
Pro(DR > 0) = 0.5	1.00	1.00	1.00	1.00	1.00	1.00

Table B.16: Frequency of put-call parity violations including transaction costs

Distribution of violations of put-call parity after accounting for bid-ask spreads in the options market for different times to maturity and levels of moneyness. The time horizon of 90 days before and 90 days after the short sale ban is split into pre-ban, ban and post-ban periods. The variable Sb (the implied short price) is the lower bound on the stock prices as derived from put-call parity, Sm is stock price as derived from put-call parity when all options are traded and Sa is the upper bound (the implied long price) on stock prices as derived from put-call parity.

Panel A: at-the-money options with long time to maturity

	Banned firms			Control firms		
	Pre-ban	Ban period	Post ban	Pre-ban	Ban period	Post ban
S < Sb	13.61%	12.13%	16.01%	17.61%	19.73%	20.81%
Sb < = S < Sm	13.28%	22.03%	12.33%	26.22%	32.78%	20.23%
Sm < = S < Sa	18.94%	34.84%	17.15%	15.20%	21.20%	18.21%
S > Sa	54.17%	31.00%	54.51%	40.96%	26.30%	40.75%

Panel B: at-the-money options with intermediate time to maturity

	Banned firms			Control firms		
	Pre-ban	Ban period	Post ban	Pre-ban	Ban period	Post ban
S < Sb	14.13%	13.54%	21.27%	15.75%	17.86%	23.45%
Sb < = S < Sm	16.17%	23.10%	16.33%	29.35%	33.46%	25.40%
Sm < = S < Sa	29.61%	37.69%	25.35%	25.89%	27.57%	22.57%
S >Sa	40.09%	25.67%	37.05%	29.01%	21.10%	28.58%

Panel C: at-the-money options with short time to maturity

	Banned firms			Control firms		
	Pre-ban	Ban period	Post ban	Pre-ban	Ban period	Post ban
S < Sb	19.36%	18.88%	30.58%	21.77%	17.93%	29.29%
Sb < = S < Sm	15.19%	21.49%	12.88%	17.29%	24.72%	15.15%
Sm < = S < Sa	25.30%	27.51%	20.47%	23.01%	22.99%	19.03%
S > Sa	40.15%	32.12%	36.19%	37.93%	34.37%	36.53%

Table B.16 (continued)

Panel D: out of the money with intermediate time to maturity

	Banned firms			Control firms		
	Pre-ban	Ban period	Post ban	Pre-ban	Ban period	Post ban
S < Sb	1.37%	5.12%	14.70%	1.25%	4.90%	17.90%
Sb < = S < Sm	10.26%	14.02%	9.49%	23.25%	24.90%	15.14%
Sm < = S < Sa	23.59%	24.20%	16.03%	21.86%	17.42%	13.27%
S > Sa	64.78%	56.66%	59.78%	53.64%	52.77%	53.69%

Panel E: in the money with intermediate time to maturity

	Banned firms			Control firms		
	Pre-ban	Ban period	Post ban	Pre-ban	Ban period	Post ban
S < Sb	41.29%	35.21%	55.27%	44.50%	38.66%	46.36%
Sb < = S < Sm	17.73%	26.94%	11.97%	23.89%	33.11%	1.37%
Sm < = S < Sa	25.04%	30.28%	14.46%	20.54%	21.84%	20.99%
S > Sa	15.96%	7.57%	18.30%	11.08%	6.39%	17.56%

Table B.17: Put-call parity and time to maturity

Distribution of deviation ratios (DR = l00[ln(s0/sm)] for at-the-money options with different times to maturity 90 days preceding and 90 days after the short sale ban announcement (September 18, 2009).

	Short			Intermediate			Long		
	All	Banned firm	Control firms	All	Banned firm	Control firms	All	Banned firm	Control firms
obs	25354	13576	11778	21482	11368	10114	14685	7666	7019
mean	1.02	1.16	0.85	1.14	1.66	0.57	2.71	3.68	1.65
percentile									
1	-9.57	-10.25	-8.76	-7.42	-7.33	-7.48	-8.78	-8.07	-9.35
5	-6.03	-6.29	-5.72	-4.92	-4.71	-5.16	-5.44	-5.02	-5.81
10	-4.27	-4.38	-4.18	-3.42	-3.21	-3.59	-3.55	-2.98	-4.07
25	-0.81	-0.88	-0.68	-0.49	-0.34	-0.60	-0.71	-0.32	-1.14
50	0.37	0.56	0.24	0.50	1.05	0.11	1.33	2.51	0.37
75	3.29	3.61	2.92	2.69	3.46	1.59	5.86	6.84	4.82
90	6.69	7.02	6.27	6.31	6.98	5.50	10.20	11.46	8.37
95	8.59	8.96	8.09	8.01	8.81	7.18	13.54	15.11	11.48
99	12.79	13.85	11.57	12.42	14.58	9.39	21.49	23.86	17.22

Table B.18: Regressions of deviation ratio on event dummy and other control variables

Multivariate regressions of the deviation ratio (DR = 100[ln(s0/sm)] on the ban dummy, post-ban dummy and other control variables: (1) logarithm of stock trading volume, (2) stock return in percentage, (3) the percentage bid-ask spread average across calls and puts, (4) daily option volume averaged across calls and puts (divided by 100), (5) open interest averaged across calls and puts (divided by 100), (6) the ratio of the implied volatility on the put over that on the call option, (7) ratio of open interest on the put to open interest on the call (divided by 10), (8) moneyness of the options (100[ln(S/k)]), (9) the time to maturity in years, and interaction term of each control variable with the dummy variable. The ban dummy equals one if it is during the short sale ban period, zero otherwise. The post-ban dummy equals one if it is after the short sale ban is lifted. Firm dummy variable equals one if firm is banned from shorting. This model adjusts standard error by including firm and time effects using cluster regression model.

	model 1	model 2	model 2.1	model 3	model 3.1	model 4	model 4.1	model 5	model 5.1
Ban dummy		-0.621	-0.050	-0.730	-0.333	-0.726	-0.334	-0.637	-0.066
		(-3.49)***	(-0.32)	(-4.13)***	(-2.19)**	(-4.10)***	(-2.20)**	(-3.56)***	(-0.42)
Post-ban dummy		-1.120	-0.735	-1.147	-0.723	-1.153	-0.730	-1.163	-0.771
		(-4.36)***	(-3.03)***	(-4.41)***	(-2.91)***	(-4.43)***	(-2.94)***	(-4.44)***	(-3.13)***
Interaction of ban dummy with firm dummy		1.468	0.390	1.341	0.594	1.340	0.600	1.494	0.408
		(3.34)***	(+1.04)	(3.00)***	(+1.59)	(3.01)***	(+1.61)	(3.39)***	(+1.08)
Interaction of post-ban dummy with firm dummy		0.289	-0.315	0.274	-0.389	0.272	-0.385	0.312	-0.301
		(+1.16)	(-1.23)	(+1.1)	(-1.5)	(+1.1)	(-1.5)	(+1.24)	(-1.17)
Log of stock trading volumes (log(svol))	0.322	0.326	0.283	0.420	0.365	0.414	0.361	0.376	0.326
	(3.81)***	(4.32)***	(3.67)***	(5.60)***	(4.85)***	(5.41)***	(4.67)***	(4.48)***	(3.84)***
Interation of log(svol) with firm dummy			-0.022		0.004		0.001		-0.024
			(-1.65)*		(+0.4)		(+0.04)		(-1.75)*
Stock return (%)	0.096	0.096	0.055	0.095	0.054	0.095	0.053	0.097	0.056
	(4.98)***	(5.24)***	(4.17)***	(5.17)***	(4.08)***	(5.16)***	(4.04)***	(5.28)***	(4.25)***
Interaction of stock returns with firm dummy			0.058		0.058		0.058		0.057
			(3.28)***		(3.28)***		(3.30)***		(3.23)***
Average option spread across calls and puts	-0.747	-1.022	-2.432					-1.037	-2.452
	(-1.43)	(-2.33)**	(-5.71)***					(-2.38)**	(-5.76)***
Interaction of average option spread with firm dummy			2.021						2.034
			(3.76)***						(3.76)***
Average option volume across calls and puts	-0.018			-0.019	-0.016			-0.018	-0.010
	(-4.80)***			(-4.65)***	(-1.57)			(-4.74)***	(-1.35)
Interaction of average option volume with firm dummy					-0.003				-0.009

Table B.18(continued)

					(-0.26)				(-1.14)
Average open interest across puts and calls	0.00001					-0.002	-0.003	-0.001	-0.003
	(+0.01)					(-2.25)**	(-1.1)	(-0.63)	(-1.05)
Interaction of average open interest with firm dummy							0.001		0.003
							(+0.43)		(+1.24)
Ratio of implied volatility on puts over that on calls	-0.042	-0.037	-0.047	-0.041	-0.058	-0.041	-0.058	-0.037	-0.047
	(-3.61)***	(-3.21)***	(-9.12)***	(-3.53)***	(-7.27)***	(-3.55)***	(-6.99)***	(-3.13)***	(-9.70)***
Interaction of ratio of implied volatility with firm dummy			0.016		0.026		0.026		0.016
			(+0.8)		(+1.15)		(+1.14)		(+0.82)
Ratio of open interest on puts over that on calls	0.002	0.002	0.002	0.002	0.002	0.003	0.002	0.002	0.002
	(+1.51)	(+1.45)	(+1.47)	(+1.43)	(+1.49)	(+1.53)	(+1.62)	(+1.5)	(+1.56)
Interaction of ratio of open interest with firm dummy			0.004		0.003		0.004		0.003
			(+0.53)		(+0.43)		(+0.47)		(+0.42)
Ln(stock prices/ exercise price) (ln(s/k)	0.319	0.313	0.318	0.317	0.329	0.317	0.329	0.312	0.317
	(23.85)***	(23.96)***	(18.49)***	(24.06)***	(18.83)***	(24.06)***	(18.80)***	(23.86)***	(18.40)***
Interaction of ln(s/k) with firm dummy			-0.010		-0.021		-0.020		-0.010
			(-0.39)		(-0.8)		(-0.78)		(-0.38)
Time to expiration in years	0.507	0.432	-0.734	0.452	-0.554	0.498	-0.553	0.341	-0.795
	(1.76)*	(+1.5)	(-2.19)**	(+1.62)	(-1.70)*	(1.75)*	(-1.67)*	(+1.21)	(-2.37)**
Interaction of time to expiration with firm dummy			2.292		2.042		2.119		2.249
			(4.64)***		(4.25)***		(4.39)***		(4.58)***
Observations	61533	61533	61533	61533	61533	61533	61533	61533	61533
R-squared	0.11	0.12	0.13	0.12	0.13	0.12	0.13	0.12	0.13

Absolute value of t statistics in parentheses. * significant at 10%; ** significant at 5%; *** significant at 1%

Table B.19: Unit root test for value-weighted price series

Statistical results of null hypothesis of a unit root for two price series (implied stock price derived from put-call parity, observed stock price) from January 1, 2007, through December 31, 2008, for banned and non-banned firms. There are 497 trading days during the sample period. INT, ITM represents intermediate term, in the money options. INT,ATM is intermediate-erm, at-the- money options. INT, OTM is intermediate, out- of-money options. S,ATM is short-term at-the-money options. L,ATM is long-term at-the-money options. The augmented Dickey-Fuller Z (ADF Z) test, Philips-Perron and the Zivot-Andrews tests are used to test for a unit root. The Akaike information criterion (AIC) is used to decide on the length of lag (4). All the models include a constant term. *, ** and *** indicate 10%, 5% and 1% significant level corresponding to the critical value table of each test.

Panel A: Implied stock price for banned firms					
	INT, ITM	INT, ATM	INT, OTM	S, ATM	L, ATM
ADF Z test	-0.35	0.24	-3.38**	0.436	-0.12
Philips-Perron	-0.912	-0.104	-11.805***	0.032	-1.09
Zivot-Andrews	-4.8**	-4.632*	-8.834**	-4.46	-4.33

Panel B: Observed stock price for banned firms					
	INT, ITM	INT, ATM	INT, OTM	S, ATM	L, ATM
ADF Z test	-0.402	0.27	-0.407	0.124	-0.128
Philips-Perron	-0.97	-0.117	-0.969	-0.19	-0.98
Zivot-Andrews	-4.95**	-4.72*	-4.847**	-4.74*	-4.51*

Panel C: Implied stock price for control firms					
	INT, ITM	INT, ATM	INT, OTM	S, ATM	L, ATM
ADF Z test	-6.120***	-4.30***	-5.35***	-4.029***	-3.69***
Philips-Perron	-12.352***	-6.624***	-13.02***	-4.885***	-7.533***
Zivot-Andrews	-8.04***	-6.74***	-6.69***	-5.662***	-5.83***

Panel D: Observed stock price for control firms					
	INT, ITM	INT, ATM	INT, OTM	S, ATM	L, ATM
ADF Z test	-6.34***	-4.15***	-4.64***	-3.659***	-3.635***
Philips-Perron	-13.24***	-6.574***	-10.68***	-4.323***	-6.421***
Zivot-Andrews	-8.06***	-6.77***	-5.35***	-5.49***	-6.21***

Table B.20: Cointegration Johansen's rank test and granger causality test (January 1, 2007 –December 31, 2008)

INT, ITM represents intermediate- term, in- the-money options. INT, ATM is intermediate-term, out-of-the-money options. INT, OTM is intermediate out-of-the-money options. S, ATM is short-term at-the-money options. L, ATM is long-term at-the-money options. Panel A of the table presents results of null hypothesis of no cointegrating relationship between stock and option markets against the alternative of one cointegrating vector (CI). CI is the number of cointegrating equation. Eig is eigenvalue in the cointegrating equation. Trace is the standard Johansen trace statistic. Event dummy is one if during short sale ban period, zero otherwise. Panel B of the table reports the result of Granger causality test for banned and control firms. The first null hypothesis of Granger test is that the stock market does not Granger-cause the options market. The second null hypothesis is that the options market does not Granger-cause the stock market. *, ** and *** indicate 10%, 5% and 1% significant level.

Panel A: Johansen's rank test

Banned	CI	INT, ATM		INT, ITM		INT, OTM		S, ATM		L, ATM	
		Eig.	Trace	Eig.	Trace	Eig.	Trace	Eig.	Trace	Eig.	Trace
With event dummy	0	0.1996	110.01***	0.1025	53.62***	0.223	125.27***	0.1293	68.43***	0.2101	116.58***
	1	0.0001	0.0515	0.0004	0.178	0.0011	0.546	0.00003	0.0192	0.0001	0.058
Without event dummy	0	0.2	109.88***	0.095	49.55***	0.223	124.87*	0.1296	68.6***	0.207	114.73***
	1	0.0002	0.078	0.0004	0.175	0.001	0.47	0.0001	0.045	0.0001	0.062

Panel B: Granger causality test (log likelyhood Ratio test~ chi-squared statistic)

Banned firms	Hypothesis	INT, ATM	INT, ITM	INT, OTM	S, ATM	L, ATM
	1. Stock market does not Granger-cause option market	18.95***	20.21***	106.82***	21.17***	77.12***
	2. Options market does not Granger-cause stock market	0.65	17.68***	6.33*	2.59	12.29***
Control firms	Hypothesis	INT, ATM	INT, ITM	INT, OTM	S, ATM	L, ATM
	1. Stock market does not Granger-cause option market	14.06***	18.10***	9.58**	23.46***	47.48***
	2. Options market does not Granger-cause stock market	0.38	19.37***	2.11	4.61	18.96***

Table B.21: Vector error correction model for change in logarithm of actual stock price and implied stock midprices

$$\Delta p_t^{option} = a_0^{option} + \alpha^{option}(\gamma^{option} p_{t-1}^{option} + \gamma^{option} p_{t-1}^{stock}) + \sum_{i=1}^{3}\Gamma_i^{option}\Delta p_{t-i}^{option} + \sum_{i}^{3}\Gamma_i^{stock}\Delta p_{t-i}^{stock} + \varepsilon_t^{option}$$

$$\Delta p_t^{stock} = a_0^{stock} + \alpha^{stock}(\gamma^{stock} p_{t-1}^{stock} + \gamma^{stock} p_{t-1}^{stock}) + \sum_{i=1}^{3}\Gamma_i^{stock}\Delta p_{t-i}^{stock} + \sum_{i}^{3}\Gamma_i^{stock}\Delta p_{t-i}^{stock} + \varepsilon_t^{stock}$$

Alpha and gamma estimates of the vector error correction model. The second term of the equation is the error correction term. Maximum length of lags are up to 3 days for the differenced price according to the Akaike information criterion (AIC). INT, ATM is intermediate-term out-of-the-money options. INT, OTM is intermediate-term out-of-the-money options. S, ATM is short-term at-the-money options. L, ATM is long-term at-the-money options.

	INT, ATM		INT, ITM		INT, OTM		S, ATM		L, ATM	
	Options	Stock	Options	Stock	Options	Stock	Options	Stock	Options	Stock
Normalized gamma coefficient	-8.83	8.86	-9.03	5.76	0.21	0.28	-3.76	3.78	-4.42	4.51
Mormalized alpha coefficient	0.995	0.098	0.86	0.49	1	0.01	-0.92	0.39	0.93	0.37

Table B.22: Correlation between stock and options market from January 1, 2007 to December 31, 2008

INT, ATM is intermediate-term out-of-the-oney options. INT, OTM is intermediate-term out-of-the-money options. S, ATM is short-term at-the-money options. L, ATM is long-term at-the-money options.

	INT, ATM		Long, ATM		Short, ATM		INT, OTM		INT, ITM	
	Stock	Options	Stock	Options	Stock	Options	Stock	Options	Stock	Options
Stock	1.000		1.000		1.000		1.00		1.000	
Options	0.968	1.000	0.923	1.000	0.906	1.000	0.580	1.000	0.987	1.000

Table B.23: Information share

$$p_t = p_0 + \psi(\sum_{i=1}^{t} \varepsilon_i) + \Psi(L)\varepsilon_t$$

$$IS_j = \frac{([\psi F]_j)^2}{\psi \Omega \psi'}$$

Information share (IS) calculated from equations (5.6) and (5.8). The length of lag is chosen by the Akaike information criterion (AIC). The order of price series in the Cholesky matrix is observed stock prices and then implied stock price in Panel A, vice versa in Panel B. Panel C reports the midpoint of the upper and lower bound. Only the result for banned firms is shown.

		A. Upper bound (for stock market)					B. Lower bound (for stock market)				
Banned firms	Contribution	INT, ATM	INT, ITM	INT, OTM	S, ATM	L, ATM	INT, ATM	INT, ITM	INT, OTM	S, ATM	L, ATM
	Option to stock	5%	4%	1%	9%	7%	78.9%	86.8%	42.0%	98.2%	62.1%
	Option to option	5%	1%	3%	9%	7%	79.1%	93.3%	49.0%	98.2%	62.5%
	Stock to option	95%	99%	98%	91%	93%	20.9%	6.7%	51.0%	1.8%	37.5%
	Stock to stock	95%	96%	99%	91%	93%	21.1%	13.2%	58.0%	1.8%	37.9%

	C. Midpoint				
Contribution	INT, ATM	INT, ITM	INT, OTM	S, ATM	L, ATM
Option to stock	41.9%	45.6%	21.4%	53.6%	34.6%
Option to option	42.0%	47.2%	25.8%	53.6%	34.7%
Stock to option	58.0%	52.9%	74.3%	46.4%	65.4%
Stock to stock	58.1%	54.5%	78.6%	46.4%	65.5%

Table B.24: Gonzalo-Granger common factor weights

The model is

$$\Delta X_t = \underset{pXr}{\gamma}\,\underset{rXp}{\alpha'} X_{t-1} + \sum_{i=1}^{\infty} \Gamma_i \Delta X_{t-i} + \varepsilon_t$$

$$\underset{k\times 1}{f_t} = \underset{k\times p}{B_1}\,\underset{p\times 1}{X_t}$$

Banned firms	INT, ATM	INT, ITM	INT, OTM	S, ATM	L, ATM
Options	9.0%	36.5%	1.0%	29.8%	28.5%
Stock	91.0%	63.5%	99.0%	70.2%	71.5%

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The author was born in Yunlin, Taiwan. She attended National Chengchi University at Taipei, Taiwan and graduated with a bachelor degree in Land Economics and an MBA degree in International Trade in June, 2001. She began to work as a research assistant in the Institution of Economics, Academia Sinica in Taipei, Taiwan for two years. The author then came to Iowa State University at Ames, Iowa and earned her master degree in Economics in the summer of 2005. Subsequently, she moved to Arlington, Texas and pursued her doctoral degree at the University of Texas at Arlington. She began to teach as an instructor at Pacific Lutheran University in the Fall of 2009. She currently is an assistant professor at Pacific Lutheran University, Tacoma, Washington.