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Hide and Seek: Uninformed Traders and the Short-sales Constraints*

Jinghan Cai, Chiu Yu Ko, Yuming Li, and Le Xia†

We examine the effect of short selling via the unique setting in the Hong Kong stock market and find that, when a stock becomes shortable, its trading activities decrease, liquidities worsen, and information asymmetries increase. This finding contradicts both the existing theoretical models, and recent empirical studies using global financial crisis data. We extend the sequential trading model with short-sales constraints of one asset by Diamond and Verrecchia (1987) to the case of multiple assets. The model predicts that our empirical results are due to uninformed traders quitting from trading the shortable securities.

Key Words: Short-sales constraint; Liquidity; Information asymmetry; Microstructure.
JEL Classification Numbers: G14, G15.

1. INTRODUCTION

Short selling has long been the focus of both academics and practitioners. Although it has been in place for decades in major financial markets around the world, its effect remains controversial. Pioneering theoretical research dates back to Miller (1977), who argues that stock prices tend to be upward biased under short-sales constraints because the pessimistic

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† Cai: Department of Economics and Finance, The University of Scranton, Scranton, U.S.A. Email: jinghan.cai@scranton.edu; Ko: Corresponding Author. Department of Economics, National University of Singapore, Singapore 117570. Email: kochiuyu@nus.edu.sg; Li: School of Business and Economics, California State University, Fullerton. Email: yli@fullerton.edu; Xia: Research Department, BBVA, Hong Kong. Email: le.xia@bbva.com.

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investors are kept out of the market. A later well-known paper is Diamond and Verrecchia (1987), who argue that stock prices under the short-sales constraints adjusts more slowly to unfavorable private information than it does to favorable private information in a rational expectation framework.

Chang, Cheng and Yu (2007) argue that most of the empirical works including Figlewski (1981), Danielsen and Sorescu (2001), and Ofek and Richardson (2003) suffer from the problem of using an imperfect proxy for the short-sales constraints, and in contrast to that, Chang, Cheng and Yu (2007) utilize the unique regulatory feature of Hong Kong market that the list of shortable stocks is revised over time and find supporting evidence for overvaluation hypothesis by Miller (1977). Continuing their study by using the same natural experiment, we find that, after the removal of the short-sales constraints, the underlying stock exhibits: (1) higher information asymmetry, represented by increased Probability of informed trading (PIN) and increased adverse selection cost; (2) wider bid-ask spreads, indicating a worsened liquidity, and (3) fewer trading activities, indicated by significantly fewer number of trades, and number of buyer-/seller- initiated trades, and lower share volume and dollar volume.

Our empirical findings cannot be explained by existing theoretical models. In particular, single-asset models cannot predict the drop in trading activities. Therefore, we extend the single-asset sequential trading model in Diamond and Verrecchia (1987) to its multiple-asset version in which a competitive, risk-neutral market maker stands to trade securities of two identical firms in the same industry but only one of them is subject to a short-sales constraint. Uninformed investors trade on public information only while informed traders receives private signals on the occurrence of an information event. The uninformed market maker sets bid-ask spread to remedy adverse selection problem, and updates bid and ask prices according to the buy-sell orders received. Different from Diamond and Verrecchia (1987), an informed trader receiving a negative industry-wide signal without any stock will short the shortable stock and hence, the shortable stock will face more informed selling than the non-shortable stock. Moreover, there are *discretionary* uninformed traders who can choose between two stocks. Fearing the potential loss from trading against informed traders with negative signals, they avoid trading the shortable stock and go for the non-shortable ones, leading to even higher bid-ask spread in the shortable stock. Trading activity and liquidity of the shortable stock decrease as long as the effect due to the runaway uninformed traders outweighs the influx of informed traders.

Our empirical results about liquidity and trading activities are in sharp contrast with those using the world-wide short-selling ban data in the 2008 crisis (see Beber and Pagano (2013), Boehmer, Jones, and Zhang (2010), Kolasinski, Reed and Thornock (2010), and Marsh and Payne (2012), etc).

They find that after banning short selling, the liquidity of stocks worsens. We reconcile this difference by looking at the trading environments in the crisis and in the normal periods, respectively. In normal period, becoming shortable does not contain valuation information of the underlying stock. However, during the crisis, the banning of short selling conveys negative information that the the prevailing prices are still too high. On receiving this signal, uninformed traders revise their beliefs downward and become informed traders, forcing the market maker to widen the bid-ask spread, and hence liquidity worsens. Therefore, the seemingly conflicting results in the literature are not inconsistent with our theoretical framework.

In the literature, there are some papers that use similar settings, including Gao, Hao, Kalcheva and Ma (2011), Bai and Qin (2014) and Zhang and Ikeda (2017). All these papers use the Hong Kong's short selling setting but focus on different aspects. Gao, Hao, Kalcheva and Ma (2011) use a sample period that covers both crisis and non-crisis periods, and find no change in liquidity around the short-selling status change events. We argue that our theory occurs in "normal" period, and we indeed find the liquidity change only during non-crisis periods. Bai and Qin (2014) and Zhang and Ikeda (2017)find some measures of liquidity decline following the addition to the list of shortable stocks, but they attribute the reason to the opinion across optimists and pessimists. We, instead, explain the reduction in liquidity from the perspective of investor composition. Moreover, we use a more comprehensive list of liquidity measures, and find out consistent results with our theoretical model.

The rest of this paper is arranged as follows. Section 2 reviews the literature and Section 3 introduces the model. Section 4 presents the data and the main empirical results, Section 5 discusses the robustness, and Section 6 concludes.

2. LITERATURE REVIEW

The first theoretical literature of the short-sales constraints is generally considered to be Miller (1977), who argues that since the stock price is determined by the belief of the marginal investor, a short-sales constraint drives up the price because holders of negative information are kept out of the market. Harrison and Kreps (1978), based on Miller (1977), construct a simple model to show that when the short-sales constraints are binding, a stock can be overvalued because it implicitly includes extra option-like value by selling them to the relatively more optimistic investors. However, Jarrow (1980) provides a counter-example to Miller's prediction in a capital asset pricing model (CAPM) where the reaction of stock price is ambiguous due to "substitution effect": short-sales constraints can lead to the increase in the demand of substitutable securities so that the demand of the underlying security may decrease.

Another well-known paper, Diamond and Verrecchia (1987), constructs a sequential trading model based on Glosten and Milgrom (1985), in which an uninformed competitive, risk-neutral market maker facing informed traders sets the bid-ask spread to solve the adverse selection problem. The market maker updates bid and ask prices after observing trades and orders. They show that the short-sales constraints do not necessarily bias the stock prices upward if investors are rational. However, short-selling prohibition effect will reduce the speed of informational adjustment of the underlying stock. Since the short-sales constraints reduce the probability of sale signalling bad news, they show that the speed of price adjustment to new information, trading activities, and liquidity of the stock will increase after removal of short-sale constraint.

Scheinkman and Xiong (2003) develop a behavioral model where some heterogeneous investors are overconfident about their private information. When short selling is prohibited, the price is the sum of its fundamental value (dividend on liquidation date) plus an option value (sell to the other investors when new information changes their relative beliefs). Lifting the short-sales constraints eliminates the resale option, which leads to lower trading volume. Bai, Chang and Wang (2006) show that in a rational expectation equilibrium the effect on trading activities depend on two competing forces: risk-sharing motive due to rebalance after fluctuation and speculation motive due to private information about the future payoff of a stock.

As theoretical papers do not agree on the effect of the short-sales constraints on liquidity and trading activities, the empirical literature also renders mixed results in this aspect. Charoenrook and Daouk (2005), who investigate the effects of market-wide short-selling restrictions on several variables for 111 countries, find that short-selling restrictions correlate with greater market-wide liquidity, as measured by total stock market trading volume. Chuang and Lee (2010) show that liquidity for the Taiwan Index 50 component stocks decreases subsequent to the removal of short-sales constraints. However, Boehmer, Jones and Zhang (2010) analyze the response of liquidity to the short-selling ban imposed during the 2008 financial crisis and find that liquidity deteriorates significantly for stocks subject to the ban. This finding is further confirmed by Kolasinski, Reed and Thornock (2010) and Marsh and Payne (2012). Beber and Pagano (2013) show that the short-selling bans and constraints in 30 countries during the 2008 financial crisis are detrimental for liquidity, and slow down price discovery.

3. THE MODEL

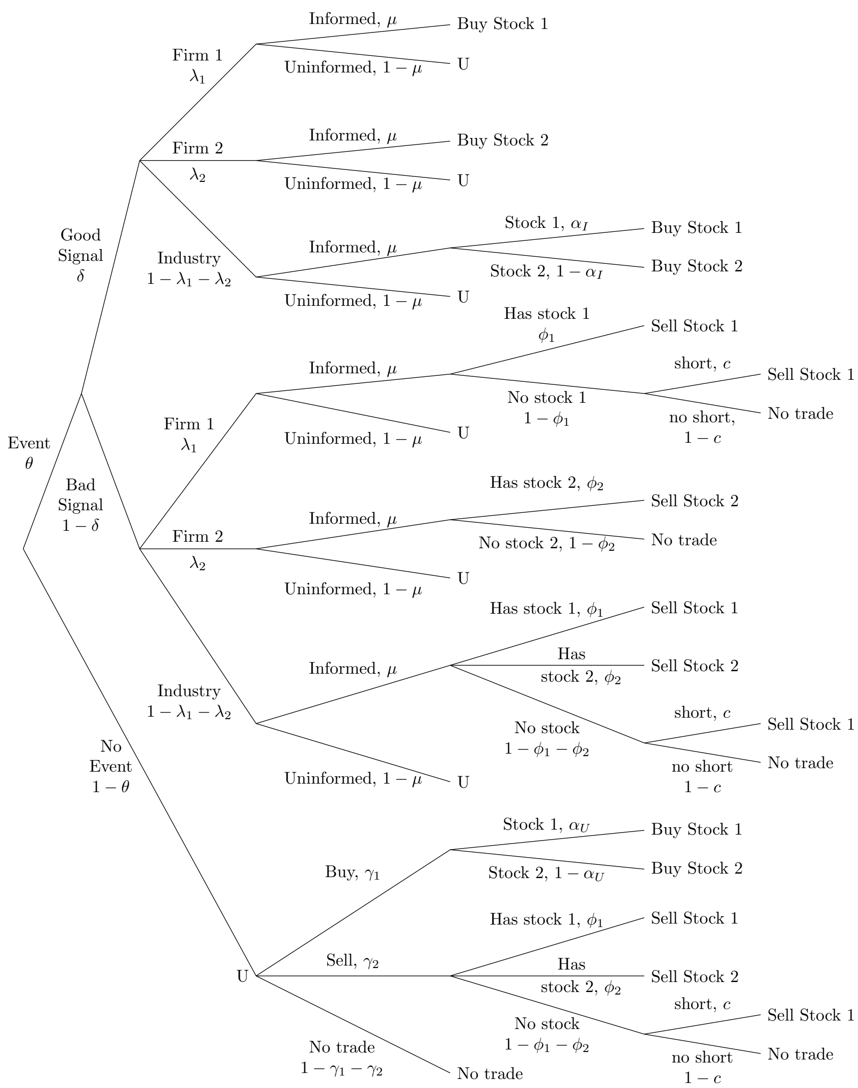
We consider a sequential trading model with multiple assets and short-sales constraints in the same spirit of Diamond and Verrecchia (1987), Easley, Kiefer and O'Hara (1996), and Tookes (2008). There are two identical firms of the same industry, and the eventual value of stock of firm $i, (i = 1, 2)$ is represented by a random variable $V_i \in \left\{V^L, V^H\right\}$ at time τ in the future. Denote stock $i, (i = 1, 2)$ as the stock of firm i. The only difference between the two firms is that stock 1 is shortable, while stock 2 is not. Let $c \in [0, 1]$ be the fraction of investors that are allowed to short the stock 1. Trades in the equity market occur during a sequence of days indexed by $j = 1, \ldots, J$. An information event at time t, as the occurrence of signal ψ_t about (V_1, V_2), occurs before the start of a trading day with probability θ.[1] When an information event occurs, the probability that it is a good signal with probability δ and a bad signal with probability $1 - \delta$. Hence, the value of stock for firm i at unconditional level is $V^M = \delta V^H + (1 - \delta) V^L$. Regardless of the nature of the signal, the probabilities that a signal is firm 1-specific, firm 2-specific or industry-wide are λ_1, λ_2 and $1 - \lambda_1 - \lambda_2$. Therefore, a signal ψ_t can take values $+_1, +_2, +_{12}$, $-_1, -_2$, and $-_{12}$ where $+_i$ and $-_i$ are firm i-specific good and bad news, $+_{12}$ and $-_{12}$ are industry-wide good and bad news.

Traders transact with a risk neutral and competitive market maker who sets prices to buy or sell securities. If an information event occurs, fraction μ of traders is informed and fraction $1 - \mu$ is uninformed traders. Clearly, if no information event occurs, all investors are uninformed. Let I and U be informed investors and uninformed investors. Facing a firm-specific good signal, an informed trader will buy the stock of the firm. Facing an industry-wide good news, the informed trader buys stock 1 with probability α_I and stock 2 with probability $1 - \alpha_I$. Since only fraction c of traders can sell sell stock 1 without holding it, we have to specify the distribution of ownership. Of all traders, fraction ϕ_1 of them has stock 1, fraction ϕ_2 has stock 2, and fraction $1 - \phi_1 - \phi_2$ owns neither stocks. Facing a firm-specific bad signal, investors owning the stock will sell it, and investors not owning the stock can short the stock if they are not subject to short-sales constraints. Facing an industry-wide bad signal, investors owning a stock will sell it and those not owning any stock short the stock if allowed. For uninformed traders, fraction γ_1 of them buy a stock, fraction γ_2 of them sell a stock and fraction $1 - \gamma_1 - \gamma_2$ of them do not trade. For those who wants to buy a stock, fraction α_U of them buy stock 1 and fraction $1 - \alpha_U$

[1] As argued in Easley and O'Hara (1992), an information event may not occur because uninformed market participants may not know whether any new information event even exists. If information is known to occur, in most stock markets, the stock would stop trading until the information is released.

of them buy stock 2. For those who wants to sell a stock, those investors owing a stock will sell it and those not owning any stock short stock 1 if allowed. See Figure 1 for the probability tree for the market maker.

FIG. 1. Probability tree for the market maker.



Let $Bid_{i,t}$ and $Ask_{i,t}$ the bid and ask prices of stock i at time t. As a standard application of Bayes' Rule, we can solve for initial bid and ask prices ($Bid_{1,0}$,$Bid_{2,0}$, $Ask_{1,0}$, and $Ask_{2,0}$) in equilibrium. The following proposition shows that when the short-sales constraint relaxes (c increases), the initial bid price for stock 1 ($Bid_{1,0}$) increases but all other initial prices remains unchanged.[2]

Proposition 1. *If more investors are allowed to short the stock 1 (c increases), then the initial bid price of stock 1 decreases while initial ask price of stock 1, initial bid and ask prices of stock 2 remain unchanged. Hence, the initial bid-ask spread of stock 1 is higher than that of stock 2.*

Relaxation of the short-sales constraint depresses the initial bid price of shortable stocks is in sharp contrast with Diamond and Verrecchia (1987) where the short-sales constraints have no impact on the initial bid-ask spread. The intuition behind Proposition 1 is that under a bad industry-wide information event, the shortable stock attracts more informed sales in the presence of another related non-shortable stock that reduces its initial bid price. This is similar to Jarrow (1980) showing substitution effect between stocks could reverse overvaluation result of the shortable stocks in Miller (1977).

Since the magnitude of bid-ask spread represents the severity of adverse selection problem, higher bid-ask spread of firm 1 implies more informed trading of stock 1.

Corollary 1. *If more investors are allowed to short the stock 1 (c increases), the percentage of informed trading for stock 1 stock goes up.*

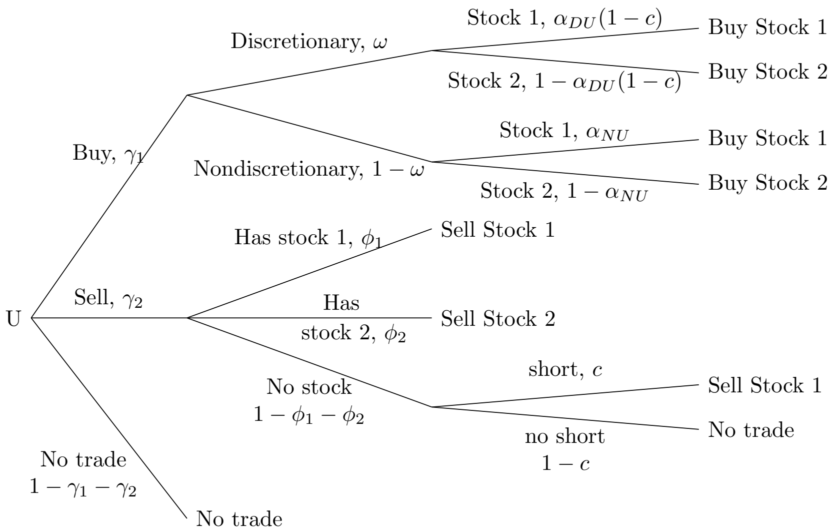
We have assumed that uninformed traders are still equally likely to buy either stock even if stock 1 becomes shortable. However, Jarrow (1980) shows that the relaxation of short-sales constraint on one stock leads to substitutions of an alternative stock in a CAPM model. In our model, when a stock becomes shortable, the originally excluded bad news holders can now sell the stock. In light of Jarrow (1980), we argue that facing more severe adverse selection in trading shortable stock, some uninformed traders, prefers stocks with lower bid-ask spread, switch their tradings to the non-shortable stock.[3] Formally, uninformed traders are divided into ω fraction of discretionary uninformed traders and $1-\omega$ fraction of non-

[2] All proofs are relegated to Appendix A.

[3] There is a substantial theoretical literature on negative externalities in the old market upon opening new markets. Biais and Hillon (1994) show that upon opening of option market, price efficiency of stock market can increase due to new informative trades but can decrease due to slower learning due to more complex trading strategies. Bhattacharya, Reny and Spiegel (1995) show that a new securities market causes collapse of the existing market. Dow (1998) argues that informed traders use related market to hedge risk of their positions in the old market, leading pure liquidity traders to exit.

discretionary uninformed traders where nondiscretionary traders are not allowed to choose what stock to buy but discretionary traders are allowed to choose to buy either stock 1 or stock 2.[4] Let DU and NU be discretionary and nondiscretionary uninformed investors, respectively. If the switching effect is directly proportional to the fraction of investors that are allowed to short stock 1, for discretionary traders, then fraction $\alpha_{DU}(1-c)$ of them want to buy stock 1 and fraction $1-\alpha_{DU}(1-c)$ of them want to buy stock 2. The corresponding fractions for nondiscretionary traders are unaffected by the switching, and hence, denoted as α_{NU} and $1-\alpha_{NU}$. The ownership distribution is the same for both types of traders. See Figure 2 for the probability tree for the market maker.

FIG. 2. Probability tree for the market maker for uninformed traders.



Proposition 2. *If some uninformed traders who are allowed to choose which stock to buy (α_{DU} increases), then the initial ask price of stock 1 increases, the initial ask price of stock 2 decreases, and initial bid prices of both stocks remains the same.*

Boehmer, Chava and Tookes (2013) document that the emergence of credit default swap contracts adversely affects equity market quality.

[4]Admati and Pfledierer (1998) extend the Kyle (1985) model by allowing uninformed traders to defer transactions in a single-asset framework to hide from informed traders. In our multi-asset model, switching to another asset is better than deferring transaction.

With Proposition 1, the initial bid-ask spread of stock 1 is larger than that of stock 2. Applying the same reason as in Corollary 1, we have the following result.

Corollary 2. *If some uninformed traders are allowed to choose which stock to buy, the percentage of informed trading for stock 1 stock goes up.*

Next, we examine the effect on trading activities. Denote $b_{i,t}$ the number of buying trade for stock i up to time t, $s_{i,t}$ the number of selling trade for stock i up to time t, and n_t the number of no trade events up to time t. Note that we always have $t = b_{1,t} + b_{2,t} + s_{1,t} + s_{2,t} + n_t$. Define $v_{i,t} \equiv b_{i,t} + s_{i,t}$ the total trading volume of stock i up to time t. Since the relaxation of short-sales constraint attracts selling but distracts buying from discretionary uninformed investors, the expected trading activities would increase if the latter effect dominates.[5]

Proposition 3. *If more investors are allowed to short the stock 1 (c increases), and the effect of discretionary investors switching to non-shortable stocks dominates the effect of new short-selling, or* $(1-\mu)\omega\alpha_{DU}\gamma_1 > \mu(1-\phi_1) + (1-\mu)\gamma_2(1-\phi_1-\phi_2)$, *then the trading activities for stock 1 decreases while that of stock 2 increases.*

In summary, after relaxation of short-sales constraints, our model predicts that when a stock is allowed to short, it is possible that more informed tradings, wider bid-ask spread, and fewer trading activities can be observed, under the condition that there is enough uninformed trades in the stock. We have the following four testable hypotheses.

Hypotheses. Consider two non-shortable stocks. When one stock becomes shortable, then, for the shortable stock,

(1) the probability of informed trades increases, (Corollaries 1 and 2)

(2) the bid-ask spread increases, (Propositions 1 and 2) and

(3) the trading activities may decrease, if there are enough uninformed traders switching to the non-shortable stock. (Proposition 3)

[5]This is similar to a behavioral-investor model by Scheinkman and Xiong (2003). They argue that some investors trade based on speculative motives to sell the stock to other less sophisticated investors. When smart money can short the stock, there is fewer opportunities to profit from less sophisticated investors as the price will be more efficient and thus speculative-motivated investors leave the market. Then the market will be crowded with smart money and trading activity reduces.

4. EMPIRICAL STUDIES OF THE HONG KONG MARKET

In this section, we empirically examine the testable hypotheses using the data from Hong Kong stock market.[6] Hong Kong Exchanges and Clearing Limited (HKEx) has started to publish the list of stocks allowing for short-selling since 1994. On announcement, stocks on the list are automatically permitted to be shorted, which produces a series of events where stocks change their status from non-shortable to shortable. On the other hand, the stocks removed from the list provide the events of short-sales prohibition. In January 1994, the HKEx introduced the scheme for regulated short selling with seventeen securities on the list and the short-selling price could not be below the best current ask price ("uptick rule"). The scheme was revised in March 1996 with the number of designated securities for short selling increased, and the uptick rule was abolished. However, the uptick rule was reinstated on September 7, 1998, upon changes in market conditions due to the Asian financial crisis. Presently the list of designated securities for short selling is revised on a quarterly basis. The stocks which meet the criteria of "eligible stocks" are added into the short-selling list, while those no longer eligible are removed from the list. More detailed discussion of the scheme can be found in Chang, Cheng and Yu (2007).

4.1. The Data

We use two datasets in this paper: (1) the intraday trading and quote data from the Hong Kong Stock Exchange Databases (HKTAQ data hereinafter). The Trade Records and the Quote Records are stored in two separate files. The Trade Records File includes the date, time, price, and quantity of every transaction occurring in the HKEx. The Quote Records Files contains the date, time, bid and ask prices, queue lengths, and quantities up to the five best queues recorded by snapshot every 30 seconds; and (2) The addition and deletion event samples are from the News Release of HKEx. The information for a stock's short-selling eligibility is first disclosed on the website of the HKEx inthe form of regular briefings and there is no preannouncement of any form. In addition to the stock names and stock identification codes, the News Release of designated short selling list also discloses the effective date of every addition event and part of announcement dates.

[6]The Hong Kong stock market is a pure order-driven market. Security prices are determined by the buy and sell orders submitted by investors in the absence of designated market makers. Limit orders are placed through brokers and are consolidated into the electronic limit-order book and executed through an automated trading system, known as the Automatic Order Matching and Execution System (AMS). The limit orders for a specified price and quantity are stored in the system and executed using strict price and time priority. Although the trading system only accepts limit orders, investors could submit market orders to their brokers who will place them in the form of limit orders that match the best price on the other side of the book.

4.2. Sample Selection

FIG. 3. Hang Seng Index, 1999-2008.

During our sample period between January 1st, 2000 to December 31st, 2008, there are 743 addition events, and 624 deletion events, summing up to 1367 events on the main board altogether. Every one of the addition (deletion) events corresponds to a stock added into (removed from) the designated short selling list of HKEx. We first exclude the stocks with less than 45 trading days either before or after the addition/deletion events, leaving 1212 events. Then, we drop off the second event if the time gap between two consecutive events occurs no longer than 60 days after the previous one, and 21 events are therefore dropped, leaving 1191 events. We further drop the events where a stock's average price in the 120-day window is less than 0.05 HK dollars, and leave the final sample of 1178, among which 653 events are addition events, and 525 are deletion events. The distribution of events in each year is displayed in Table 1.

In this paper, we adopt [-25 days, -5 days from announcement date) and (5 days from effective date, 25 days] as the pre- and post-event windows around both addition and deletion events. The descriptive statistics for the samples in the pre-event are shown in Table 2.

4.3. Probability of Informed Trading

Hypothesis 1 predicts that the information asymmetry will increase after a stock is allowed to short. A natural candidate to proxy information asymmetry is the Probability of INformed trading (PIN). Developed by Easley, Kiefer, O'Hara and Paperman (1996), PIN estimates the probability that a given stock is subject to informed trading over a certain period of time. This measure has been widely used in recent literature in pricing (Easley, Hvidkjaer and O'Hara, 2002), stock splits (Easley, O'Hara and Saar, 2001), stock analyst coverage (Easley, O'Hara, Paperman, 1998), purchased order

TABLE 1.

Number of Addition Events.

Year	Addition Events	Deletion Events	Sum
2000	24	9	33
2001	23	82	105
2002	43	35	78
2003	57	32	89
2004	64	33	97
2005	76	31	107
2006	93	25	118
2007	212	42	254
2008	61	236	297
Total	653	525	1178

The event is a stock's addition into the designated short selling list. All the sample events occur between January 1, 2000 and December 31, 2008. The stocks are traded on the main board of the HKEx.

TABLE 2.

Descriptive Statistics.

Panel A	Daily trading volume (HK$)	Daily trading volume (shares)	Daily # of trades	close price	Market Cap.
Deletion	4124797.10	8230072.58	116.70	1.56	1315.23
Addition	19807076.00	15463244.33	296.77	3.62	4138.10

Panel B	Group	Daily trading volume (HK$)	Daily trading volume (shares)	Daily # trades	of close price	Market Cap.
Deletion	low price	2,866,258.70	8,168,103.18	101.37	0.49	823.55
	medium price	4,395,864.10	6,017,273.37	123.49	1.21	1,097.35
	high price	5,316,781.50	7,326,975.44	118.91	3.04	2,130.95
Addition	low price	13,793,907.00	21,707,651.87	248.56	1.31	2,157.68
	medium price	16,273,776.00	11,753,203.76	281.93	2.95	3,288.11
	high price	39,190,083.00	28,537,810.94	488.80	6.62	7,304.98

This table shows the descriptive statistics for the stocks in the addition events and deletion events respectively.

flows (Easley, Kiefer and O'Hara, 1996), and ownership structure (Dennis and Weston, 2001).

As a standard assumption to estimate PIN, the arrival of orders follows the Poisson distribution. Both buying orders and selling orders of uninformed trades arrive at rate ε per minute and those of informed trades are η. Since there are informed trades only if there is an information event on that day, both buying and selling orders will arrive with the rate of ε on days without any news. On days with good news, there will be more buy orders with arrival rates $\varepsilon + \eta$, while sell orders arrive at rate ε. On bad news days, there will be more sell orders with arrival rates $\varepsilon + \eta$, while buy orders still arrive at rate ε.

Let $P(t) = [P_n(t), P_b(t), P_g(t)]$ be the belief of the market maker at time t where $P_n(t)$, $P_b(t)$, and $P_g(t)$ represent the probabilities of no news, bad news, and good news, respectively. The initial belief is $P(0) = [1-\alpha, \alpha, \alpha(1-\delta)]$. As orders arrive, the market maker updates the belief by Bayes' rule. Let S_t the event of a sell order arriving at time t and B_t the event of a buy order. Then, the likelihood function is:

$$L(B,S) = (1-\alpha)\left\{e^{-\varepsilon T}\frac{(\varepsilon T)^B}{B!}e^{-\varepsilon T}\frac{(\varepsilon T)^S}{S!}\right\} + \alpha\delta\left\{e^{-\varepsilon T}\frac{(\varepsilon T)^B}{B!}e^{-(\eta+\varepsilon)T}\frac{((\eta+\varepsilon)T)^S}{S!}\right\} + \alpha(1-\delta)\left\{e^{-(\eta+\varepsilon)T}\frac{((\eta+\varepsilon)T)^B}{B!}e^{-\varepsilon T}\frac{(\varepsilon T)^S}{S!}\right\}$$

where T is the number of time intervals in each trading day.

The problem is now reduced to the estimation of the four parameters $(\alpha, \delta, \varepsilon, \eta)$. The selling order and the buying order are identified using the algorithm of Lee and Ready (1991). The numbers of selling and buying orders are then computed for further estimation. By maximum likelihood estimation, we estimate the four parameters over the pre-event and post-event estimation window. Then we estimate the PIN for the pre-event window and post-event window of each event as follows:

$$PIN = \frac{\alpha\eta}{\alpha\eta + 2\varepsilon}$$

The estimation result of PIN is shown in Table 3.

Panel A of Table 3 indicates that the average PIN of the underlying stocks rises from 26.5% to 28.20% after the lift of the short-sales constraint. The change is significant at 1% level, and the median also increases significantly. Furthermore, the arrival rates for uninformed trades (ε) and informed trades (μ) all decreases for the addition events, implying that it might be the case that some investors may quit from trading these (now shortable stocks). The results support hypothesis 1: if a stock is allowed to short, the probability of informed trading increases, due to the quit of uninformed traders. As a comparison, Panel B of Table 3 shows that the average PIN of the deletion events decreases from 34.2% to 33.3% (although not significant). Also in sharp contrast to the results of Panel A, the arrival rates for uninformed trades and informed trades both increase, which implies that, first, after banning short selling, some investors enter the stock and trade; second, the reduction of ε and μ in Panel A is not

TABLE 3.

Probability of Informed Trading

Panel A: Addition	Pre	Post	*Pairwise-t / Signrank-z*	p-value
Probability of an Information Event, α				
Mean	0.373	0.395	2.58	0.010
Median	0.423	0.500	2.79	0.005
Arrival Rates of Uninformed Trades, ε				
Mean	117.52	92.28	−5.77	0.000
Median	64.11	48.44	−7.43	0.000
Arrival Rates of Informed Trades, μ				
Mean	204.50	156.46	−7.25	0.000
Median	139.97	105.21	−7.27	0.000
Probability of Information Based Trades				
Mean	0.265	0.280	2.69	0.007
Median	0.254	0.279	2.27	0.023
Panel B: Deletion	Pre	Post	*Pairwise-t / Signrank-z*	p-value
Probability of an Information Event, α				
Mean	0.431	0.404	−2.96	0.003
Median	0.500	0.500	−2.85	0.004
Arrival Rates of Uninformed Trades, ε				
Mean	36.36	41.67	2.04	0.042
Median	20.85	21.97	1.36	0.175
Arrival Rates of Informed Trades, μ				
Mean	88.32	101.31	2.86	0.005
Median	58.48	66.65	2.31	0.021
Probability of Information Based Trades				
Mean	0.342	0.333	−1.15	0.251
Median	0.354	0.338	−0.97	0.335

The table reports arrival rates of uninformed and informed trades, as well as the probability of informed trading before and after stock additions into (deletions from) the designated short selling list and the differences between the post- and pre-event windows of 60 days. P-values of pairwise t-test for means and the signrank pairs-matched test for medians are presented in the last column.

from a market-wide trend. The results in Panels A and B both support Hypothesis 1.

4.4. Bid-ask spread

Our model may render sharply different results from existing literature on trading activities and liquidity. Specifically, we argue that trading may be less active after the lift of the short-sales constraints, contrary to Diamond and Verricchia (1987). Hypothesis 2 predicts that the spread will widen after the lift of the short-sales constraints. In this section, we examine the change of quoted spread, effective spread and relative spread around the addition/deletion events. Then quoted spread at time t is $Ask_t - Bid_t$. The relative spread is $(Ask_t - Bid_t)/P_t$. Define $M_t = (Ask_t + Bid_t)/2$ as the quote midpoint at time t. Then the effective spread is $2|P_t - M_t|$.

TABLE 4.

Bid-ask Spread.

Panel A: Addition Group	Pre	Post	*Difference*	*Pairwise-t/ Signrank-z*	p-value
Absolute Spread (HK$)					
Mean	0.027	0.029	0.0012	2.50	0.012
Median	0.009	0.023		2.26	0.024
Relative Spread					
Mean	0.010	0.011	0.0006	3.34	0.001
Median	0.009	0.010		3.69	0.000
Effective Spread (HK$)					
Mean	0.031	0.032	0.0010	1.96	0.050
Median	0.023	0.023		0.54	0.593
Panel B: Deletion Group	Pre	Post	*Difference*	*Pairwise-t/ Signrank-z*	p-value
Absolute Spread (HK$)					
Mean	0.023	0.020	−0.0028	−3.75	0.000
Median	0.013	0.012		−4.39	0.000
Relative Spread					
Mean	0.019	0.018	−0.0009	−1.78	0.075
median	0.016	0015		−3.33	0.001
Effective Spread (HK$)					
Mean	0.024	0.021	−0.0029	−3.89	0.000
Median	0.015	0.013		−4.61	0.000

The table reports bid-ask spreads in the pre- and post-window around the events. P-values of based on pair-wise t-test for mean differences and the Wilcoxon signrank test for median differences. The absolute spread is the difference between ask and bid prices. The effective spread is 2 times the absolute value of the difference between the transaction price and the average of bid and ask prices, and relative spread is the absolute price over the transaction price.

Table 4 reports the changes of the daily average bid-ask spread over the estimation windows. The means of all three types of spread increase in after the short-sales constraints are removed and the increases are statistically significant at 5% level. Specifically, the mean quoted spread (in Hong Kong dollars) increases from 0.027 to 0.029 HK$; The mean relative spread increases from 0.010 to 0.023, and the mean effective spread increases from 0.031 to 0.032 HK$, all of which are significant at 5% level. The median changes are highly consistent with the mean, except that the median of effective spread increases insignificantly. The results in Panel A indicate that the liquidity worsens after the lift of short sales constraints, which is what our model predicts. As before, the concerns come from the possibility that the widened spread is also coming from some unknown market-wide events. To eliminate the concerns, we check the change of spread after an originally shortable stock becomes banned from shorting. The results are in Panel B of Table 5: all the mean and median changes flip the signs around deletion events, implying that the results in Panel A may not come from some market-wide events. Overall, results in Table 4 confirm with our model that the bid-ask spread of underlying stocks increases after the removal of the short-sales constraints, and decreases after the introduction of the short-sales constraints.

4.5. Trading Activities

In this section, we empirically check the change of trading activities around the change of shortability. We measure trading activities by the (daily) number of trades, share volume (the total amount of traded shares within a trading day) and dollar volume (the equivalent money amount of share volume).

Table 5 reports the daily average trading activities before and after additions into (deletions from) the designated short selling list and differences between the post- and pre-event windows. p-values of pair-wise t-test for mean differences and the Wilcoxon pair-matched test for median differences are presented in the last column.

All measures in Panel A of Table 5 indicate that trading activities decrease after the lift of the short-sales constraints. Specifically, the daily number of trades decreases from 336 trades to 258 per day, which corresponds with a 16% (pairwise) decrease. Consistently, daily share volume falls from 19.6 million to 11.3 million, with log-difference 17.7%; and the mean dollar volume drops from 22.8 million to 16.8 million HK$, with log-difference of 22% percent lower. Consistently, the daily number of buyer-initiated / seller initiated trades also decrease about 15% after the removal of short sales constraints. All the above difference is significant at 1% level.

One concern about the results in Panel A of Table 5 is that, one may suspect that there might be some other market-wide, systematic changes around the addition events.[7] In order to test whether these market-wide changes may explain the result, we further check the deletion events, and find that all the signs of paired change of mean (and median) number of trades, share volume, dollar volume, number of buyer- (seller-) initiated trades, flip, compared with those form Panel A of Table 5, implying that after an (originally shortable) stock is prohibited from being shorted, the

[7]We are going to discuss the exogeneity problem of the events in Section 5.

TABLE 5.

Trading Activities.

Panel A: Addition Group Number of obs: 653	**Pre**	**Post**	*Diff* */logged diff*	*Pairwise-t* */Signrank-z*	p-value
Number of trades					
Mean	335.6	258.0	−0.162	−6.19	0.000
Median	141.5	122.3		−6.70	0.000
Share Volume (10^6 shares)					
Mean	19.6	11.3	−0.177	−5.71	0.000
Median	3.4	2.8		−6.46	0.000
Dollar Volume (HK$$10^6$)					
Mean	22.8	16.8	−0.220	−6.58	0.000
Median	6.5	5.3		−7.05	0.000
Number of Seller-Initiated Trades					
Mean	167.2	131.0	−0.162	−6.32	0.000
Median	70.6	61.6		−6.93	0.000
Number of Buyer-Initiated Trades					
Mean	168.4	127.0	−0.158	−5.69	0.000
Median	70.9	60.0		−6.05	0.000
Order Imbalance					
Mean	0.471	0.474	0.003	1.00	0.318
Median	0.470	0.471		0.65	0.516

Panel B: Deletion Group Number of obs.: 525	**Pre**	**Post**	*Diff* */logged diff*	*Pairwise-t* */Signrank-z*	p-value
Number of trades					
Mean	113.1	120.3	0.020	0.59	0.558
Median	54.5	59.0		0.12	0.906
Share Volume (10^6 shares)					
Mean	7.1	9.4	0.043	1.06	0.291
Median	1.9	1.9		0.58	0.560
Dollar Volume (HK$$10^6$)					
Mean	4.1	4.2	0.000	0.01	0.994
Median	1.5	1.6		0.57	0.570
Number of Seller-Initiated Trades					
Mean	57.4	60.2	0.012	0.27	0.788
Median	30.0	31.1		0.38	0.702
Number of Buyer-Initiated Trades					
Mean	55.8	60.0	0.034	0.91	0.361
Median	26.0	26.9		0.58	0.571
Order Imbalance					
Mean	0.453	0.458	0.005	1.40	0.163
Median	0.448	0.457		1.39	0.164

The table reports daily average trading activities before and after stock added into (deleted from) the designated short selling list and differences between the post- and pre-event windows. P-values of pairwise t-test for mean differences and the Wilcoxon signrank test for median differences are presented in the last column. Order imbalance is compared using the difference between post-event value and pre-event value, while other variables are compared using the paired log-difference.

trading gets more active. These results are consistent with our model, and the argument that market-wide changes take a role does not explain the opposite directions between addition and deletion events.

Table 5 further looks at the trades initiated by buyers and sellers, as well as the daily order imbalance, which is defined as the number of buyer-initiated trades less the number of seller-initiated trades on day t, then divided by the total number of trades on day t (see Chordia, et al, 2002). Not surprisingly, both buyer- and seller-initiated trades significant decrease for the addition events. For the deletion events, both increase, but insignificantly. However, the change in order imbalance remains insignificant for both the addition and the deletion events. If the influx of informed investors dominates, we expect to see that the order imbalance will decrease, which is caused by the short sellers' shorting behaviors on the sell side. The above results imply that the leave of uninformed traders may dominate, since the quit of uninformed may result in the reduction of trades on both the buy side and the sell side.

Further evidences about the deletion events are consistent with the said story: to ban short selling may attract some (uninformed) investor back trading the stock, and thus the increase of trading activities may be witnessed. The deletion events witness an increase in buyer- and seller-initiated trading (although not significant). Moreover, no evidence shows an order imbalanced change, which is consistent with our story, and implies that the effect of the run-away uninformed investors may dominate the influx of informed traders.

4.6. Robustness check

4.6.1. Decomposition of bid-ask spread

So far we have used PIN to scale the information asymmetry. The PIN methodology is adopted since our model is directly based on sequential trading model. Although it is certainly one of the models widely used to evaluate trading conditions, PIN methodology is not impeccable. It is worth noting that the model parameters are sensitive to the volume of trading (since it is based on number of trades), and with a non-trivial change in volume between the pre- and post-event, it is then vulnerable to solely rely upon just this model to reach a conclusion. Similarly, other feasible measures of liquidity may be needed to confirm our results. In this section, we follow Madhaven et al.'s (2003) methodology (MRR model hereinafter) and estimate the components of the spread, which is another commonly used measure of information asymmetry, and is independent of trading volume. We now briefly introduce the MRR model as follows.

The price of transaction at time t is denoted as p_t, and Q_t is defined to be the buy-sell indicator variable for the transaction price where $Q_t = +1$ if the transaction is buyer initiated and Q_t =-1 if the trade is seller initiated. The change in transaction price can be described as:

$$\Delta p_t = p_t - p_{t-1} = \alpha(Q_t - \rho Q_{t-1}) + \beta(Q_t - Q_{t-1}) + u_t$$

where the first term captures the revision in belief, and the second term captures the effect of bid-ask bounce. The three parameters governing the behavior of transaction prices and quotes are: α (the adverse selection cost or asymmetric information parameter), β (the cost of liquidity supplying or order processing), ρ (the autocorrelation of the order flow) and (the probability that the price falls between bid and ask quote). They can be estimated using generalized method of moments (GMM), which imposes very weak distribution assumptions. This is important because the error term includes rounding errors due to discreteness of stock prices (see Ahn, et al., 2002). Moreover, the GMM procedure also easily accounts for the presence of conditional heteroskedasticity of unknown form. Specifically, the GMM procedure chooses parameter values that minimize a criterion function based on the following moment conditions:

$$E[f(\Delta p_t, Q_t, Q_{t-1}, \alpha, \beta, \rho)] = 0$$

where

$$f\left(\Delta p_t, Q_t, Q_{t-1}, \alpha, \beta, \rho\right) = \begin{pmatrix} Q_t Q_{t-1} - \rho Q_{t-1}^2 \\ u_t - u_0 \\ (u_t - u_0)Q_t \\ (u_t - u_0)Q_{t-1} \end{pmatrix},$$

u_t is $\Delta p_t - \alpha(Q_t - \rho Q_{t-1}) - \beta(Q_t - Q_{t-1})$, and u_0 is a constant drift. The estimates of adverse selection component (α) is shown in Table 6.

TABLE 6.

Bid-Ask Spread Decomposition.

Panel A: Addition Group	No of Obs	Pre	Post	*diff*	*Pairwise-t/ Signrank-z*	*p*-value
Mean	622	0.0157	0.0163	0.0006	0.95	0.34
Median	622	0.0089	0.0096		3.36	0.001
Panel B: Deletion Group	No of Obs	Pre	Post	*diff*	*Pairwise-t/ Signrank-z*	*p*-value
Mean	482	0.0134	0.0113	-0.0022	-4.17	0.000
Median	482	0.0073	0.0068		-4.92	0.000

This table contains the GMM estimations of the MRR model of bid-ask decomposition.

Panel A of Table 6 shows that, after a stock is allowed to short, the adverse selection cost of spread increases from 0.0157 to 0.0163 HK$, the change is positive but not significant. The median increases from 0.0089 to 0.0096 HK$, which is significant at 1% level. In contrast to that, for the stocks that are deleted from the designated list, the adverse selection costs decreases, and both the mean and the median are significant, as shown in Panel B. To summarize, the information asymmetry measured by the decomposition of spread show consistent results with those from PIN model: after the lift of the short-sales constraints, information asymmetry indeed increases, while after prohibition of short selling, information asymmetry significantly decreases.

4.6.2. Other measures of liquidity

Our model remains silent on other liquidity measures like depth, etc. In order to check the robustness, we adopt the depth at bid, depth at ask, the quality index (QI), as well as Amihud illiquidity ($ILLIQ$) as alternative liquidity measures, where QI is defined as

$$QI = \frac{BidDepth + AskDepth}{2 * Percentage - Quoted - Spread}$$

and $ILLIQ$ is defined as

$$ILLIQ_i = (1/D_i) \sum_{j=0}^{4} |R_{id}| VOLD_{id}$$

where D_{ij} is he number of days in the estimation window of stock i, event j, R_{id} is the return of stock i on day d, and $VOLD_{id}$ is the respective trading volume in dollars of stock i on day d.

Table 7 shows the change of depth at bid, depth at ask, Amihud illiquidity and Quality index. All the measures of liquidity show highly consistent results as in bid-ask spread and trading liquidity: after the introduction of short selling, the liquidity worsens; while after the banning of short selling, liquidity improves.

4.6.3. The events

There are substantial concerns about using the Hong Kong short selling events, which is the criteria for adding (and deleting) firms from the designation list. The potential reasons why a stock is added to the list include inclusion in the major indices of Hong Kong (e.g., Hang Seng index), issuing structural products (e.g., warrants, etc.), among others.[8], which suggests

[8]Detailed criteria can be found in http://www.hkex.com.hk/eng/market/sec_tradinfo/regshortsell.htm. Note the HKEx does not disclose the precise reason why one specific stock is added to the list.

TABLE 7.

Other measures of liquidity.

Panel A: Addition Group	Pre	Post	*Log-Diff*	*Pairwise-t/ Signrank-z*	p-value
Depth at bid					
Mean (10^8)	95.1	20.7	−0.292	−6.63	0.000
Median (10^7)	2.1	1.6		−7.53	0.000
Depth at ask					
Mean (10^8)	86.5	2.2	−0.281	−6.21	0.000
Median (10^7)	2.0	1.6		−6.80	0.000
Amihud Illiquidity					
Mean (10^{-9})	9.3	10.8	0.194	6.12	0.000
Median (10^{-9})	4.2	5.0		6.24	0.000
Quality Index					
Mean (10^8)	4.6	3.7	−0.129	−4.95	0.000
Median (10^7)	3.7	3.2		−6.48	0.000
Panel B: Deletion Group	Pre	Post	*Log-Diff*	*Pairwise-t/ Signrank-z*	p-value
Depth at bid					
Mean (10^{11})	1.3	1.9	0.133	2.18	0.030
Median (10^6)	7.7	9.6		1.72	0.085
Depth at ask					
Mean (10^8)	64.8	2.0	0.082	1.45	0.147
Median (10^6)	7.2	8.1		1.30	0.201
Amihud Illiquidity					
Mean (10^{-8})	6.7	10.0	−0.032	−0.67	0.503
Median (10^7)	2.6	2.0		−1.06	0.293
Quality Index					
Mean (10^{10})	11.7	2.9	0.098	2.62	0.009
Median (10^7)	2.2	2.3		2.92	0.004

The table reports other liquidity measures before and after the event.

that the observed patterns may come from other structural changes in the underlying stocks, rather than the addition/deletion events. Fortunately, these criteria are documented in the literature to generate the opposite effects instead of what we observe in this paper. For example, if a stock is added to the index, then the liquidity of the stock may improve (Chen et al., 2004; Becker-Blease and Baul, 2003; Hedge and McDermott, 2003), and trading volume tends to be enlarged due to trading pressure from arbitrage (Lin and Kensinger, 2007), because of index trading or hedging. Hence, our observed results are clearly not the consequence of the inclusion of index or issuance of derivatives. This actually strengthens, rather than weakens, our conclusion.

Another concern about the events is that they are definitely not independent. Thus, all the stocks making a change will be subject to the same market-wide effects. In response to that, event-time clustering renders the independence assumption for the captioned measures in the cross-section incorrect (see Collins and Dent, 1984, Bernard, 1987, and Petersen, 2005). To address the bias, the significance of the event-period average can be gauged using the variability of the time series of event portfolio in the period preceding or after the event date. We first construct a "portfolio" of all event firms and obtains a time series of daily trading activity/liquidity measures for the 20-day window before and after the event, and the standard deviation of the portfolio is then used to assess the significance of the event-window average of measures. By doing this, the cross-sectional dependence is accounted for since the variability of the portfolio measure through time incorporates all cross-dependence among the returns on individual event securities (see Khotari and Warner, 2006). The results are shown in Table 8, and the results are, again, highly consistent with our previous ones. suggesting that our observed results are not the results of dependence of events.

One further concern of the events is that, the stocks added to the list might be those who have experienced, in their recent history, unusually high volumes. To find a reduction in trading, therefore, may not be surprising. Although trading volume is not explicitly expressed in the criteria of reason of addition to (deletion from) the namelist in HKEx, the non-exogeneity feature of the events may well imply that there might be abnormal trading volume change before the events. Thus it is worthwhile that we test the relationship between the change of the trading volume and the addition/deletion event. Specifically, we try to test whether the increase/decrease of trading volume is a predictor of addition/deletion event. We introduce the following regressions:

$$volume_{it} = \alpha_i + \beta_i time_t + \varepsilon_{it}(1)$$

and

$$logit(1)_i = \theta_i + \delta_1 \hat{\beta}_i + \delta_2 Control_i + u_i(2)$$

In the regression models we use all the observations in the pre-event window. $volume_{it}$ is the daily share volume of event i on day t. $time_t$ is sequence number of day t preceding the event. Regression (2) is is a logit model, where $logit(1)_i$ takes the value of 1 if event i is an addition event, and 0 if it is a deletion event. $\hat{\beta}_i$ is the estimated slope of equation (1).

TABLE 8.

Time-series of trading activities and spread.

Panel A: Addition Group Number of Obs: 653	**Pre**	**Post**	*Diff/ logged diff*	*Pairwise-t/ Signrank-z*	p-value
Number of trades					
Mean	335.6	258.0	−0.261	−9.67	0.000
Median	326.5	251.0		−5.27	0.000
Share Volume (10^6 shares)					
Mean	19.6	11.3	−0.538	−9.14	0.000
Median	17.9	10.8		−5.28	0.000
Dollar Volume (HK$$10^6$)					
Mean	22.8	16.8	−0.302	−9.04	0.000
Median	21.8	16.6		−5.36	0.000
Number of Seller-Initiated Trades					
Mean	167.2	131.1	−0.242	−9.66	0.000
Median	163.7	130.3		−5.38	0.000
Number of Buyer-Initiated Trades					
Mean	168.4	127.0	−0.280	−8.56	0.000
Median	162.4	122.0		−5.19	0.000
Order Imbalance					
Mean	0.471	0.474	0.0027	0.71	0.481
Median	0.472	0.473		1.03	0.304
Spread					
Mean	0.0274	0.0286	0.0012	4.19	0.000
Median	0.0272	0.0285		3.44	0.001
Relative Spread					
Mean	0.0104	0.0109	0.0006	9.38	0.000
Median	0.0103	0.0109		5.22	0.000
Effective Spread					
Mean	0.0306	0.0316	0.0010	3.18	0.003
Median	0.0304	0.0317		2.89	0.004

$Control_i$ Includes the average market capitalization, the average price, the mean daily number of trades, share volume and dollar volume in the pre-event window of event i. The error term u_is are bootstrapped and clustered by year.

The following results can be found from Table 9. First, There is no significant increase or decrease in trading volume as time elapses prior to the addition/deletion events. Moreover, the difference in the trend of trading volume between the addition and deletion groups is not significant, as shown from Model (1). Second, the slope of trading volume against

TABLE 8—*Continued*

Panel B: Deletion Group Number of Obs: 525	**Pre**	**Post**	*Diff/ logged diff*	*Pairwise-t/ Signrank-z*	p-value
Number of trades					
Mean	113.1	120.3	0.053	1.23	0.227
Median	114.1	116.9		0.87	0.387
Share Volume (10^6 shares)					
Mean	7.1	9.4	0.258	3.63	0.001
Median	7.1	8.7		3.00	0.003
Dollar Volume (HK$$10^6$)					
Mean	4.1	4.2	0.027	0.48	0.634
Median	3.9	4.0		0.43	0.665
Number of Seller-Initiated Trades					
Mean	57.4	60.2	0.040	1.05	0.300
Median	58.1	59.8		0.73	0.465
Number of Buyer-Initiated Trades					
Mean	55.8	60.0	0.066	1.31	0.199
Median	55.1	57.2		0.97	0.330
Order Imbalance					
Mean	0.453	0.458	0.0050	1.22	0.228
Median	0.454	0.459		1.38	0.168
Spread					
Mean	0.0226	0.0199	−0.0028	−6.89	0.000
Median	0.0223	0.0202		−4.90	0.000
Relative Spread					
Mean	0.0191	0.0183	−0.0009	−2.92	0.006
Median	0.0189	0.0182		−2.27	0.023
Effective Spread					
Mean	0.0243	0.0214	−0.0029	−7.07	0.000
Median	0.0239	0.0215		−5.03	0.000

TABLE 9.

Trading volume and short-selling probability

	Model (1)		Model (2)	
Mean $\hat{\beta}_i$	Addition	0.0034(1.76)	Coefficient of $\hat{\beta}_i$	−1.47(−1.17)
	Deletion	0.0025(1.01)	constant	$-1.21^{**}(-2.70)$
	Addition-Deletion	−0.0009(−0.29)	No. of obs.	1133
			Pseudo R^2	0.200

time trend is not a valid predictor of whether or not a stock will be added to or deleted from the designated list. The results from Table 9 imply that, the dynamics of trading volume is not a major driving force of the addition/deletion events.

4.6.4. The windows of events

We have chosen 20-day windows in all previous results. By varying the length between 20 days and 120 days, we find our empirical results are consistent over varied event window length. Also, the present results exclude 5 trading days immediately around the events, and we redo all the earlier exercises by adding the 5 days back. We also get highly consistent results with the reported ones.

4.6.5. Difference-in-difference regression

To further confirm our results are not due to market-wide factors, we check our robustness by difference-in-difference regression in this section. Specifically, we introduce the following regression:

We estimate the following regression equation:

$$Y_{i,t=1} - Y_{i,t=0} = \alpha + \delta Addition_i + \theta Control_i + \varepsilon_i$$

where $Y_{i,t}$ is the mean of measures (three types of spread, trading activities and other liquidity measures) or estimated measures (PIN, adverse selection component of spread) of stock i in the window before the event (for $t = 0$) and after the event (for $t = 1$). $Addition_i$ takes the value of 1 if event i is in the addition group and 0 for deletion group. $Control_i$ includes the mean share volume, market capitalization, and mean price of $event_i$ in the pre-event window. The results are shown in Table 10.

Table 10 exhibit highly consistent results as we mentioned earlier, that the removal of the short-sales constraints lead to higher information asymmetry, lower trading activity, and worsened liquidity.

4.6.6. Discussion

Our empirical observations on trading activities, and especially on bid-ask spread are in sharp contrast with the existing empirical studies. Boehmer, Jones, and Zhang (2010) analyze with panel data techniques the response of liquidity to the short-selling ban imposed from September 18 to October 8 in the United States and find that bid-ask spread deteriorates significantly for stocks subject to the ban. Kolasinski, Reed and Thornock (2010) find that the June 2008 emergency order that already restricts naked short selling for 19 stocks has a similar adverse effect on liquidity.

TABLE 10: Difference in Difference regression

Y_{it}	**PIN**	**No. of trades**	**Share volume**	**Dollar volume**	**Spread**	**Relative spread**	**Effective spread**	**Depth-at-bid**	**Depth-at-ask**	**Illiq**	**QI**	**Adverse selection**
Addition	0.043***	−0.216**	−0.240***	−0.237***	0.0033***	0.0011**	0.0033***	−0.291***	−0.243***	0.205**	−0.148**	0.003**
	(6.39)	(−2.32)	(−3.10)	(−2.70)	(5.13)	(2.48)	(3.83)	(−3.80)	(−2.04)	(2.18)	(−2.21)	(2.55)
Share vol	−0.637***				0.059	0.0010	0.054	−0.214***	−0.253***		−0.090***	0.054*
(10^{-2})	(−2.30)				(0.65)	(0.11)	(0.57)	(−15.35)	(−13.98)		(−8.88)	(1.75)
Market	−0.012***	**0.021**	−0.005	−0.009	**0.0005**	**0.0005**	**0.0005**	−0.021	−0.001	−0.041	−0.040	0.0004***
cap	(−3.50)	**(0.53)**	(−0.09)	(−0.12)	**(1.25)**	**(0.95)**	**(0.92)**	(−0.34)	(−0.02)	(−0.64)	(−0.77)	**(3.15)**
Price	−0.001	−0.320	−0.302	−0.404	0.000	0.000	0.000	−0.002**	−0.156	0.529	−0.124	−0.000
(10^{-5})	(−0.02)	(−0.07)	(−0.02)	(−0.09)	(0.05)	(0.02)	(0.12)	(−0.00)	(−0.00)	(0.06)	(−0.00)	(−0.01)
constant	0.151***	0.496	0.633	1.018	−0.013	−0.008	−0.012	4.510***	5.372***	−1.451***	2.250***	−0.014***
	(2.62)	(1.28)	(1.36)	(1.51)	(−0.84)	(−1.04)	(−0.82)	(8.36)	(11.85)	(−2.59)	(7.86)	(−2.93)
Industry fixed effect	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**
No. of Obs.	1088	1133	1133	1133	1133	1133	1133	1133	1133	1133	1133	−3.27
R^2(%)	4.85	6.90	6.76	6.72	4.05	4.12	3.85	12.89	16.05	6.11	8.05	−2.91

Marsh and Payne (2012) analyze order and transaction-level data for the U.K., and find that as soon as the ban applied to financial stocks, their bid-ask spreads widen. Beber and Pagano (2013) study the world-wide short selling ban around late 2008 and also prove that liquidity worsens after the ban of short selling. These papers show solid evidence that if the short-sales constraints are lifted, it is expected that bid-ask spread will decrease.

Why do our results contradict those in the literature? We argue that the following two reasons may at least partially reconcile the seemingly inconsistent results: (1) types of underlying stocks; (2) the information content of the addition/deletion events.

First, our model setting implies that the predicted effects will be more prominent for stocks with more uninformed traders. It is found in the literature that low price stocks and small stocks are more likely to attract small or uninformed investors (see Kryzanowski and Zhang (1996), Guo et al, (2008) among others). In this section, we test the relationship between the stock price, stock size, and the change of the liquidity, trading activity, and information asymmetry. Specifically, we introduce the folliowing models:

$$\begin{aligned} Y_{i,t=1} - Y_{i,t=0} &= \alpha + \beta_1 Addition_i + \beta_2 Addition_i * price_i \\ &+ \beta_3 Addition_i * mktcap_i \theta Control_i + \varepsilon_i \end{aligned}$$

where Y_{it} is the measure of information asymmetry, trading activities and liquidity of stock-event i in the pre-event window for t=0 and post-event window for $t = 1$. So the left hand side of the model is the change (or logged change) around the event. $Addition_i$ is a dummy variable which takes the value of 1 if event i is an addition event, and 0 otherwise. $price_i$ is the mean close price of stock-event i in the pre-event window, $mktcap_i$ is the mean capitalization of stock-event i in the pre-event window. $Control_i$ is the vector of control variables including the mean share volume, mean market capitalization, and mean close price in the pre-event window. The t-values are shown in the table.

Table 11 shows evidences that the empirical results documented above are more likely to occur in the low-price groups. In this table, it is shown that, in all measures, the intersection terms of $Addition_i$ with either $price_i$ or $mktcap_i$ have the opposite signs against the coefficients of $Addition_i$,

TABLE 11: Stock types, trading activity, liquidity and information type change.

Diff-in-diff result	**PIN**	**No. of trades**	**Share volume**	**Dollar volume**	**Spread**	**Relative spread**	**Effective spread**	**Depth-at-bid**	**Depth-at-bid**	**Illiq**	**QI**	**Adverse selection**
$Addition_i$	2.87***	−3.29***	−4.01***	−4.08***	3.46***	3.81***	2.95***	−4.84***	−4.80***	4.40***	−4.92***	4.11***
$Addition_i \times Price_i$	−0.27	3.59***	1.35	3.13***	−3.20***	−2.86***	−3.01***	−0.53	−0.32	−3.84***	−2.06**	−1.25
$Addition_i \times mktcap_i$	−0.23	0.81	1.76*	2.19**	−0.66	−3.51***	−0.49	1.87*	2.35**	−2.31**	2.32**	−1.31
constant	−0.41	15.28***	15.45***	17.55***	−0.57	−1.18	3.05***	1.69*	3.92***	6.99***	2.13**	−2.24
No of obs.	1088	1133	1133	1133	1133	1133	1133	1133	1133	1133	1133	1133
R^2(%)	0.05	0.11	0.11	0.11	0.05	0.05	0.05	0.11	0.14	0.09	0.10	0.05

Note: *, ** and *** represent significance level of 10%, 5% and 1%, respectively.

and almost all of them are significant, implying that as prices/firm sizes decrease, the difference-in-difference in the changes of liquidity/trading activity/information asymetry measures is more prominant, and that our papers' results are dominated by the small/low-price stocks. In comparison to that, a similar paper in the literature is Boehmer et al (2013), which show that, after the US Securities and Exchange Commission bans the short selling, the liquidity worsens in all groups but the smallest quartile, impying that the prevailing financial crisis papers' results are concentrated in large stocks. Also, as far as we know, no paper in the literature so far studies the relationship between price and liquidity. These results suggest that the discrepancies between our results and the existing literature are not as large as they seem be. Our results are more likely to be found in low-price stocks or small stocks, while their results are more likely to occur on large stocks (e.g., financial stocks, etc). In this sense, our paper can be considered as providing supplementary evidence for better understanding the impact of the short-sales constraints on the more uninformed-trader concentrated stocks. Furthermore, the above evidences also echoes Section 4.5, in which we only test the unconditional version of Hypothesis 3 that trading activities decrease (unconditionally) after a stock is allowed to short. But we remain silent on the question whether this is true only if the run-away effect of the uninformed investors dominates. The results in Table 11 indicate that, trading activities decrease more prominently in low price stocks and small stocks, which are more likely to be uninformed-trader concentrated. These results provide supportive evidence consistent with (the full version of) our Hypothesis 3.

Another potential difference between our setting and the existing literature is that we analyze a period of low volatility in the stock market, during which adding to the short-selling list is information neutral for the underlying stock, in the sense that the onlist event itself does not contain any valuation information of the underlying stock. However, during the financial crisis, the banning of short selling conveys negative information about the underlying stock. This may arouse the concerns that the prevailing prices of the underlying stocks are still too high, and short selling is banned to prevent a further price drop. When the policy is scrutinized this way, the originally uninformed traders may well perceive the ban as bad news, so they become informed traders, who would like to sell the stock or stop buying the stock. The risk-neutral market makers are then obliged

TABLE 12: Subsample results

Panel A: Non-bear period	**PIN**	**No. of trades**	**Share volume**	**Dollar volume**	**Spread**	**Relative spread**	**Effective spread**	**Depth-at-bid**	**Depth-at-ask**	**Illiq**	**QI**	**Adverse selection**
onlist	0.043***	−0.216**	−0.240***	−0.237***	0.072***	0.0011**	0.0033***	−0.291***	−0.243***	0.205**	−0.148**	0.003**
	(6.39)	(−2.32)	(−3.10)	(−2.70)	(5.15)	(2.48)	(3.83)	(−3.80)	(−2.04)	(2.18)	(−2.21)	(2.55)
Share vol	−0.637***				0.052	0.0010	0.054	−0.214***	−0.253***		−0.090***	0.054*
(10^{-2})	(−2.30)				(0.79)	(0.11)	(0.57)	(−15.35)	(−13.98)		(−8.88)	(1.75)
Market	−0.012***	**0.021**	−0.005	−0.009	**0.0005**	**0.0005**	**0.0005**	−0.021	−0.001	−0.041	−0.040	0.0004***
cap	**(−3.50)**	**(0.53)**	**(−0.09)**	**(−0.12)**	**(1.25)**	**(0.95)**	**(0.92)**	**(−0.34)**	**(−0.02**	**(−0.64)**	**(−0.77)**	**(3.15)**
Price	−0.001	−0.320	−0.302	-0.404	0.000	0.000	0.000	−0.002**	−0.156	0.529	−0.124	−0.000
(10^{-5})	(−0.02)	(−0.07)	(−0.02)	(−0.09)	(0.05)	(0.02)	(0.12)	(−0.00)	(−0.00)	(0.06)	(−0.00)	(−0.01)
constant	0.151***	0.496	0.633	1.018	−0.013	−0.008	−0.012	4.510***	5.372***	−1.451***	2.250***	−0.014***
	(2.62)	(1.28)	(1.36)	(1.51)	(−0.84)	(−1.04)	(−0.82)	(8.36)	(11.85)	(−2.59)	(7.86)	(−2.93)
Industry fixed effect	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**
No. of Obs.	1088	1133	1133	1133	1133	1133	1133	1133	1133	1133	1133	−3.27
R^2 (%)	4.85	6.90	6.76	6.72	4.05	4.12	3.85	12.89	16.05	6.11	8.05	−2.91
Panel B: Bear period												
onlist	0.070***	−0.204	−0.078	0.072	−0.0006	−0.0009	−0.0004	−0.199	−0.013	−0.112	0.195	−0.003
	(3.15)	(−1.53)	(−0.43)	(0.44)	(−0.22)	(−0.37)	(−0.07)	(−1.19)	(−0.06)	(−0.05)	(0.84)	(−1.21)
Share vol	0.098				0.431***	−0.049	0.450***	0.172***	−0.153**		−0.063	0.001
(10^{-2})	(0.14)				(4.79)	(−0.78)	(2.88)	(−3.07)	(−2.23)		(−1.15)	(1.00)
Market	−0.023**	−0.188***	−0.292***	−0406***	**0.0014**	0.0035***	**0.0011**	−0.389***	−0.355***	−0.041	−0.312**	0.0015*
cap	**(−2.12)**	−3.73)	**(−3.43)**	**(−4.91)**	**(0.58)**	**(3.06)**	**(0.45)**	**(−3.88)**	**(−3.51)**	**(−0.64)**	**(−2.45)**	**(1.95)**
Price	0.003	−0.002	−0.090	0.040	−0.0013	−0.010	0.000	−0.006	−0.007	−0.000	−0.006	−0.000
(10^{-5})	(0.00)	(−0.01)	(−0.10)	(0.03)	(−0.09)	(−0.06)	(0.12)	(−0.25)	(−0.62)	(−0.00)	(−0.82)	(−0.02)
constant	0.078	1.937***	2.632***	3.680***	−0.076***	−0.026***	−0.076***	4.510***	5.544***	−3.933***	3.128**	−0.030
	(0.55)	(6.12)	(4.94)	(7.11)	(−3.16)	(−4.37)	(−2.58)	(8.36)	(4.19)	(−3.92)	(2.50)	(−1.28)
Industry fixed effect	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**
No. of Obs.	283	294	294	294	294	294	294	294	294	294	294	269
R^2 (%)	16.12	8.11	8.05	9.45	2.29	5.74	2.52	16.32	18.56	8.22	21.43	11.08

to increase the spread to offset the potential loss with the "new" informed traders, leading to worsened liquidity.

We look at our results by subperiods of bear market and non-bear market and redo the above exercise. As Table 12 shows, our above results are mainly driven by the non-bear market period. During the bear market, we do not observe any predicted results, which is consistent with our reasoning that, banning short-selling in bear markets may change the mechanism of our model.

5. CONCLUSION

We propose a simple model to show that when short-sales constraints are lifted, although the originally excluded negative private information holders (informed traders) will step in trading the designated stock, some uninformed traders, fearing the potential loss from trading against these (new) informed traders, will avoid further trading of the (now shortable) designated stock. Thus, the removal of short-sales constraints worsens the liquidity and decreases the trading activity of the underlying stock, accompanying the increase of speed of price adjustment and probability of informed trading. A direct test using the unique short-selling regulation of the Hong Kong stock market provides strong evidence supporting our model. Our empirical results on liquidity and trading activity are in stark contrast implies effects of short-sale constraints can be completely opposite depending on availability of correlated assets and the market sentiment. Unlike the existing papers studying the short selling in 2008 financial crisis, we provide evidences about the short selling in more uninformed trader concentrated stocks in normal period, and argue that the market may exhibit different reaction from what the existing literature documents. This paper thus suggests that setting policies concerning the short-sales constraints has to be more cautious.

APPENDIX A

Proofs for Propositions 1-3

Let the history of trade and transaction prices at time t be h_t and $h_0 \equiv \{\phi\}$. Let trade $Q_t \in \{B_1, B_2, S_1, S_2, NT\}$ where B_i, S_i, NT represent buying of stock i, selling of stock i, and no trade of either stock at time t, respectively. Denote $\psi_t = \times$ no information event occurred at time t.

Consider at time $t = 0$. From Figure 1, dropping the time subscript, we have

$$P\left(S_1|\psi\right) = \begin{cases} \left(1-\mu\right)\gamma_2\left(\phi_1+\left(1-\phi_1-\phi_2\right)c\right) & \text{if } \psi = +_1, +_2, +_{12}, -_2 \\ \mu\left(\phi_1+\left(1-\phi_1\right)c\right)+\left(1-\mu\right)\gamma_2\left(\phi_1+\left(1-\phi_1-\phi_2\right)c\right) & \text{if } \psi = -_1 \\ \left(\mu+\left(1-\mu\right)\gamma_2\right)\left(\phi_1+\left(1-\phi_1-\phi_2\right)c\right) & \text{if } \psi = -_{12} \\ \gamma_2\left(\phi_1+\left(1-\phi_1-\phi_2\right)c\right) & \text{if } \psi = \times \end{cases}$$

$$P\left(S_2|\psi\right) = \begin{cases} \left(1-\mu\right)\gamma_2\phi_2 & \text{if } \psi = +_1, +_2, +_{12}, -_1 \\ \left(\mu+\left(1-\mu\right)\gamma_2\right)\phi_2 & \text{if } -_2, -_{12} \\ \gamma_2\phi_2 & \text{if } \psi = \times \end{cases}$$

$$P\left(B_1|\psi\right) = \begin{cases} \mu+\left(1-\mu\right)\gamma_1\alpha_U & \text{if } \psi = +_1 \\ \left(1-\mu\right)\gamma_1\alpha_U & \text{if } \psi = +_2, -_1, -_2, -_{12} \\ \alpha_I\mu+\left(1-\mu\right)\gamma_1\alpha_U & \text{if } \psi = +_{12} \\ \gamma_1\alpha_U & \text{if } \psi = \times \end{cases}$$

$$P\left(B_2|\psi\right) = \begin{cases} \left(1-\mu\right)\gamma_1\left(1-\alpha_U\right) & \text{if } \psi = +_1, -_1, -_2, -_{12} \\ \mu+\left(1-\mu\right)\gamma_1\left(1-\alpha_U\right) & \text{if } \psi = +_2 \\ \left(1-\alpha_I\right)\mu+\left(1-\mu\right)\gamma_1\left(1-\alpha_U\right) & \text{if } \psi = +_{12} \\ \gamma_1\left(1-\alpha_U\right) & \text{if } \psi = \times. \end{cases}$$

Proof of Proposition 1. The initial bid price is the expected value of stock 1 given there is a sale:

$$\begin{aligned} Bid_1 &= E\left[V_1|S_1\right] \\ &= V^H P\left(+_1 \cup +_{12}|S_1\right) + V^L P\left(-_1 \cup -_{12}|S_1\right) + V^M P\left(\times \cup +_2 \cup -_2|S_1\right) \\ &= \frac{V^H A_1 + V^L A_2 + V^M A_3}{P\left(S_1\right)} \end{aligned}$$

where $A_1 \equiv \left(1-\mu\right)\gamma_2\left(\phi_1+\left(1-\phi_1-\phi_2\right)c\right)\left[P\left(+_1\right)+P\left(+_{12}\right)\right]$, $A_2 \equiv \mu\phi_2 c P\left(-_1\right)+$ $(\mu+(1-\mu)\gamma_2)(\phi_1+(1-\phi_1-\phi_2)c)\left[P\left(-_1\right)+P(-_{12})\right]$, and $A_3 \equiv \gamma_2\left(\phi_1+\left(1-\phi_1-\phi_2\right)c\right)$ $\left(\left(1-\mu\right)P(-_2 \cup +_2)+P\left(\times\right)\right)$.

First note that

$$\begin{aligned} \frac{dA_1}{dc} &= \gamma_2\left(1-\mu\right)\left(1-\phi_1-\phi_2\right)\left(P\left(+_1\right)+P\left(+_{12}\right)\right), \\ \frac{dA_2}{dc} &= \mu\phi_2 P\left(-_1\right)+\left(\mu+\left(1-\mu\right)\gamma_2\right)\left(1-\phi_1-\phi_2\right)\left(P\left(-_1\right)+P\left(-_{12}\right)\right), \text{and} \\ \frac{dA_3}{dc} &= \gamma_2\left(1-\phi_1-\phi_2\right)\left(\left(1-\mu\right)P(-_2 \cup +_2)+P\left(\times\right)\right). \end{aligned}$$

Then we can rewrite

$$A_1 = \frac{dA_1}{dc}c + a_1,\ A_2 = \frac{dA_2}{dc}c + a_2 \text{ and } A_3 = \frac{dA_3}{dc}c + a_3$$

where $a_1 \equiv \left(1-\mu\right)\gamma_2\phi_1 P\left(+_1 \cup +_{12}\right)$, $a_2 \equiv \left(\mu+\left(1-\mu\right)\gamma_2\right)\phi_1 P\left(-_1 \cup -_{12}\right)$ and $a_3 \equiv \gamma_2\phi_1(\left(1-\mu\right)P(-_2 \cup +_2)+P\left(\times\right))$. We first show that $\frac{dA_1}{dc}a_2 < \frac{dA_2}{dc}a_1$, $\frac{dA_1}{dc}a_3 = \frac{dA_3}{dc}a_1$ and $\frac{dA_2}{dc}a_3 > \frac{dA_3}{dc}a_2$:

$$\begin{aligned}
& \frac{1}{\gamma_2\phi_1}\left(\frac{dA_1}{dc}a_2 - \frac{dA_2}{dc}a_1\right) \\
= & \ (1-\mu)(1-\phi_1-\phi_2) P(+_1 \cup +_{12})(\mu + (1-\mu)\gamma_2)(P(-_1) + P(-_{12})) \\
& -\mu\phi_2 P(-_1)(1-\mu) P(+_1 \cup +_{12}) \\
& -(\mu + (1-\mu)\gamma_2)(1-\phi_1-\phi_2) P(-_1 \cup -_{12})(1-\mu) P(+_1 \cup +_{12}) \\
= & \ -(1-\mu)[P(+_1) + P(+_{12})]\mu\phi_2 P(-_1) < 0.
\end{aligned}$$

$$\begin{aligned}
& \frac{dA_1}{dc}a_3 - \frac{dA_3}{dc}a_1 \\
= & \ (1-\mu)\gamma_2(1-\phi_1-\phi_2) P(+_1 \cup +_{12})\gamma_2\phi_1((1-\mu)P(-_2 \cup +_2) + P(\times)) \\
& -\gamma_2(1-\phi_1-\phi_2)((1-\mu)P(-_2 \cup +_2) + P(\times))(1-\mu)\gamma_2\phi_1 P(+_1 \cup +_{12}) = 0.
\end{aligned}$$

$$\begin{aligned}
& \frac{dA_2}{dc}a_3 - \frac{dA_3}{dc}a_2 \\
= & \ (\mu\phi_2 P(-_1) + (\mu + (1-\mu)\gamma_2)(1-\phi_1-\phi_2) P(-_1 \cup -_{12}))(\gamma_2\phi_1(1-\mu) P(-_2 \cup +_2) + P(\times)) \\
- & \ \gamma_2(1-\phi_1-\phi_2)((1-\mu)P(-_2 \cup +_2) + P(\times))(\mu + (1-\mu)\gamma_2)\phi_1 P(-_1 \cup -_{12}) \\
= & \ \mu\phi_2 P(-_1)\gamma_2\phi_1((1-\mu)P(-_2 \cup +_2) + P(\times)) > 0.
\end{aligned}$$

Now we are ready to show

$$\begin{aligned}
\frac{dBid_1}{dc} &= \frac{1}{P(S_1)^2}\begin{bmatrix} P(S_1)\left(V^H \frac{dA_1}{dc} + V^L \frac{dA_2}{dc} + V^M \frac{dA_3}{dc}\right) \\ -\left(V^H A_1 + V^L A_2 + V^M A_3\right)\frac{dP(S_1)}{dc} \end{bmatrix} \\
&= \frac{1}{P(S_1)^2}\begin{bmatrix} (A_1 + A_2 + A_3)\left(V^H \frac{dA_1}{dc} + V^L \frac{dA_2}{dc} + V^M \frac{dA_3}{dc}\right) \\ -\left(V^H A_1 + V^L A_2 + V^M A_3\right)\left(\frac{dA_1}{dc} + \frac{dA_2}{dc} + \frac{dA_3}{dc}\right) \end{bmatrix}
\end{aligned}$$

By substituting $A_k = \frac{dA_k}{dc}c + a_k$ for $k = 1, 2$ and 3, we have, with some simplifications,

$$\frac{dBid_1}{dc} = \frac{1}{P(S_1)^2}\begin{bmatrix} \left(V^H - V^L\right)\left(\frac{dA_1}{dc}a_2 - \frac{dA_2}{dc}a_1\right) \\ +\left(V^H - V^M\right)\left(\frac{dA_1}{dc}a_3 - \frac{dA_3}{dc}a_1\right) \\ +\left(V^L - V^M\right)\left(\frac{dA_2}{dc}a_3 - \frac{dA_3}{dc}a_2\right) \end{bmatrix} < 0$$

since $V^H > V^M > V^L$.

Similarly, we have

$$\begin{aligned}
Bid_2 &= \frac{V^H A_4 + V^L A_5 + V^M A_6}{P(S_2)} \\
Ask_1 &= \frac{V^H A_7 + V^L A_8 + V^M A_9}{P(B_1)}, \text{ and} \\
Ask_2 &= \frac{V^H A_{10} + V^L A_{11} + V^M A_{12}}{P(B_2)}
\end{aligned}$$

where $A_4 \equiv (1-\mu)\gamma_2\phi_2[P(+_2)+P(+_{12})]$, $A_5 \equiv [\mu\phi_2+(1-\mu)\gamma_2\phi_2]P(-_2)+(\mu+(1-\mu)\gamma_2)\phi_2 P(-_{12})$, $A_6 \equiv \gamma_2\phi_2[(1-\mu)P(-_1 \cup +_1)+P(\times)]$, $A_7 \equiv (\mu+(1-\mu)\gamma_1\alpha_U)P(+_1)+(\mu\alpha_I+(1-\mu)\gamma_1\alpha_U)P(+_{12})$, $A_8 \equiv (1-\mu)\gamma_1\alpha_U [P(-_1)+P(-_{12})]$, $A_9 \equiv \gamma_1\alpha_U[(1-\mu)P(-_2 \cup +_2)+P(\times)]$, $A_{10} \equiv (\mu+(1-\mu)\gamma_1(1-\alpha_U))P(+_2)+(\mu(1-\alpha_I)+(1-\mu)\gamma_1(1-\alpha_U)) P(+_{12})$, $A_{11} \equiv (1-\mu)\gamma_1(1-\alpha_U)[P(-_2)+P(-_{12})]$, and $A_{12} \equiv \gamma_1(1-\alpha_U)[(1-\mu)P(-_1 \cup +_1)+P(\times)]$. Since Bid_2, Ask_1 and Ask_2 are not functions of c, they are independent of short-sale constraint. ∎

Proof of Proposition 2. From Figures 1 and 2, we have

$$P(B_1|\psi) = \begin{cases} \mu+(1-\mu)\gamma_1(\omega\alpha_{DU}(1-c)+(1-\omega)\alpha_{NU}) & \text{if } \psi = +_1 \\ (1-\mu)\gamma_1(\omega\alpha_{DU}(1-c)+(1-\omega)\alpha_{NU}) & \text{if } \psi = +_2, -_1, -_2, -_{12} \\ \alpha_I\mu+(1-\mu)\gamma_1(\omega\alpha_{DU}(1-c)+(1-\omega)\alpha_{NU}) & \text{if } \psi = +_{12} \\ \gamma_1(\omega\alpha_{DU}(1-c)+(1-\omega)\alpha_{NU}) & \text{if } \psi = \times \end{cases}$$

$$P(B_2|\psi) = \begin{cases} (1-\mu)\gamma_1(\omega(1-\alpha_{DU}(1-c))+(1-\omega)(1-\alpha_{NU})) & \text{if } \psi = +_1, -_1, -_2, -_{12} \\ \mu+(1-\mu)\gamma_1(\omega(1-\alpha_{DU}(1-c))+(1-\omega)(1-\alpha_{NU})) & \text{if } \psi = +_2 \\ (1-\alpha_I)\mu+(1-\mu)\gamma_1(\omega(1-\alpha_{DU}(1-c))+(1-\omega)(1-\alpha_{NU})) & \text{if } \psi = +_{12} \\ \gamma_1(\omega(1-\alpha_{DU}(1-c))+(1-\omega)(1-\alpha_{NU})) & \text{if } \psi = \times \end{cases}$$

Hence, the initial ask price for stock 1 is

$$Ask_1 = \frac{V_1^H A_{13} + V_1^L A_{14} + V_1^M A_{15}}{P(B_1)}$$

where $A_{13} \equiv (\mu+(1-\mu)\gamma_1(\omega\alpha_{DU}(1-c)+(1-\omega)\alpha_{NU}))P(+_1)+(\mu\alpha_I+(1-\mu)\gamma_1(\omega\alpha_{DU}(1-c)+(1-\omega)\alpha_{NU}))P(+_{12})$,
$A_{14} \equiv (1-\mu)\gamma_1(\omega\alpha_{DU}(1-c)+(1-\omega)\alpha_{NU})P(-_1 \cup -_{12})$ and
$A_{15} \equiv (1-\mu)\gamma_1(\omega\alpha_{DU}(1-c)+(1-\omega)\alpha_{NU})P(-_2 \cup +_2)$

$+\gamma_1(\omega\alpha_{DU}(1-c)+(1-\omega)\alpha_{NU})P(\times)$. First, we have

$$\frac{[P(B_1)]^2}{\gamma_1\omega}\frac{dAsk_1}{d\alpha_{DU}}$$

$$= \begin{bmatrix} P(B_1|+_1)P(+_1) \\ +P(B_1|+_{12})P(+_{12}) \\ +P(B_1|-_1)P(-_1\cup -_{12}) \\ +P(B_1|-_2)P(-_2\cup +_2) \\ +P(B_1|\times)P(\times) \end{bmatrix} \begin{bmatrix} V^H(1-\mu)(1-c)P(+_1) \\ +V^H(1-\mu)(1-c)P(+_{12}) \\ +V^L(1-\mu)(1-c)P(-_1\cup -_{12}) \\ +V^M(1-\mu)(1-c)P(-_2\cup +_2) \\ +V^M(1-c)P(\times) \end{bmatrix}$$

$$- \begin{bmatrix} V^H P(B_1|+_1)P(+_1) \\ +V^H P(B_1|+_{12})P(+_{12}) \\ +V^L P(B_1|-_1)P(-_1\cup -_{12}) \\ +V^M P(B_1|-_2)P(-_2\cup +_2) \\ +V^M P(B_1|\times)P(\times) \end{bmatrix} \begin{bmatrix} (1-\mu)(1-c)P(+_1) \\ +(1-\mu)(1-c)P(+_{12}) \\ +(1-\mu)(1-c)P(-_1\cup -_{12}) \\ +(1-\mu)(1-c)P(-_2\cup +_2) \\ +(1-c)P(\times) \end{bmatrix}$$

$$= (1-c)(1-\mu)\begin{bmatrix} \left(V^H-V^L\right)P(+_1)P(-_1\cup -_{12})\left(P(B_1|-_1)-P(B_1|+_1)\right) \\ +\left(V^H-V^L\right)P(+_{12})P(-_1\cup -_{12})\left(P(B_1|-_1)-P(B_1|+_{12})\right) \\ +\left(V^H-V^M\right)P(+_1)P(-_2\cup +_2)\left(P(B_1|-_2)-P(B_1|+_1)\right) \\ +\left(V^H-V^M\right)P(+_{12})P(-_2\cup +_2)\left(P(B_1|-_2)-P(B_1|+_{12})\right) \end{bmatrix}$$

$$+ \begin{bmatrix} +\left(V^H-V^M\right)P(+_1)P(\times)\left(P(B_1|\times)(1-\mu)-P(B_1|+_1)\right) \\ +\left(V^H-V^M\right)P(+_{12})P(\times)\left(P(B_1|\times)(1-\mu)-P(B_1|+_{12})\right) \\ +\left(V^M-V^L\right)P(\times)P(-_1\cup -_{12})\left(P(B_1|-_1)-P(B_1|\times)(1-\mu)\right) \end{bmatrix}$$

which is negative because $P(B_1|-_1)=P(B_1|-_2)<P(B_1|+_{12})<P(B_1|+_1)$, $P(B_1|\times)(1-\mu)<P(B_1|+_1)$, $P(B_1|\times)(1-\mu)<P(B_1|+_{12})$ and $P(B_1|-_1)=P(B_1|\times)(1-\mu)$. Similar calculation shows $dAsk_2/d\alpha_{DU}>0$ and $dBid_1/d\alpha_{DU}=dBid_2/d\alpha_{DU}=0$. ▮

Proof of Proposition 3. Let $\hat{c}>c>0$ be two different fractions of investors not subject to short-sales constraints. Denote $\Delta c\equiv\hat{c}-c>0$ be the change in fraction of investors that are able to short firm 1. Time t can be decomposed to "trade of stock i" and "no trade of stock i" so that expected total trading volume of stock i conditional on a signal is a binomial random variable. Therefore, given history h_t, for all positive integers k the exchanged changes of trading volume of stock 1 from time t to time $t+k$, are

$$\begin{aligned} & E[v_{1,t+k}|\psi_t=-_1,h_t,\hat{c}]-E[v_{1,t+k}|\psi_t=-_1,h_t,c] \\ = {} & k\Delta c\left(\mu(1-\phi_1)+(1-\mu)\left(-\omega\alpha_{DU}\gamma_1+\gamma_2(1-\phi_1-\phi_2)\right)\right) \\ < {} & 0 \end{aligned}$$

for $\psi_t\in\{-_1,-_{12}\}$ and

$$\begin{aligned} & E[v_{1,t+k}|\psi_t,h_t,\hat{c}]-E[v_{1,t+k}|\psi_t,h_t,c] \\ = {} & -k\Delta c(1-\mu)\left(-\omega\alpha_{DU}\gamma_1+\gamma_2(1-\phi_1-\phi_2)\right)<0 \end{aligned}$$

for $\psi_t \neq -_1, -_{12}$ where both of inequalities follow from the given assumption. Therefore, expected trading activities for stock 1 reduces. For stock 2, since

$$\begin{aligned} & E\left[v_{2,t+k}|\psi_t, h_t, \hat{c}\right] - E\left[v_{2,t+k}|\psi_t, h_t, c\right] \\ = & -\left(E\left[v_{1,t+k}|\psi_t, h_t, \hat{c}\right] - E\left[v_{1,t+k}|\psi_t, h_t, c\right]\right) > 0, \end{aligned}$$

expected trading activities increases. ▮

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