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THE IMPACT OF CALL AUCTIONS ON CHINA'S STOCK MARKET LIQUIDITY AND PRICE QUALITY

Willa H. Zheng

A thesis submitted in fulfilment

of the requirements for the award of the degree of

DOCTOR OF PHILOSOPHY

From

UNIVERSITY OF WOLLONGONG

School of Accounting, Economics and Finance, Faculty of Business

November 2016

CERTIFICATION

I, Willa H. Zheng, declare that this thesis, submitted in partial fulfilment of the requirements for the award of Doctor of Philosophy, in the School of Accounting, Economics and Finance of the Faculty of Business at the University of Wollongong, is wholly my own work unless otherwise referenced or acknowledged. The document has not been submitted for qualifications at any other academic institution.

Willa H. Zheng

27 January 2016

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This thesis is dedicated to my family. They are the spirit behind this journey. Semper fidelis.

LIST OF PUBLICATIONS INCLUDED AS PART OF THE THESIS:

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Synopsis

This dissertation contains three essays that examine the impact of call auctions in China. Since they were introduced in the mid-1990s, call auctions have become the most popular method to open and close daily trading in equity markets around the world. By aggregating orders and trade information at a single point in time, call auctions facilitate price setting and are a valuable tool in managing the liquidity of the trading market.

This dissertation focuses on China. Up until now, the vast majority of the empirical literature in this area are concerned with developed markets. During the time period covered by this dissertation, China was a rapidly growing emerging market, unique in that it was dominated by uninformed, individual traders. Market participants in this environment face issues such as asymmetric information and stock illiquidity. The conclusions drawn from this dissertation will be of interest to market regulators, traders and fund managers interested in investing in the Chinese equity market.

The first essay examines the relationship between the transparency of the opening call auction and the liquidity of the continuous market. It is inspired by the event that took place on the Shanghai Stock Exchange on 1 July 2006, when the exchange changed its pre-market opening auction system from an entirely black box into a more transparent system with indicative auction prices, indicative equilibrium volume and indicative unexecuted volume disseminated in real time throughout the pre-opening period. This essay uses the natural experiment offered by the Shanghai Stock Exchange to investigate the impact of opening call transparency on market liquidity. The dynamics

of the opening process and its impact on trading activity for the rest of the day is of interest to traders because traders can either cluster their trades during the non-trading period or withhold their orders until the market opens. The results indicate that the dissemination of indicative trade information during the opening call session led to an overall improvement in liquidity costs. Bid-ask spreads narrowed because adverse selection risk fell significantly and there is less price volatility in the continuous market. This effect is greater for actively traded securities than illiquid securities. The results also reveal a temporary decrease in trading volume in the first hour.

The second essay builds upon the first essay by examining the impact the introduction of opening call auction transparency and the resulting decline in trading activity, on the price discovery process of the continuous market in Shanghai. Market efficiency is assessed on both the dimensions of price discovery and noise. The results reveal some price discovery migration from the call auction to the continuous trading period. As a result, the overall price discovery in the first hour of continuous trading rose. The proportional increase in this price discovery was observed to be greater for inactively traded stocks than for actively traded stocks. Additionally, the continuous market became less noisy, even after controlling for trading activity.

The third essay turns its attention to another exchange in mainland China, the Shenzhen Stock Exchange. It competes with the Shanghai Stock Exchange for a share in China's booming stock market capital. On the very date that Shanghai modified its opening call auction design, the Shenzhen Stock Exchange modified its market closing procedure by adopting call auctions to close its continuous market trading. Even now, Shanghai and Hong Kong are the only top 10 equity markets in the world that do not

use a closing call auction. This essay studies the effect of the new closing mechanism on the quality of the closing market and on the trading behaviour of the Chinese market participants. It employs high-frequency data to examine the effects of the closing call auction on market quality measures such as spreads, volatility, turnover, trade size, and price discovery in one-minute intervals. The results illustrate that the closing call auction did not cause a substantial migration of trading activity from the continuous market to the call. Instead, the closing call auction generated a new peak in trading activity just prior to the closure of the continuous market as traders sought to avoid the informationally opaque closing call. Bid-ask spreads also narrowed just before the end of continuous trading. The quoted and effective spreads generated at the end of the call auction were substantially lower than pre-reform, when the closing price was generated by continuous trading prices. In terms of closing price discovery, the results find that the efficiency of actively traded stocks improved but the efficiency of the closing price of the inactive stocks worsened.

Chapter 1. Introduction

Call auctions can facilitate trading and price discovery where normal continuous market trading fail. In illiquid markets and in markets where there is a high level of information asymmetry, call auctions do this by pooling orders and executing them at a uniform price. As a result, it minimises market impact costs and reduces the risk of front running. Call auctions facilitate price discovery from informed traders while at the same time protecting uninformed traders by enhancing market liquidity. As exchanges around the world move towards an electronic order-book system, the majority of stock markets have adopted some form of call auction to open or close daily market trading.

But the effectiveness of a call auction is contingent on its design and trading rules (Comerton-Forde, Rydge and Burridge, 2007). The design and trading rules address call action concerns such as price manipulation and the free-rider problem about revealing private order information. Design questions include: what type of orders should be submitted, what is the length of the auction, how should the auction price be computed, and what is the optimal level of transparency?

The goal of this dissertation is to examine some of the contentious design features of call auctions. In particular, it aims to determine the influence of design features, like call auction information transparency, on investor trading behaviour. Given the important role of call auctions in price setting, an understanding of the impact of these design features is extremely valuable.

This dissertation consists of three essays. The first two essays investigate the Shanghai Stock Exchange and its reform of their opening call auction in 2006. The third essay is focused on the Shenzhen Stock Exchange and their introduction of a closing call auction during the same time period. Whilst the topic of 'call auctions' has been extensively explored in the academic literature, both empirically and theoretically, very little work has been published about China, which has unique market characteristics that give new insight into the behaviour of uninformed individuals in financial markets.

The following sections introduce each topic in detail and explains the contribution of the work to the existing body of knowledge.

1.1 Call auction transparency and market liquidity

There currently exists a large body of research on the pre-trade information transparency of continuous markets but scant literature on the transparency of call auctions, and even scarcer literature on the link between the transparency of opening call auctions and the liquidity of the continuous market.

Even amongst the literature on the pre-trade information transparency of continuous markets, academic conclusions have been mixed. This is possibly due to the differing designs of the exchanges, and due to the varying degrees of transparency between exchanges.

Most studies that examined stock market transparency have adopted either a theoretical or empirical approach. Under a theoretical approach, it is not possible to

construct a theoretical model without making behaviour-restricting assumptions about the market. Under an empirical approach, it is often difficult to detangle the effects of information transparency from the other changes occurring in the market at the time. Additionally, the majority of event studies in the area have examined markets with already some level of information transparency. As such, the outcome of an additional increase in transparency has tended to be minor.

The issue of how changes in market design affect liquidity is important enough to merit further investigation from both an academic and regulatory standpoint, especially when both theoretical predictions and empirical evidence are divided. Furthermore, the dynamics of the opening process and its impact on trading activity for the rest of the day is of interest to traders because traders can either cluster their trades during the non-trading period or withhold their orders until the market opens.

The essay in chapter 3 uses the natural experiment offered by the Shanghai Stock Exchange to investigate the relationship between the transparency of the opening call auction and the liquidity of the continuous market. It is significant because it observes a major change in the information transparency of the call auction. Prior to 1 July 2006, the opening call auction was a 'black box'. On 1 July 2006, the Shanghai stock market began disseminating the indicative auction price, indicative equilibrium volume and indicative unexecuted volume in real time throughout the pre-opening period. In effect, a veil was lifted over the opening call auction. This fairly significant transition in the transparency level of the opening call auction has rarely been studied and is invaluable in attempting to document a strong relationship between information transparency and market liquidity.

Finally, this study also sheds light on the liquidity patterns of a rapidly growing emerging market. Like many developing markets, the trading day divided into morning and afternoon sessions, with a long 90-minute trading break in the middle of the day. This study will confirm whether Shanghai's liquidity pattern differs from other studied markets.

1.2 Call auction transparency and market efficiency

Market efficiency improvement was the main reason for Shanghai's reform of its opening call auction on 01 July 2006. It was hoped that information transparency would enhance the overall price discovery of the market. However, this outcome was not certain. When Hong Kong commenced using an opening call auction in 2002, they employed a call auction system very similar to that adopted in Shanghai post-reform. It was found by Comerton-Forde, Rydge and Burridge (2007) that the market quality on the Hong Kong Stock Exchange declined, particularly in less actively traded stocks. The authors attributed this to a lack of interest in the opening call auction, thus preventing it from providing meaningful price discovery and also alleviating the price uncertainty at market openings.

This second essay will establish whether the implementation of call auction transparency mitigated the problems that motivated SSE to reform, namely poor price discovery at the start of the day. A distinctive feature of the Chinese market is the absence of alternative platforms during non-trading hours, such as Electronic Communication Networks (ECNs) or Broker Crossing Networks (BCNs). Given that

the opening call is preceded by an extended period of non-trading, the need for price discovery is highest at the start of the trading day.

China is an emerging capital market dominated by uninformed individual investors. Instead of focusing just on the call auction, the study extends its analysis to the post-opening trading activities, examining how market participants deal with the information revealed during the call auction. These information reflect market sentiment, and thus have ramifications not just for the call, but also for subsequent trading periods.

In doing so, it is also an opportunity to confirm Comerton-Forde, Rydge and Burridge (2007)'s findings in a different, albeit similar, market by assessing the level of market interest in this form of call auction. It will establish whether, in the context of Shanghai and Hong Kong, a semi-transparent call auction is better for market efficiency than a fully opaque one.

The study takes a thorough approach, by assessing market efficiency on both dimensions of price discovery and noise. In this regard, it provides a comprehensive and robust answer to the abovementioned questions.

1.3 The impact of a closing call auction on the Shenzhen Stock Exchange

On 1 July 2006, as a first in mainland China, Shenzhen Stock Exchange commenced using a call auction to close normal market trading. This call auction had a number of unusual characteristics, which combined, made its design unique in the world. It was unusually short, fully opaque, and existed on a pure limit order book market that did

not have an alternative trading platform during the non-trading hours. The Shenzhen stock market, like Shanghai, was a market dominated by uninformed rumour-based individual traders, rather than institutional traders who relied heavily on the closing price to set the benchmark price for their indexes and funds.

As Hong Kong's aborted experience of the closing call auction revealed, not all introductions of the closing call auction have been positive for the market. The performance of call auctions is largely influenced by its design and trading rules (Comerton-Forde, Ryde and Burridge, 2007). The impact of this unique 'black-box' closing call auction is, thus, worthy of academic study.

Also, the Shenzhen stock market exists as a competitor to the Shanghai stock market. Presently, Shanghai and Hong Kong are the only two major, top 10, equity markets in the world that does not employ a call auction to determine the day's closing price.

Thus this third essay attempts to answer the pertinent question for both exchange regulators: whether the closing call auction is effective in the Chinese trading environment and whether Shanghai should adopt a closing call auction. The essay does this by examining the effects of the new closing mechanism on the quality of the continuous market and on the trading behaviour of the market participants. The essay contributes to the academic literature by using high-frequency data to study the effects of the closing call auction on spreads, volatility, turnover, trade size, and price discovery in one-minute intervals. Previous studies have tended to examine these in five-minute or half-hour intervals. Focusing on a much briefer time interval allows the study to isolate the effects of market structure from the broader market movement

effects; particularly in the minutes preceding the close, when the market is most volatile and active.

1.4 Summary

The three essays contained in this dissertation each examine the impact of a stock market call auction reform on market quality. The insights provided by these essays are important given the influential role of call auctions in price setting and managing market liquidity. Each essay is about a controversial feature of the call auction, rarely examined empirically, particularly in a Chinese or emerging market context. The empirical findings presented in this dissertation will be of interest to regulators, academics and investors in the Chinese market alike.

The rest of this dissertation is organised as follows: Chapters 2, 3 and 4 present the three research essays discussed in this chapter. Each chapter contains sections describing the prior academic literature, the institutional setting, data and sample, research design, empirical results and the conclusions reached. Chapter 5 summaries the results and highlights how the results presented in this dissertation can be used by exchange regulators and traders to gain insight into the behaviour of market participants under the conditions of asymmetric information that exist in China.

Chapter 2. Call auction transparency and market liquidity: Evidence from China

2.1 Introduction

Literature has documented that transparency, the ability of market participants to observe information in the trading process (O'Hara, 2001), is vital to the performance of the equity market. The transparency regime of a trading mechanism is directly reflected in the operational performance of financial markets and in fundamental market variables such as liquidity and price efficiency (Huisman and Koedijk, 1998). As capital market information can be divided into two types, pre- and post-trade information, capital market transparency also exists in two dimensions: pre-trade transparency (order book or quote information) and post-trade transparency (the dissemination of trade price and volume of completed transactions) (Madhavan, 2000). This study is mainly focused on the former type and investigates whether and to what extent the transparency of the call market has a flow-on effect for the liquidity of the continuous market in a Chinese context.

Given the importance of market transparency, a large body of literature has examined the impact of transparency on market liquidity but produced mixed results. Most of these studies are based on developed markets, and there is still little empirical evidence from emerging markets, such as China. Traditional studies on this issue tend to suffer from endogeneity, as both market liquidity and transparency can be jointly influenced by unknown factors. The growing Chinese capital market provides us with an ideal institutional setting in which to conduct our study without being influenced by the endogeneity issue because, compared to the developed markets with stable regulatory policies on information disclosure, the emerging Chinese market provides

us a setting with changing policies, which enables us to conduct event studies by using the policy change as an exogenous shock.

In particular, as the policy change is implemented by the government exchange-wide, across all stocks and to all investors, we can observe that the change in market liquidity follows the regulatory policy change without being influenced by unobserved factors. On July 1, 2006, the pre-trading system of the Shanghai Stock Exchange (SHSE) changed from a closed call auction to an open call auction system. This made the pre-trade information change from an opaque 'black-box' to a semi-transparent level of information transparency. The purpose of this study is to investigate the effect of the changing call auction information transparency on market liquidity. The rationale is: if information transparency matters to market liquidity, this improved transparency should result in a change in liquidity on the following trading day.

Traditional literature, either from the theoretical or empirical approach, argues that pre-trade transparency should be positively related to market liquidity because the increased transparency reduces the search cost for traders, the savings of which are then passed to their posted quotes or orders. In the meantime, transparency also makes traders more confident about posting their limit orders, since adverse selection risk is reduced (Flood et al., 1999, Pagano and Roell, 1996, Biais, 1993, Boehmer et al., 2005).

However, more recent empirical studies generate predictions that increased pre-trade transparency can be detrimental to liquidity. For instance, Madhavan et al. (2005) discovered that after the Toronto Stock Exchange publicly disseminated the contents of its limit order book on the traditional floor and automated trading system, the spread widened and volatility increased. Another empirical paper by Bortoli et al. (2006) examined the impact after the Sydney Futures Exchange increased the level of order

book disclosure from the best bid and ask to three price levels. They found that while there was no significant change to spread, market liquidity diminished as limit order traders began charging market order traders a premium for execution quality by withdrawing depth from the best quotes.

This strand of literature argues that too much pre-trade transparency makes informed traders reluctant to place limit orders for fear that their private information may be ‘picked off’ by opportunistic traders (Bloomfield and O’Hara, 1999, Flood et al., 1999), which eventually impairs the market liquidity, especially in illiquid markets (Admati and Pfleiderer 1988, Pagano and Roell 1996, Baruch, 2005, Rindi, 2007).

While we agree that pre-trade transparency may have both a positive (it encourages the trading activity of small individual investors) and a negative (it discourages the trading activity of informed traders) effect on market liquidity, the net effect that pre-trade transparency has on liquidity should depend on whether the positive effect outweighs the negative effect. We expect there should be a net positive effect between pre-trade transparency and liquidity in the Chinese market, given that trading activity is still dominated by uninformed individual investors[1], compared to developed equity markets where a form of polarization between individual and institutional investors is evident (Ng and Wu, 2007). In other words, although the increased transparency may discourage the trading of informed investors, the positive effect of encouraging small investors’ trading activities dominates, resulting in an improved overall market liquidity.

Using the regime change of pre-trade transparency in SHSE as an exogenous shock, this study provides evidence that the overall stock market liquidity increased after the

[1] As of June 2013, individual investors hold merely 26% of total market capitalization but account for 78% of daily trading volume. source: https://fundsus.deutscheawm.com/EN/docs/research/CHINESE-WHITE.pdf

dissemination of indicative trade information during the opening call session, which confirms the positive effect that pre-trade transparency has on market liquidity (Flood et al., 1999, Pagano and Roell, 1996, Biais, 1993, Boehmer et al., 2005). In particular, our empirical results show that bid-ask spreads narrowed and there is less price volatility, and lower adverse selection cost in the market after the pre-trade information change from a totally opaque to a semi-transparent level of information transparency, and that the above effect is found to be greater for actively traded securities than illiquid securities.

Although the trading volume deceases temporarily in the first trading hour, the volume increases in the rest of the trading hours of the day. We explain that the temporary drop in trading volume is caused by the fact that investors are now able to cancel or amend their orders, which results in less unexecuted orders. Then less unexecuted orders are automatically transferred from the pre-open call auction period for execution than the pre-reform period. We further document that market intraday liquidity is also improved after the reform. Our findings are robust when we test using a longer/shorter benchmark sample period before and after the reform; longer/shorter periods of trading after market opens; and a smaller sample of stocks that do not undertake share split reform during our sample period.

This study contributes to current literature in the following ways. First, the majority of event studies in the area have examined markets which already have some level of information transparency. As such, the impact after an additional increase in transparency has tended to be minor. By taking advantage of the emerging Chinese market, we examine the change of liquidity when the degree of change in call auction transparency is significant, i.e. it changes from a previously totally opaque to a semi-transparent level. By doing so, we are able to document a much stronger relationship

between transparency and market liquidity. Second, we contribute to the current literature regarding market liquidity in an emerging market because most previous studies in this area focus on developed markets. We provide empirical evidence that in an immature emerging market that is dominated by individual noise investors, increased pre-trade transparency improves market liquidity. From this perspective, our study has important implications for the regulators in emerging markets when making the regulatory policy regarding information transparency.

The remainder of the paper is organized as follows. Section 2.2 describes the institutional details of the Shanghai Stock Exchange. Section 2.3 presents the details of our data and sample. The empirical results are presented and discussed in Section 2.4. Section 2.5 concludes the paper.

2.2 Institutional Details: Shanghai Stock Exchange

The trading system in the SHSE is based on the electronic Consolidated Open Limit Order Book (COLOB). A 10-minute opening call auction is held at 09:15 and ends at 09:25. This is followed by two continuous auction sessions, the morning session from 09:30 to 11:30 and the afternoon session from 13:00 to 15:00. Continuous trading is conducted through the submission of limit orders. These orders are matched by price-time priority.

While no special trading mechanism is used to close the morning session or open the afternoon session, a special mechanism is used at the close of the afternoon session. Closing prices of the stocks of the trading day are generated by taking a weighted average of the trading prices of the final minute of each trading day. The information of the best five offers and bids and their associated volume, as well as the price and volume for the latest transaction on the stock exchanges during the continuous trading

sessions, must be displayed on computer terminals viewable by investors on and off both exchanges. The market is closed on Saturdays and Sundays and other public holidays announced by the exchange.

There are no designated dealers (specialists) to intervene in trading in the market. Investors place their orders with the brokers in the form of either a market order or limit order, and only good-to-day limit orders are accepted by the trading system. At the end of the trading day, all orders are purged from the COLOB. The minimum tick sizes for all stocks are 1 cent (RMB0.01 Yuan). Shares cannot be sold on the same day as they are bought. The minimum trading size for both purchase and sell is 100 shares. Floor trading among member brokers and short selling are strictly prohibited over our study period. During trading sessions on the SHSE, a stock is allowed to trade at a price plus or minus 10% from the previous day's closing price in order to avoid sharp price increases caused by 'buy manias' and sharp declines caused by 'sell panics'.

On July 1, 2006 a new call auction was introduced to open trading. In the past, the SHSE closed its order book over the pre-open period. There was also no information regarding order books available to investors during the auction process, except for the final clearing price generated at the end of the auction. Therefore, the pre-open call auction was entirely devoid of information dissemination. During this 10-minute call auction period, investors could place limit orders and participate in the opening auction, but no orders would be allowed to be withdrawn. Orders that are not executed in the opening auction were automatically transferred to the period of continuous trading. The determined opening price at 09:25 is continued to 09:30.

On July 1, 2006, a limit or semi-transparent call auction was introduced to open trading. Information of an indicative auction price (IAP), an indicative equilibrium

volume indication (IEV), and an expected unexecuted volume indication (IUV) [2] was disseminated to the market in real time through the pre-open period, although the order book was not yet open to the market. It was hoped that by providing pre-trade information during the opening period, the SHSE could increase its efficiency in determining an opening price and would encourage more investors to participate during the pre-opening auction.

There are two relevant time periods in the 10-min pre-open call auction period. During the first period between 09:15-09:20, allowable messages to the system include limit orders and order modifications or cancellations. During the second period between 09:20-09:25, modifications and cancellations are not allowed, but new orders are accepted before the final opening price and quantity is generated in the market. The market then takes a five-minute break between the periodic auction at 09:25 and the start of the morning session at 09:30 with the continuous trading mechanism. The arrangement of five-minute cooling-off period is similar to the two-minute blocking period between 09:58 and 10:00 in the Hong Kong Exchanges and Clearing Limited after 2002 (Asian Etrading 2009). The situation in Shanghai's current pre-opening arrangement is now similar to the Deutsche Börse AG, which discloses information about unbalanced amounts but is a closed order book during the opening call auction.

2.3 Data and sample

The data used in this study are obtained from the Reuters database maintained by the Securities Industry Research Centre of Asia-Pacific (SIRCA). The data consists of trades and the best bid and ask quotes for all stocks in the Shanghai A-share Index.

[2] The IAP is an indication of the call auction price if the auction was held at that instant. The IEV and IUV indicate the volume of shares that will execute and remain unexecuted at the IAP.

Details of all trades and changes in best bid and ask prices are time-stamped to the nearest second.

A period of five weeks before and after the disclosure of partial order information in the opening call auction of the SHSE is used in the study for analysis[3]. This gives us a sufficient window to capture the immediate as well as the permanent effect of the change in opening call auction transparency.

Initially, all stocks in the Shanghai A-share index are sampled. The Shanghai A-share index is of particular interest as it accounts for a substantial proportion of total Shanghai trade volume and market capitalization. The A-share index consists of 891 stocks as at December 31, 2006, and accounts for around 95% of the total market capitalization of listed stocks, including both A and B-shares. One hundred and ten stocks are excluded from the sample due to their inactive trading during this period, reducing the final stock sample size to 780. However, the final number of observations is much more because high-frequency data is used, and each firm has thousands of observations.

2.4 Empirical Results

2.4.1 The effect of transparency on liquidity in the first hour of trading: univariate test results

Due to the build-up of information during the overnight non-trading period, information asymmetry is greatest at the start of each trading day. Market volatility, as shown later in Figure 3.3, takes approximately one hour to stabilise. Thus the impact

[3] The period of this study ends on Aug 7, 2006. On Aug 8, 2006, the SHSE introduced market orders to the exchange. This study is purely concerned with limit orders. For robustness we also repeat our study to cover a much longer period of time before and after the reform; however, our main findings are unchanged.

of the dissemination of indicative opening prices and opening volumes under an efficient market is expected to be greatest during the first hour of trading. This influences traders' decision either to cluster their trades during the non-trading period or to withhold their orders until the market opens. Call auctions are sometimes desirable to traders since they can absorb the market impact of liquidity shocks (Barclay et al., 2008) and reduce asymmetric information problems by providing all traders with access to the same price (Madhavan, 1992). Therefore, we start our empirical study by examining the impact of pre-open information transparency on liquidity in the first trading hour.

2.4.1.1 Measures of stock liquidity

The following liquidity measures are investigated for each stock:

$$PROPORTIONAL\ BID-ASK\ SPREAD\ (\%) = (ask\ price - bid\ price)/(bid-ask\ midpoint)*100$$

$$EFFECTIVE\ SPREAD = 2*abs[transaction\ price-(bid-ask\ midpoint\ immediately\ prior\ to\ the\ transaction)]$$

$$PROPORTIONAL\ EFFECTIVE\ SPREAD\ (\%) = effective\ spread/transaction\ price \times 100$$

$$DEPTH: sum\ of\ best\ bid\ and\ ask\ volume$$

$$DOLLAR\ DEPTH = (best\ ask\ price \times best\ ask\ volume) + (best\ bid\ price \times best\ bid\ volume)$$

$$NUMBER\ OF\ TRADES: transacted\ trades\ during\ the\ first\ hour$$

$$TIME\ BETWEEN\ TRADES: in\ the\ first\ hour$$

$TOTAL\ TRADING\ VOLUME: in\ the\ first\ hour$

$VOLATILITY:\ standard\ deviation\ of\ transaction\ prices$

$RATIO\ OF\ TRANSACTED\ VOLUME\ FROM\ CALL\ AUCTION\ TO$

$TRADE\ VOLUME\ DURING\ THE\ FIRST\ HOUR$

$$= \frac{Transacted\ call\ volume}{trade\ volume\ in\ the\ first\ hour}$$

2.4.1.2 The effect of transparency on liquidity in the first hour of trading of full sample of stocks

In order to do our univariate test, we first compute separately the average values of the above liquidity measures during the first trading hour (between 9:30 and 10:30) of each trading day for both the pre-event and post-event period. Then values for the pre-event period are subtracted from the values for the post-event period matched by time, and student *t*-tests are performed to assess whether the changes are statistically significant. Table 2.1 presents the univariate test results. Panel A presents the entire sample, while Panels B to F present the results for Quintile 1 to Quintile 5, based on whether the stock is actively traded or not.

We find that the spread narrowed for all three spread measures. Average quoted proportional spread fell by 1.8%. Effective spreads narrowed more significantly, by 17.0% and 17.5% respectively for average effective spread and proportional effective spread. Order book depth fell by 20% on average, and the average wait between consecutive trades lengthened by 23%. The results suggest that as the pre-trade information becomes more transparent, which means more information is now available at the initial stages of the day's trading, the bid-ask spreads are narrowed and order book depths are reduced at the same time. The results are consistent with Bortoli

et al. (2006), who document a decline in depth when the limit order book disclosure was increased in the Sydney Futures Exchange in January 2001. Furthermore, the greater confidence with which the market in the post-reform period regards the opening price is also evidenced by lower price volatilities after the market opens.

However, the total trading volume decreased by 28.9% and the number of trades declined by 14% in the post-reform period compared to pre-reform period during the first trading hour period. Intuitively, these results seem to be inconsistent with our argument that increased transparency in the post-reform period should result in improved market liquidity, so the trading volume should also increase to match lower adverse selection cost[4].

The probable reason for this phenomenon is: Under the pre-reform call auction system, investors did not know the orders placed by other investors and they were not allowed to withdraw their orders once they were placed, so for self-protection, investors tended to place orders either too high or too low, which meant a large proportion of the orders had not been executed. These unexecuted orders in the opening auction were automatically transferred to the period of continuous trading, resulting in a large trading volume and trading activity in the first trading hour. Under the new semi-transparency system, investors know the indicative auction price and equilibrium volume and they are allowed to amend and cancel their orders during the first five minutes of the pre-open auction period, and thus their orders are more likely to be executed and only a small proportion of unexecuted orders are transferred for the continuous trading compared to the previous system, resulting in a decrease in trading volume during the first hour of continuous trading. However, as discussed later, the

[4] We are grateful to the reviewers for pointing out this question.

trading volume actually bounces back from the second trading hour (see evidence from Figure 2.4).

Taken together, our results support the argument that increased transparency results in better market liquidity, which is consistent with previous studies, such as Flood et al., 1998; Pagano and Roell, 1996; Biais, 1993; Boehmer et al., 2005. In particular, the bid-ask spreads and price volatility both decrease significantly during the first trading hour in the post-reform period. Although the trading volume decreases temporarily during the first trading hour in the post-reform period, it turns around after the first trading hour.

2.4.1.3 The effect of transparency on liquidity in the first hour of trading of different groups of stocks

It is suggested that increased transparency during the opening call auction will influence trading behaviour differently according to stock liquidity. Comerton-Ford and Rydge (2006) find that the change in the transparency regime enhances price efficiency more significantly for actively traded stocks than for illiquid stocks. Similarly Madhaven et al. (2005) report that illiquid stocks are adversely affected by increased pre-trade transparency, because it discourages traders from placing their orders for fear of revealing their information. The absence of orders at the open may impair liquidity and subsequent price discovery.

To see how the impact of transparency varies between liquid and illiquid stocks, Shanghai A-shares are sorted into roughly equal quintiles based on average daily turnover. Quintile one in Panel B represents the most actively traded stocks, while quintile 5 in Panel F represents the least active stocks traded on the Shanghai stock exchange during our sample period. To control for the influence of trade volume on

trade liquidity, we further split each liquidity quintile into three subgroups based on their average trade volumes during the study period. Trade volume subgroup 1 represents stocks with the largest trade volumes, while trade volume group 3 represents the smallest. As trading volume here is used as a grouping variable, we do not report the results for trading volume in panels B to F. As expected, quintile 1, the most actively traded stock group, has the majority of its stocks contained in the trade volume one subcategory, the group with the highest average trade volumes during our study period. The converse is true for quintile 5.

The results confirm the view of Madhaven et al. (2005) that thinly traded stocks are adversely affected by information transparency. Quintile 5 is the only quintile group whose average proportional spread increased after the change. And notably, the subgroup with the least average trade volume is observed to have higher average proportional quoted spreads in the post-event period, for all quintile groups.

Inactive stocks, which already have long time lags between trades, experience the largest increases in time between trades (32% on average). Even among the more actively traded stocks, stocks with smaller trade volumes have longer time differences within their quintile groups. However, market impact cost, as proxied by the effective spread measures, fell for all quintile groups and their respective trade volume subgroups.

There is no discernible pattern in the depth measures. Overall depth and dollar depth values fell after the regime change, but for quintile 3 it rose slightly. The ratio of call auction volume to continuous trade volume rose for the most active quintile but we are unable to conclude that this ratio changed statistically in the post-reform period for any of the other quintile groups. Price volatility dropped by levels that are

proportionate to stock liquidity. Average volatility fell by 15% for quintile 1 and 10% for quintile 2.

[Insert Table 2.1 here]

2.4.2 The effect of transparency on liquidity in the first hour of trading: regression analysis

Although the univariate results indicate a significant reduction in both proportional bid-ask spreads and depth in the first hour when the opening call auction moves to a more transparent state, other factors affecting spread and depth could also account for those results. Harris (1994) and McInish and Wood (1992) identified price volatility as a significant factor that influences market depth and bid-ask spreads. Market capitalisation has been shown to have a negative effect on spread, and a positive effect on depth (Huberman and Hulka, 2001). And volume has been recorded as affecting the level of spread (Stoll, 2000).

The simultaneous regression models are used in this study for the following reasons: first, spread and depth are contemporaneously related (Lee et al., 1993; Kavajecz, 1999; Dupont, 2000), which means that the issue of endogeneity may potentially arise if the contemporaneous relation between spread and depth is uncontrolled. In addition, Stambaugh (1999) suggests that when the dependent variable is highly autocorrelated (the first-order autocorrelation of proportional effective spread is 0.532, [see panel B of Table 2.2]), while the dependent and independent variables are contemporaneously correlated, *t*-statistics and hence *R*-square measures tend to be biased away from zero, so simulation regression models are recommended.

Therefore, the following two regression models are established and conducted simultaneously.

$$peffspread_{it} = \beta_0 + \beta_1 * \ln(depth_{it}) + \beta_2 * \ln(volume_{it}) + \beta_3 * \ln(market\ capitalisation_{i}) + \beta_4 * volatility_{it} + \beta_5 * change_{it} + \sum_{n=1}^{11} \beta_n * time\ interval\ dummies + \varepsilon_{it} \quad (1)$$

$$\ln(depth_{it}) = \gamma_0 + \gamma_1 * peffspread_{it} + \gamma_2 * \ln(market\ capitalisation)_i + \gamma_3 * volatility_{it} + \gamma_4 * change_{it} + \sum_{n=1}^{11} \gamma_n * time\ interval\ dummies + \varepsilon_{it} \quad (2)$$

where *depth* is the sum of order book volume at the best bid and ask prices. *peffspread* is the effective spread divided by transaction price. *Market capitalization* is equity market capitalization based on closing prices on June 30, 2006. *Volatility* is the 'High Low Range Volatility', developed by Parkinson (1980)[5]. *Change* is a dummy variable that takes a value of one after the change to the opening call system, and a value of zero otherwise. Also included are 11 five-minute time interval dummies for the first hour of trading, to capture the time-varying characteristics of these liquidity measures. We convert tick data into an average value of five minutes for all variables except for market capitalization in our regressions. Therefore, we create twelve observations (one observation for each five-minute time interval) for each individual stock on one particular day, and have a final observation of 407,486 (we use all observations from the May 29 to June 30, 2006 event-period and the July 1 to August 7, 2006 event-period centred on the change in call auction transparency). Our results are reported in Table 2.2.

[5] As shown by Parkinson (1980), this volatility measurement, properly scaled, is not only an unbiased estimator of volatility but is five times more efficient than the classic estimator of volatility.

Panel A of Table 2.2 reports the summary statistics of the main variables. The average proportional effective spread, depth, volume, market capitalization and volatility of our sample are 0.39%, 52,553, 5,443, 787.15 million RMB, and 4.42% respectively. With regard to the autocorrelation of each variable as reported in panel B of Table 2.2, one of our main dependent variables, *peffspread*, is highly autocorrelated with a first-order autocorrelation coefficient of 0.532, market capitalization has an autocorrelation of 1 because it is a fixed value for each individual stock, and all other variables are not highly autocorrelated.

The regression results for our simultaneous two-equation regression model are reported in Panel C of Table 2.2. The *change* variable in both equations is statistically significant and negative, which rejects the null hypothesis that a change in call auction transparency has no effect on the spread and depth of the market, at all conventional levels. This result is consistent with our findings from the univariate analysis. In terms of the liquidity of the market during the first hour, call auction transparency alleviates somewhat the high bid-ask spreads at market opening and at the same time reduces order book depth in the market, a result consistent with Bortoli et al. (2006), who document a decline in depth when the limit order book disclosure was increased in the Sydney Futures Exchange in January 2001. Coefficient estimates for the rest of the controlling variables are significant and are of the expected signs.

[Insert Table 2.2 here]

2.4.3 Spread decomposition

We have shown that bid-ask spreads narrow following the introduction of information transparency into the opening auction process. To confirm that the drop in spread during the first hour is driven by reduced adverse selection risk and not by

another factor, we decompose spread and examine the changes in the spread components.

Previous studies have developed several models on the components of bid-ask spread. In general, the models can be classified into two types: the first relies on the serial covariance properties of the observed transaction prices and decomposes spread into two components: adverse selection cost and order processing cost (see Roll, 1984; Choi et al., 1984, George et al., 1991; Stoll, 1989; Huang and Stoll, 1994; Lin et al., 1995); the second class of model is based on the trade initiation indicator variable and decomposes spread into three components: adverse selection, inventory-carrying, and order processing components (Madhavan and Smidt, 1993; Huang and Stoll, 1997). More recent studies have indicated that inventory cost may not exist in order-driven markets due to the absence of liquidity suppliers; the two-way decomposition models, therefore, provide better estimates of the adverse selection cost (Brockman and Chung, 1999; Majois and Winne, 2003). As we deal with an order-driven environment that is absent of market makers, we follow the approach of Lin et al. (1995) which decomposed effective spread into just two components: adverse selection cost and order processing cost. The adverse selection and order processing components are estimated using the following regression models from Lin et al. (1995):

Adverse selection cost component: $\Delta Q_{t+1} = \lambda z_t + e_{t+1}$ (3)

Order processing cost component: $\Delta P_{t+1} = -\gamma z_t + \mu_{t+1}$ (4)

where Q is the log quote midpoint, z is the difference between log trade price and log quote midpoint, and P is the log trade price. e *and* μ are normally distributed error terms. λ in equation (3) is the adverse selection component of effective spread while

γ in equation (4) measures the order processing cost component. The estimated average values of λ and γ for 806 stocks are reported in table 2.3.

[Insert table 2.3 here]

The results reveal a considerable reduction in adverse selection cost as a component of effective spread. On average, adverse selection dropped by 42%. Adverse selection costs altered from being the majority component of effective spread to being roughly even with order processing costs in the post-event period. Interestingly, prior to the reform, more actively traded stocks have adverse selection cost forming a bigger component of the bid ask spread. This is probably due to the positive relationship that Lin et al. (1995) found adverse selection to have with trade size. After the reform, the pattern is reversed. So the establishment of transparency into Shanghai's opening call auction has had a bigger effect on lowering the adverse selection risk and bid-ask spread of actively traded stocks than illiquid securities.

2.4.4 Effect on intraday liquidity

While we provided plenty of evidence regarding the effect of transparency on market liquidity during the first trading hour, in this section, we aim to further investigate whether increased transparency also influences intraday liquidity.

Empirical studies have typically identified either a U-shaped[6] or L-shaped[7] pattern in intraday spreads. U-shaped spread patterns feature a gradual fall in spread after the session opening and a gradual rise towards the daily closing. Intraday spread patterns are L-shaped if they open with relatively high spreads but this spread either remains

[6] McInish and Wood (1992), Chan et al. (1996), Lehman and Modest (1994).

[7] Chan et al. (1995a), Chan et al. (1995b). For China, this pattern was noticed by Tian and Guo (2007).

constant or declines over the remainder of the trading day. Stock exchanges that rely on a specialised or designated dealer system for the provision of liquidity typically exhibit U-shaped spread patterns, while exchanges that are based on multi-dealer systems generally exhibit L-shaped spread patterns (Brockman and Chung 1999). In addition to spread, trading volume and volatility have also been found to be U-shaped[8]. Intraday liquidity flows are of concern to the investment strategy of portfolio managers and traders because they assist market participants to time their transactions to occur at certain parts of the day, and better manage their trading costs. The morning and closing periods, with their higher than average level of trading activity, are more desirable for traders who regard execution speed as an important criterion in execution quality and less desirable for traders looking to minimise price variation.

China's intraday liquidity pattern may differ from the above-mentioned studies because the market has a 90-minute trading break in the middle of the day. Thus the purpose of this section of the paper is twofold: firstly, to observe whether the U-shaped or L-shaped liquidity pattern holds for the Shanghai Stock Exchange; and whether the liquidity in the morning and afternoon trading sessions are symmetrical. Secondly, to test how the intraday liquidity patterns are influenced by the pre-trade information transparency.

To analyse the intraday behaviour of various liquidity and trading activity measures, we partition each trading day into five-minute intervals and compute the average values for each time interval five trading days before and five trading days after the opening call auction transparency change. Eighty-three stocks that had trading suspended due to abnormal fluctuations during this sample period[9] were removed. The

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[8] Cheung et al., (1994), Chang et al., (1993)

[9] On the SHSE, these suspended stocks resume trading at 10:30am.

ten-day time frame captures the immediate impact of the change and minimizes the possibility of other changes in market conditions that might affect these liquidity measures.

[Insert Table 2.4 here]

Table 2.4 presents the results for the average proportional spread, depth, volatility, volume and proportional volume values for each of the time intervals in the pre- and post-event periods respectively. On the whole, our results support our main argument that transparency improves intraday market liquidity because the proportional spread narrowed and trading volume increased after the reform. However, no clear results are found regarding the depth, volatility and proportional volume. In order to further demonstrate the intraday liquidity patterns and the change of intraday liquidity after the reform, we graph Figures 2.1-2.5, to show how the five liquidity measures change over time throughout the trading day.

Figure 2.1 confirms the L-shaped intraday pattern of the average proportional spreads in SHSE, which supports Brockman and Chung (1999). Opening spread is about 1.7 times the proportional spread for the rest of the day. In addition, we observe a clear and significant lower proportional spread when the pre-trade information transparency has improved after the event, which is consistent with our results in Table 2.1 above and supports our main argument that better information transparency results in a lower spread.

[Insert Figure 2.1 here]

Figure 2.2 depicts the intraday depth pattern in the market. In general, depth is quite low at the start of the day and climbs steadily during the morning session. By the afternoon session, depth has plateaued. It drops slightly in the last 20 minutes. Consistent with our results in Table 2.1, the increase in pre-trade information

transparency results in a lower depth during the first 45-minutes of trading; during the rest of the day, post-reform depth seems to be similar to pre-reform depth.

[Insert Figure 2.2 here]

Figure 2.3 depicts the intraday volatility pattern in the market. It displays an inverse J-shaped pattern. Intraday volatility overall is similar between the two time periods, although post-reform volatility in the first hour is smoother and generally lower.

[Insert Figure 2.3 here]

Due to a trading break in the middle of the day, intraday volume on the SHSE shows an asymmetric double-U pattern, as displayed in Figures 2.4 and 2.5. Except for the spikes at the start and end of the session, absolute and proportional volume is relatively flat during the morning session. By contrast, in the afternoon trading session, they both trend in an upward direction. Some interesting results are identified when comparing post-reform to pre-reform volume. In particular, Figure 2.4 shows that over the post-reform period, the absolute trading volume rises significantly between 10:30 and 11:30, and remains at a higher level during the rest of the day; while from Figure 2.5, we find that the proportional volume drops substantially only during the first trading hour, and settles down during the rest of the trading day.

Overall, our results, combining Figures 2.4 and 2.5, suggest that investors alter their trading strategies after the reform by increasing their trading volume after 11:30[10]. As discussed in the above sections, the temporary drop of trading volume during the first trading hour is caused by the fact that investors are now able to cancel or amend their orders, which results in fewer unexecuted orders being automatically transferred from the pre-open call auction period for execution.

[10] We appreciated a reviewer's comment on this addition.

[Insert Figure 2.4 here]

[Insert Figure 2.5 here]

2.4.5 Robustness tests[11]

For robustness of our main findings, we further conduct the following two types of new tests: (1) we increase and decrease the length of our benchmark, and increase and decrease the period of trading hours; and (2) we repeat our study for A-shares that did not undergo a share split reform during our sample period, and compare the results with A-shares that underwent the share split reform. The results for robustness tests are reported and discussed below.

2.4.5.1 The effect of transparency on liquidity different length of benchmark and different period of trading hours

The length of our benchmark and the period of trading hours are important to our results. One potential issue about our paper is that whether our results still hold if a different length of benchmark and a different period of trading hours are used. In order to address this issue, we first increase the length of our benchmark to ten weeks before and after the pre-trade information transparency reform, and decrease the length to two weeks before and after the reform (currently five weeks). The results, as reported in panels A and B of Table 2.5, are similar to our main results in Table 2.1 and suggest the main findings are robust. Regressions are also conducted but the results, not reported in order to save space, are quantitatively similar to our results in Table 2.2. We further increase and decrease the periods of trading hours to two hours and half an hour after the market opens (currently the period is one hour), with similar results being found, but not reported in order to save space.

[11] We appreciated a reviewer's comment on this addition.

[Insert Table 2.5 here]

2.4.5.2 The effect of transparency on liquidity of A-shares that had (and not) reformed the share split structure

The share split reform, which was conducted during 2005 to 2007 for Chinese listed firms, has been identified as increasing the price discovery from better risk-sharing and better market fundamentals (Li et al., 2011; Liao et al., 2014) and increasing stock liquidity after the reform (Chu et al., 2014), so if a firm undergoes a share split reform during our sample period, the better liquidity may be caused by the share split reform rather than the market transparency reform. Therefore, we repeat our study for A-shares that had reformed their split share structure and those without during our event period, to see whether the market transparency reform has similar or different effect on liquidity of A-shares that had or had not reformed the split share structure. The results are reported below in Table 2.6.

Our results suggest that A-shares that had reformed the split share structure have an overall better market liquidity (lower spreads) in Panel A than those without the reform in Panel B, which is consistent with Chu et al. (2014). Nevertheless, liquidity is improved significantly after the transparency reform in both A-shares with and without split share structure reform, suggesting that our main results is not driven by the share split reform because improved liquidity after the transparency reform is observed even in A-shares that did not undergo a split share reform.

[Insert Table 2.6 here]

2.5 Summary and conclusion

The call auction market competes with the continuous market for order flow. This study examines how the increased information transparency in the pre-open call auction period affects liquidity in the continuous trade market of the SHSE. By using the pre-trade call auction reform as an exogenous shock, we find that increased opening call auction transparency is associated with lower average price volatility, a smaller proportion of adverse selection cost in effective spread, and a narrower bid-ask spread for the first trading hour, especially for actively traded stocks. Trading volume decreases temporarily in the first trading hour, but turns around thereafter.

Overall, we provide empirical evidence that the quality of the Chinese capital market was greatly improved when information transparency increased after the pre-trade call auction reform, which supports the argument by Flood et al. (1999) who document that the dissemination of pre-trade information during the opening call phase reduces the impetus for traders to actively place orders to 'test' the market and bring about a faster price discovery in the early moments of trading. Our study suggests that in an emerging market, where the market is dominated by individual investors, although improved transparency may discourage trading by informed investors, small non-institutional investors do benefit from better market transparency.

Chapter 3. Call auction transparency and market efficiency: The Shanghai experience

3.1 Introduction

The call auction's contribution to market quality can be analysed from two perspectives: (i) its ability to attract order flow and provide an alternative trading venue to the continuous order-driven market, and (ii) its impact on market efficiency. In chapter 2, I found that there was decreased trading activity in the first hour of the continuous market following the onset of semi-transparency to the call auction system. Trading activity is intrinsically linked to the price formation process, determining the amount and timing of price discovery over daily trading cycles (Ibikunle 2015). The following chapter investigates whether Shanghai's opening call auction transparency, and the resulting decline in trading activity, had any impact on the price discovery process of the continuous market, particularly within the first hour after market opening.

The motivation for this empirical investigation is due to market efficiency being the main reason for the microstructural design change that took place on the Shanghai Stock Exchange (SSE) on 01 July 2006. In an efficient market, prices 'fully reflect' all available information[12]. Therefore, recognising the importance of having appropriately set prices at the start of the day and responding to the lack of participation and transparency in its existing 'black box' opening call auction system, the Shanghai Stock Exchange partially opened up its order book to reveal indicative opening prices and quantities as the call auction takes place. It was hoped that this change would enhance the overall price discovery of the market.

[12] Fama (1970)

The Shanghai experience warrants investigation because the new opening call auction design closely matched the design of Hong Kong's opening call auction. The pre-opening time period is unusually short, divided into phases and order restriction rules apply. After Hong Kong introduced a call auction to open its daily trading in 2002, Comerton-Forde, Rydge and Burridge (2007) reported a decline in market quality, particularly in less actively traded stocks. Amongst existing empirical literature, this was an anomaly. The authors attributed it to the design of this opening mechanism, which at the time differed significantly from other international call markets. According to Comerton-Forde, Rydge and Burridge (2007), the lack of interest at the opening call auction prevented it from providing meaningful price discovery and alleviating the price uncertainty at market openings.

Given the worsening of overall market efficiency, an examination of the Shanghai experience is useful in two ways. On a qualitative level, it allows me to confirm Comerton-Forde, Rydge and Burridge (2007) findings in a different, but similar market by assessing the level of market interest in this form of call auction. Noting that in this empirical study, Shanghai moved from a fully opaque to a partially transparent call auction, rather than from no call auction to a partially transparent auction, I hope to quantitatively use this event to ascertain whether Hong Kong's call auction experience could have been alleviated by a fully opaque opening auction instead. If the results show that information transparency of the open call auction is detrimental to continuous market efficiency in Shanghai, then we may propose for Hong Kong to adopt a fully opaque call auction as well.

This chapter contributes to existing literature in several ways. First, it is a unique event. The reform in Shanghai on 01 July 2006 represented a fairly significant switch from no transparency at all to a typical semi-form of information transparency. Given that most exchanges have used a semi-transparent form of call auction since they adopted calls to open or close those markets, a further regime change can only be incremental. Hence, there have not been many opportunities to directly examine the influence of call auction transparency. The SSE reform provides an ideal institutional setting to observe changes in overall market efficiency without being influenced by other exogenous factors.

The second contribution is that I am able to examine whether the implementation of call auction transparency mitigated the problems that motivated SSE to reform, namely poor price discovery at the start of the day. A distinctive feature of the Chinese market is the absence of alternative platforms during non-trading hours, such as Electronic Communication Networks (ECNs) or Broker Crossing Networks (BCNs). Given that the opening call is preceded by an extended period of non-trading, the need for price discovery is highest at the start of the trading day. Furthermore, China is an emerging capital market dominated by uninformed individual investors. Instead of focusing just on the call auction, I extend my analysis to the post-opening activities, examining how market participants deal with the information revealed during the call auction. These information reflect market sentiment, and thus have ramifications not just for the call, but also for subsequent trading periods.

Finally, I examine whether the introduction of call auction transparency affected price discovery behaviour differently in stocks with different levels of liquidity. In chapter 2, I showed that this was detrimental to the liquidity of thinly traded stocks. I evaluate

how different liquidity stocks respond to price discovery uncertainty at market opening, under the conditions of information asymmetry that characterise the Chinese stock market.

I examine a sample of 780 A-share securities traded on the SSE five weeks before and five weeks after the reform to the opening call auction. The results find a migration of price discovery from the call auction to the continuous trading period. Overall price discovery in the first hour of continuous trading is boosted in the post-event period, on an overall and individual trade basis. I observe a larger proportional increase in this price discovery for inactively traded stocks, than for actively traded ones. Call auction transparency did not have as large of an impact for them. The level of noises in the continuous market, in the post event period, is quieter, even after controlling for the diminished level of trading activity.

The remainder of this chapter is structured as follows: Section 3.2 reviews the relevant literature and outlines the hypotheses, Section 3.3 describes the institutional setting, Section 3.4 and 3.5 present the methodology and data, Section 3.6 reports the results and Section 3.7 concludes.

2.2 Literature review and hypothesis development

There exists a fertile body of literature that examine whether the introduction of a call auction trading system adversely or positively affects market characteristics.[13] But as was the case for chapter 2, few papers have linked the market design of the call auction,

[13] Biais et al (1999) - Paris Bourse, Pagano Peng Schwartz (2013)- NASDAQ, Chang et al (2008) and Comerton-Ford, Lau and McInish (2007) - Singapore Stock Exchange. Except for Biais et al (1999), these papers investigated the introduction of opening call auction in tandem with the closing call, as the calls were introduced to the exchanges at the same time.

in this case, information transparency, to the quality of the continuous market in the subsequent trading period. As more exchanges move to adopt a call auction to open trading at the start of a trading day, this is a question worth investigating because "[a] well designed opening call auction provides traders with an alternative trading mechanism that may reduce trading costs and determine more efficient prices at the open. A good design may also generate increased trading activity"[14].

The general view is that information transparency is good for price discovery and market efficiency[15]. Madhavan (1996) and Pagano and Roell (1996) compared a fully opaque call auction with a transparent call that offered order book information to market participants. Both papers concluded that the latter should lead to higher market quality due to the greater volume of information revealed during the bidding process. Hendershott and Jones (2005) showed that after the Island ECN went dark, price discovery became less efficient within the ETF market, and between the ETF and futures markets. Glosten (1999) argued that "transparency should lead to greater commonality of information. Greater commonality of information means that adverse selection becomes less of an issue", implying therefore that prices become more efficient.

However, excessive transparency may reduce efficiency if traders fear that placing orders will reveal their information (Domowitz and Madhavan, 2001). Boehmer Saar Yu (2005) found that in a market that was transparent, investors submitted smaller limit orders in order to manage their order exposure. Hinterleitner et al (2012)

[14] Comerton-Ford, Rydge and Burridge (2007)
[15] Bloomfield and O'Hara (1999), Madhavan (1996), Pagano and Roell (1996), Baruch (2005)

conducted an experiment whereby they compared a continuous double auction after an opening call auction with a stand-alone continuous auction. The call auctions differed in their level of transparency. They found no significant differences in the effect generated between the transparent and non-transparent call auctions. A transparent call auction did not lead to a more efficient opening price, nor generate higher liquidity, at the opening, than the non-transparent call auction. Rather than facilitate discovery of the fundamental value of stocks, the authors suggested that observing the order flow and price discovery during the pre-opening phase increased the feeling of uncertainty in the market, which spilt into subsequent periods. Also, participants could have been overwhelmed by the amount of information available in the pre-opening phase and a fully transparent call auction gave greater room for price manipulation. (Arifovic and Ledyard, 2007)

I hypothesise the following events happening. The transparency of the call will eliminate much of the prior incentive for information traders, holding valuable private information, to trade during the call. Those that still make the strategic decision to participate in the call auction will wait until the second half of the opening call, when only new orders can be submitted and existing orders cannot be modified or cancelled, before placing their orders and thus revealing their private information to the market. Therefore I hypothesis that there will be less discovery of private information during the call auction.

However, the ability to look in, watch prices being determined by the market, and the ability to amend their orders based on the updating public information, will alleviates the high level of asymmetric information after an overnight period of nontrading, boost

investor confidence in the prices determined by the call auction and lower the risk of adverse selection for market participants. I hypothesis that there will be fewer price adjustments in the subsequent time periods and thus less 'noise'.

Based on the above discussion, the following hypotheses are proposed:

Hypothesis 1: *The introduction of transparency to opening call auction leads to a decrease in price discovery during the call auction*

Hypothesis 2: *The introduction of transparency to opening call auction leads to an overall increase in price discovery in the continuous trading period immediately after the call.*

Hypothesis 3: *The introduction of transparency to opening call auction leads to less price discovery noise in the continuous trading period immediately after the call.*

3.3 Institutional Detail

The trading system on the SHSE is based on the electronic Consolidated Open Limit Order Book (COLOB). Each morning, a 10-minute opening call auction is held from 09:15 to 09:25. This is followed by two continuous auction sessions, between 09:30 and 11:30 and 13:00 to 15:00.

Trading is conducted through the submission of limit orders. The minimum tick size is 1 cent (RMB0.01 Yuan) and the minimum order size is 100 shares. There are no designated dealers (specialists) to intervene in trading. Only good-to-day limit orders are accepted by the trading system. These orders are matched by price, and then time, priority. The information of the best five bids and offers, their associated volume, and

the price and volume for the latest transaction must be displayed on computer terminals viewable by investors both on and off the exchange. The market is closed on Saturdays and Sundays and other public holidays announced by the exchange.

At the end of the trading day, all orders are purged from the COLOB. To prevent buying or selling panics, trading is halted for the whole day if prices deviate more than 10% from the previous day's close. In addition, shares cannot be sold on the same day as they are bought. Floor trading among member brokers, and short selling are strictly prohibited during this study period.

Prior to July 1 2006, the pre-open call auction was entirely devoid of information dissemination. There was no information regarding order books available to investors during the auction process, except for the final clearing price generated at the end of the auction. During this 10-minute call auction period, investors could place limit orders and participate in the opening auction, but no orders would be allowed to be withdrawn. Orders that are not executed in the opening auction were automatically transferred to the period of continuous trading. The determined opening price at 09:25 is continued to 09:30.

On July 1 2006, a limited or semi-transparent call auction was introduced to open trading. Information of an indicative auction price (IAP), an indicative equilibrium volume indication (IEV), expecting unexecuted volume indication (IUV) were disseminated to the market in real time throughout the pre-opening period. It was hoped that by providing pre-trade information during the opening period, the SHSE

could increase its efficiency in determining an opening price and would encourage more investors to participate during the pre-opening auction.

There are two relevant time periods in the 10-min pre-open call auction period. During the first period between 09:15-09:20, allowable messages to the system include limit orders and order modifications or cancellations. During the second period between 09:20-09:25, modifications and cancellations are not allowed, but new orders are accepted before the final opening price and quantity is generated in the market. The market then takes five-minute break between the periodic auction at 09:25 and the start of the morning session at 09:30 with continuous trading mechanism. The arrangement of 5-minute cooling-off period is similar to the 2-minute blocking period between 09:58 and 10:00 in the Hong Kong Exchanges and Clearing Limited after 2002 (Asian Etrading 2009). The situation in Shanghai‘s current pre-opening arrangement is now similar to the Deutsche Borse AG, which discloses information about unbalanced amounts but is a closed order book during opening call auction.

3.4 Methodology

The academic approach to measuring market efficiency can be essentially distilled into two categories: in terms of price discovery or noise.

3.4.1 Price Discovery

Price discovery is defined as the speed at which new information is incorporated into stock prices. To measure the intraday period-by-period price discovery, I used the well-established weighted price contribution (WPC) introduced by Barclay and Warner (1993). It measures the permanent price impact component of price change in

each intraday time period, as opposed to how smoothly prices move together in daily time periods.

WPC calculations involve calculating the fraction of the price change over the period *t* relative to close-to-close price change on each day, for each stock & for a given period *t*. Then, each day's contribution of period *t* is weighted based on that day's contribution to the cumulative absolute price change over the entire sample period.

The WPC has been used to calculate price discovery and trading after hours[16], across trading venues[17], across dealers in different geographic locations[18], during the preopening period[19], and during the opening and closing auctions[20].

I divide the daily close to close return into four time periods: the opening call auction (previous close to opening call), the opening trade (the opening call auction just after 0925am to the first continuous trade after 0930am), first 60minutes of the trading day, and the remainder of the trading day[21].

For each stock, the WPC of time period *t* is defined as:

$$WPC_t = \sum_{d=1}^{D} \left(\frac{|ret_d|}{\sum_{d=1}^{D} |ret_d|} \right) \times \left(\frac{ret_{t,d}}{ret_d} \right) \quad (1)$$

[16] Barclay Hendershott 2003
[17] Huang 2002
[18] Anand et al 2011
[19] Cao et al 2000
[20] Ellul et al 2005
[21] This is because information asymmetry is at its highest level for the day just before open. The trades are more likely to be informed than at any other time of the day. I expect that the trades executed at the start of the day, either during the call auction or the first hour after market opening will contribute significantly to the day’s price discovery.

Where ret_d is the close-to-close on day d, and $ret_{t,d}$ is the logarithmic return for period t on day d.[22]

I calculate the WPC for each stock, and then obtain crossectional averages across the time periods. [23]

The WPC normalises the price discovery per period such that the WPCs sum to one. (Barclay Hendershott 2008) The weights in the WPC reduce the heteroskedasticity in the observations and avoid the difficulties associated with zero price changes.

Even if the total price discovery appears to be low, individual trades may reveal more information. To measure the price discovery by trade, I divide the WPC for each time period by the weighted fraction of trades occurring in that period, and obtain the weighted price contribution by trade (WPCT). The WPCT for each stock at time period t is defined as:

$$WPCT_i = \frac{\sum_{d=1}^{D}\left(\frac{|ret_d|}{\sum_{d=1}^{D}|ret_d|}\right)\times\left(\left[\frac{ret_{t,d}}{ret_d}\right]\right)}{\sum_{d=1}^{D}\left(\frac{|ret_d|}{\sum_{d=1}^{D}|ret_d|}\right)\times\left(\frac{tr_{t,d}}{tr_d}\right)} \qquad (2)$$

where $tr_{t,d}$ is the number of executed trades during time period t on day d, and tr_d is the total number of trades on day d.

[22] Some previous studies use price changes rather than returns (see Cao et al 2000). However, I follow Barclay and Hendershott (2008) in using returns to make the results comparable across stocks and to facilitate the calculation of standard errors.

[23] The WPC is typically calculated on a stock-by-stock basis, and then averaged across the stocks. (see Cao et al 2000, Huang 2002, Barclay and Hendershott 2008) It is said that stock correlations, due to common components in stock returns, complicate statistical inferences about the mean WPC. (Barclay and Hendershott 2003) Thus I also computed WPC for each day, and then averaged across days. The results [not reported] are qualitatively similar.

3.4.2 Noise

One popular[24] method for capturing the noisiness of stock prices is the R-square methodology first employed by Pagano and Schwartz (2003) in their study of the Paris Bourse. This approach, based on earlier work by Cohen et al (1983), uses a market model to contrast the short and long run relationship between individual stocks and the broader market index over different time intervals. The technique is based on the idea that frictions in the trading process would delay the adjustment of prices to new information. The result is that Ordinary Least Squares (OLS) estimators of beta would become biased or inefficient. Thus, an increase in the adjusted-R squares following the reform will indicate greater synchronicity in prices, a tighter fit between the individual asset returns and market returns, and improved price efficiency.

The use and interpretation of results derived from the R-square approach do have limitations. This technique uses daily data (opening and closing prices) rather than allowing for analysis of market efficiency on an intraday basis. Furthermore, Bramante et al (2013) found, on the use of R-square as a measure of price efficiency, that for China, R-square did not increase with market capitalisation. Smaller market cap stocks have higher R-squares than large cap, which would imply that large cap stocks are less informationally efficient that smaller cap stocks.

Therefore for this study, I use the alternative 'unbiasedness regressions' developed by Biais Hillion and Spatt (1999) to measure the informational efficiency of prices as price discovery takes place. For each stock and each one minute time period, I regress

[24] Pagano and Schwartz (2003), Pagano and Schwartz (2005), Chelley-Steeley (2009), Battig and Chelley-Steeley (2010), Comerton-Forde, Lau and McInish (2007),

the daily close-to-close return (ret_{cc}) on the return from the previous close to the end of that time period *t* (ret_{ct}):

$$ret_{cc} = \alpha + \beta \text{ x } ret_{ct} + \varepsilon_t \qquad (3)$$

In a 'perfect' efficient market that learns from past price information, β should be approximately one. However, Barclay and Hendershott (2003) points out that the coefficient estimate in the unbiasedness regression suffers from bias due to measurement error. Assuming an efficient market, they theorize that β is equal to one as long as stock prices are serially uncorrelated and precisely gauged. These two assumptions rarely occur in reality. Both bid-ask spreads and pricing errors may cause market prices to be serially correlated. Thus, the observed price will always be contaminated by noise and the coefficient estimate from ordinary least squares will be biased downwards.

Instead, Barclay and Hendershott (2003, 2008) suggest that β be interpreted as a signal to noise ratio[25] since:

$$\hat{\beta} \overset{p}{\to} \beta\left(\frac{\sigma^2_{RET_{ct}}}{\sigma^2_{RET_{ct}}+\sigma^2_u}\right) \qquad (4)$$

where RET_{cc} and RET_{ct} are the unobservable 'true' returns. $ret_{cc} = RET_{cc}+v$ and $ret_{ct} = RET_{ct}+u$. $\sigma^2{}_{RET_{ct}}$ is the variance of the 'true' returns from the previous close to time *t*. (ie. the signal) u and v have zero mean and variances equal to σ_u^2 and σ_v^2 respectively. (ie. the noise)

[25] or more precisely, a signal-to-signal-plus-noise ratio

Therefore, the extent to which the estimated OLS slope coefficient, $\hat{\beta}$, is less than one allows us to infer the extent of noise in period *t*.

Finally, I control for trading activity and other factors affecting stock price volatility by performing the following regression:

$$Volatility_{i,t,d} = \beta_0 + \beta_1 * ln(market\_cap_i) + \beta_2 * ln(turnover_{i,t,d}) + \beta_3 * effspread_{i,t,d} + \beta_4 * change + \sum_{n=5}^{15} \beta_n * time\ interval\ dummies + \varepsilon_{it} \quad (5)$$

Where $Volatility_{i,t,d}$ is the Parkinson (1980)[26] 'High Low Range Volatility' for stock *i*, at 5-minute interval *t*, on day *d*. $market\_cap_i$ is the equity market capitalization for stock *i* based on closing prices on 30 June 2006. $turnover_{i,t,d}$ is the total turnover for stock *i*, during time interval *t*, on day *d*. $effspread_{i,t,d}$ is the mean effective spread[27] for stock *i*, during time interval *t*, on day *d*. *Change* is a dummy variable that takes a value of one after the reform to the opening call system, and a value of zero if otherwise. Also included are 11 five-minute time interval dummies from 0930 to 1030, in order to capture the time varying characteristics of these volatility measures.

3.5 Data

Just as it was the case in Chapter 2, a period of five weeks before and after the event date is selected to capture the immediate and permanent impact of the change in opening call auction transparency on the SSE. The pre-event period runs from 29 may 2006 to 30 June 2006. The post-event period covers 01 July 2006 to 04 August 2006. The sample of 780 A-share securities is also the same. These stocks are divided into

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[26] As shown by Parkinson (1980), this volatility measurement properly scaled, not only is an unbiased estimator of volatility but is five times more efficient than the classic estimator of volatility.

[27] $\text{Effective spread} = 2\text{x}|\text{transaction price} - \text{bidask midpoint immediately prior to the transaction}|$

quintiles based on their average trade volume during the study period. Quintile 1 represents the most active securities, whereas quintile 5 is the least active.

All of my daily transaction and order book data is obtained from the *Reuters* database maintained by the *Securities Industry Research Centre of Asia-Pacific* (SIRCA).

3.6. Results

3.6.1 Price discovery

3.6.1.1 Weighted Price Contribution

Table 3.1 presents the average WPC as well as the mean change in WPC following the reform on 01 July 2006. The findings support hypothesis 1 and hypothesis 2.

The introduction of a more transparent opening call auction saw price discovery move away from the call auction to the continuous market. The return contribution of the opening call auction price halved (from 20% to 11%), as did the level of price discovery in the first continuous trade of the trading day (from 2.4% to 1.5%). This was observed across all quintile groups.

Price discovery becomes more concentrated in the 60 minutes after the market opens. In the post-event period, the first hour of the trading day now accounts for 31% of the day's permanent price change. Whilst the first hour of trading absorbed the majority of the price discovery that would have taken place in the opening call auction pre-reform, not all of the price information that would have been disseminated under the previous call auction system migrated to the immediate 60 minute trading period. As such, the level of price discovery in the subsequent period also increased. This is expected, because without the aid of a black-box call auction to place trades whilst

concealing private information, some traders opted to reveal their information in a more gradual manner, over the course of the entire trading day.

Amongst the quintile groups, there is an overall greater level of price discovery for actively traded stocks during the first hour of the trading day than for inactively traded stocks. This confirms existing literature that price discovery of illiquid stocks with high information asymmetry is more gradual, revealed over the course of the trading day. But the effect of the call transparency regime change is a bigger boost in price discovery during the first hour for inactive stocks than active ones. This confirms my finding in Chapter 2 that a transparent call auction is discouraging to traders of illiquid stocks, causing the dissemination of public and private information through trade to migrate from the call auction to the continuous trading market.

[insert Table 3.1 here]

Finally, to illustrate how permanent price changes are disseminated over the course of an entire trading day, I divide the trading day into 15 minute time intervals and calculated the mean WPC for each interval. The results are presented in Table 3.2 and Figure 3.1. The time intervals with price discovery having the biggest permanent impact on prices are at the start of the continuous trading day, towards the end of morning trading session, and at the closure of market.

[insert Table 3.2 here]

[insert Figure 3.1 here]

3.6.1.2 Weighted Price Contribution per Trade

As I found in Chapter 2, there was decreased trading activity in the first hour of the continuous market following the reform. In this section, I attempt to evaluate price discovery, whilst controlling for the level of trading activity.

[insert Table 3.3 here]

The WPCT results in Table 3.3 reveal that opening call auction trades on Shanghai Stock Exchange contribute little to price discovery, and became even less informative in the post-event period. The low level of information contained in opening prices in Shanghai is somewhat surprising given the accumulation of public and private information overnight that awaits dissemination through public trading. This result is at variance with Barclay and Hendershott (2003) and Ibukunle (2015)'s findings on Nasdaq and London Stock Exchange, respectively, that WPCT is highest during the pre-opening period. On the SSE, there is an evident reluctance by traders to post competitive orders that move prices or signal material information during the pre-opening period, and it was not mitigated by making the call auction more transparent.

Instead, the call auction reform increased the price contribution of trades during the first hour of trading. WPCT rose from 5.33 to 6.7, indicating that individual trades during the first hour contained more information, as opposed to noise, and worked more at making prices more efficient, than it did pre-reform.

Individual trades of active stocks have more permanent price impact than inactive stocks. The contribution to price discovery of trades increased in the first hour across all quintiles. As it was the case for the WPC, the reform had a bigger impact on less liquid stocks than active ones.

3.6.2 Noise

3.6.2.1 Unbiasedness Regression

The WPC results reveal that about 50% of the day's price discovery takes place on the SSE before the first hour of continuous trading is complete. But how informationally efficient is that price discovery process, given the noise, large spreads, and price reversals that impede market efficiency? And did a more transparent call auction enhance the efficiency of price discovery in the critical first hour of continuous trading, as it sets the mood for trading for the rest of the day?

[insert Figure 3.2 here]

Figure 3.2 plots the mean coefficient estimates, as well as their 5% confidence intervals calculated using the standard errors of the coefficient estimates.

Consistent with existing empirical literature[28], the opening β estimates are less than one. That beta is less than one at the start of the day is also due to transitory order imbalances at the open that add noise to prices. In Chapter 2, I showed that depth is lowest at the start of the day and steadily increased as the trading day progressed.

However, the average opening $\hat{\beta}$ is much lower in the post-event period, dropping from 0.93 to 0.68. This was across all quintile groups. But the pattern for the signal-to-noise ratio in the pre-event period is remarkable in that it opened high but then declined for a few minutes afterwards, indicating more noise in the market prices. A plausible explanation is that as part of the reform, traders were now able to cancel or amend their orders in the call auction, resulting in less unexecuted orders automatically

[28] Biais et al (1999) – Paris Bourse, an order-driven market with no market-makers, no trading during the pre-open, report median β value of 0.68 at opening
Barclay and Hendershott (2003) – NASDAQ, a quote-drive market with market makers, shares are traded in the pre-open – report β between 0.8-0.9 at market open.

transferred to the continuous market from the pre-opening period. The slight dip in information efficiency just after the call auction could be directly caused by those inefficient limit orders.

In the post-event period, signal-to-noise ratio opened lower but rose steadily towards one, gaining price efficiency as available information was absorbed into the trading process. When the stocks were split into quintile groups, we observed a momentary rise in noise just after opening for all of the actively traded quintile groups, and sometimes in the post-event period as well.

After the signal-to-noise ratio recovered from the dip at the open, it hoovered around 1 for the remainder of that first hour. By contrast, after the change to call auction transparency, the signal-to-noise ratios tended to push past 1, hugging around 1.1. At first glance, when one sees β estimates around 1, one might automatically conclude that the market was more efficient before the regime change. But Biais, Hilion and Spatt (1999) warned that interpretations of unbiasedness regression β findings of 1 should be done cautiously. It could reflect the countervailing effects of noise in prices (which drive the slope below one) and staleness (which drives prices above one). I showed in Chapter 2 that trading volume is relatively low in morning trade, apart from trading at market open; therefore there is also considerable noise.

The fact that average β in the post-event period is statistically >1 suggests that prices are either stale, or the market slightly underreacts to information, because cov (ret_{cc}, ret_{ci})>0.

[insert Figure 3.3 here]

The general reduced level of noise in the price discovery process after the reform is further supported by Figure 3.3, which reveal lower root mean standard errors (RMSE) for all quintiles.

The RMSE chart illustrates learning in the market. Fluctuations in the RMSE charts reflect the fact that the rate at which incremental information is impounded is not stationary. Figure 3.3 shows that in general, the biggest acceleration in the speed of learning takes place in the first half an hour after opening. In the first 30 minutes, we observe the biggest fall in RMSE. After that, they decline more gradually. It is also worth noting that as stocks become less actively traded, the RMSE time series has more volatility. For Quintile 1, the RMSE exhibit is almost a smooth line.

3.6.2.2 Volatility regression

A basic feature of efficient markets is low noise or price volatility[29]. But the fact that the SSE is less noisy in the post-event period could simply be due to a diminished level of trading activity, as opposed to improvements in the efficiency of price discovery.

The volatility regression results are reported in Table 3.4.

[insert Table 3.4 here]

The *change* variable is statistically significant and negative[30]. Therefore, even after controlling for a reduced level of trading activity in the first hour, call auction transparency made the continuous market less noisy. This result mirrors the reduction in RMSE of the unbiasedness regression and is consistent with hypothesis 3.

[29] Black (1981)
[30] I note that the coefficient is close to zero, so this change is not an economically significant one.

3.7 Conclusion

Establishing an opening reference price after an overnight period of inactivity can be a challenging process, but the opening price is important to trading strategy and sets the investor sentiment for the remainder of the trading day.

The move from a fully opaque to a semi-transparent auction system caused a significant shift in price discovery from the call auction to the continuous market. I observed a higher level of price discovery in the first hour of continuous trading, as well as the individual trades during that first hour becoming more informative. This effect was more strongly felt amongst inactive stocks than actively traded ones.

The opening prices in the post-event period have a lower signal-to-noise ratio, confirming that the opening price contained less information, as most of the price discovery has not taken place yet. But the signal-to-noise ratio quickly rises and remains steadily higher than the pre-reform period for the remainder of the first hour time period. Even controlling for a slightly diminished level of trading activity in the first hour, the market was calmer. Foucault (1999) shows that in a market with less volatility, passive traders face less risk of being picked off at stale prices, and thus submit more aggressive limit orders.

As previously mentioned, much of this could be due to the cancellation or amendment of otherwise unexecuted call auction orders. That is only possible if traders are able to 'look in' at the price discovery taking effect during the opening call auction, even if it prompts many informed investors to wait until the continuous market before disseminating their private information by trade.

I agree with Comerton-Forde, Rydge and Burridge (2007) that call market design and trading rules can have a significant effect on its outcomes. Overall, I conclude that call auction transparency improved the efficiency of the Shanghai Stock Exchange.

Chapter 4. The impact of a closing call auction on the Shenzhen Stock Exchange

4.1 Introduction

Since 1996, when it was introduced for illiquid stocks on the Paris Bourse, call auctions have increasingly been used to determine the closing price on international stock markets. Call auctions are argued to aggregate information by pooling orders, lower execution and market impact costs, eliminate the risk of front running and information disclosure, and lower price manipulations (Agarwalla, Jacob and Pandey, 2015). Around closing times, market prices are subject to transitory inefficiencies, marked by high volatility and trade volume, as traders speed up their order entry to close out their position before the end of the trading day. The call auction is often advocated as the best solution to handle such order imbalances and mitigate the transitory inefficiencies at the end of the trading day (Pagano, Peng and Schwartz, 2013).

But while academic studies into the introduction of call auctions have generally shown that they improve price efficiency [31] and reduce market manipulations, not all introductions of the call auction to close markets have been positive. When Hong Kong adopted the closing call auction in 2008, it was hampered by chaotic price swings and the call auction was abandoned after just 10 months. It cannot, therefore, be assumed that all call auctions are superior to other price formation mechanisms. The performance of call auctions is largely influenced by its design and trading rules (Comerton-Forde, Rydge and Burridge, 2007). Each example of closing call auction and its associated auction design is worthy of investigation.

[31] A market that is price efficient is one in which prices 'fully reflect' all available information. (Fama, 1970)

On 01 July 2006, the Shenzhen stock exchange (SZSE) commenced using a three minute call auction to close each day's continuous market trading. The Shenzhen experience is of particular study interest for two reasons. First, Shenzhen's closing call auction has a number of unusual characteristics. It is unusually short[32], fully opaque, and exists on a pure limit order book market that does not have an alternative trading platform during the non-trading hours. It is a market dominated by uninformed rumour-based individual traders rather than institutional traders that rely heavily on the closing price to set the benchmark price for indexes and funds. During the time period covered by this study, there were no futures contracts, so the results of this chapter are not contaminated by abnormal trading behaviour on option expiry days.

A quick, 'black box' call auction may have been designed to reduce the risk of price manipulation like that experienced by Hong Kong, but it comes at the expense of price discovery, an oft-cited merit of call auctions. Pagano and Schwartz (2005) argue that transparency is critical for a closing call to be effective. "The driving force behind good price discovery at the close is for participants to see any buy or sell imbalances, and to benefit from an imbalance by entering an order that offsets it." During SZSE's three-minute closing call, the system disseminates no information about imbalances or indicative closing prices. Therefore in the context of Shenzhen, an otherwise continuous trading market, I aim to find out whether a black box closing call auction worsens price discovery and deters traders that favour execution certainty.

[32] The typical pre-closing period on other equity markets are 5-10 minutes.

The second motivation is that the SZSE exists as a competitor to the Shanghai Stock Exchange on the mainland Chinese stock market. Companies can only be listed on one, but not both exchanges. Therefore, SZSE competes with Shanghai for a share in China's stock market capitalisation.

Right now, Hong Hong and Shanghai are the only two top 10 equity markets in the world that do not employ a call auction to determine the day's closing price. The high price volatility near the end of the day makes it difficult for investors to match the closing price, which is needed to facilitate the execution of portfolio valuation and index rebalancing. (Aitken, Lepone and Chan, 2011). In 2006, the SZSE was about 1/3 the market capitalisation of the SHSE. It held 532 listed companies, whereas Shanghai had 834.[33] By July 2015, Shenzhen had grown to a market capitalisation of 3.3 trillion RMB and had 1729 listed companies. SHSE had also grown during this time to 4.8 trillion RMB, with 1071 listed companies. With SZSE quickly gaining on SHSE in scale and their otherwise very similar trading mechanism, it is a pertinent regulatory question whether the closing call auction is effective in the Chinese trading environment and whether Shanghai should follow the rest of the world in adopting it as well.

I use this natural experiment to examine the effects of the new closing mechanism on the quality of the continuous market and on the trading behaviour of the market participants. I contribute to the literature by using high-frequency data to study the effects of the closing call auction on spreads, volatility, turnover, trade size, and price discovery in one-minute intervals. Focusing on such brief time intervals allows me to isolate the effects of market structure from broader market movement effects. It is particularly

[33] Source: http://www.world-exchanges.org/statistics

relevant in the minutes that precede the close as the market is most volatile and active. (Kandel et al, 2012)

I find that the closing call auction did not generate a substantial migration of trading activity from the continuous market, only 1.4% of daily turnover was transacted. The call auction, however, made trading in the continuous market just prior to 03:57, even more active, but not more volatile, amongst traders seeking to avoid the informationally non-transparent closing call auction. Bid-ask spreads narrowed just before the close of continuous trading. The quoted and effective spreads generated at the end of the call auction is substantially lower than when the closing price was generated by continuous trading. In terms of closing price discovery, the efficiency of actively traded stocks improved but the efficiency of the closing price of the inactive stocks declined.

The remainder of the chapter is structured as follows. Section 4.2 provides the theoretical and empirical framework and develops the hypotheses. Section 4.3 provides an overview of the institutional features of the SZSE and describes the call auction implementation. Section 4.4 provides the theoretical framework and develops the hypotheses. Sections 4.5 and 4.6 describe the data and method used, respectively. Section 4.7 reports the results and Section 4.8 concludes.

4.2 Literature review and hypothesis development

A stream of literature has examined the impact of the introduction of the closing call auction on market quality.

The general academic opinion is that closing call auctions improve price discovery[34]. It does so in two ways. First, closing call auctions pool information. "With continuous trading, the technological ability to measure time and fire in orders with sub-millisecond precision fractures the order flow, thereby thinning out liquidity and disrupting the efficiency of price discovery. In contrast, call auctions by their very design match multiple orders so as to find the prices that best clear the market."[35]

Secondly, calls prevent the manipulation of the closing price (Hoffman and Bommell, 2010). Hillion and Souminen (2004) showed that the introduction of closing call auction in Paris reduced price manipulation at the end of the continuous phase. Similarly, in Singapore, Comerton-Forde, Lau and McInish (2007) found significantly reduced skewness and kurtosis for day-end returns, also suggesting reduced price manipulation.

However, as the previous two chapters showed, the call market design, trading rules and institutional settings can have a significant impact on the call auction's outcomes. A 'plain vanilla' call auction mechanism in Hong Kong was discovered to be susceptible to price manipulation, particularly in the form of sniping. Suen and Wan (2012) explained: 'The HKEx experience is exceptional in that it is the only major stock exchange in the world that adopted a closing auction procedure without any precaution against price manipulation.' This eventually led to its abandonment.

Although it is the opinion of Pagano and Schwartz (2003) that call auctions deliver a more efficient closing price than continuous trading, Ho, Schwartz and Whitcomb (1985) showed that the prices in a call market, in general, are not equal to Walrasian equilibrium

[34] See Chelley-Steeley (2008, 2009), Battig and Chelley-Steeley (2010) – London
Pagano and Schwartz (2005) – NASDAQ
Pagano and Schwartz (2003) – Paris
Comerton-Forde, Lau and McInish (2007), Chang, Rhee, Stone and Tang (2008) – Singapore
[35] Schwartz (2010)

unless (a) there is 'symmetry in the distribution of individual buy/sell orders', and (b) traders' expectation about market clearing prices are accurate. Because the traders in Shenzhen have no idea about the market clearing price during its 3 minute call auction, I expect the call closing price to be less than optimal, but nevertheless still an improvement upon the previous system because it ameliorates order imbalances and deters price manipulation. Furthermore, the volume of liquidity-motivated traders migrating to the call auction and the fully opaque nature of the call auction order book, might lure informed traders and thus further enhance price discovery in the call. The following hypothesis is proposed:

Hypothesis 1: *The introduction of a closing call auction in Shenzhen improved the efficiency of the market closing price*

Since the closing call auction offers an alternative trading venue that is competitive with the continuous market, it has been argued that a significant proportion of volume shifts from the end of the continuous phase to the call auction (Kandel et al, 2012). Institutional, for example, mutual fund investors have strong incentives to trade at the closing price, in order to minimise their tracking errors. Kandel et al (2012) confirmed that this order migration is more pronounced when the closing price is set as the reference price.

A shift in trade volume has direct implication for the liquidity of the continuous market. According to the limit order book model of Foucault et al (2005), the introduction of the closing call auction gives liquidity demanders another opportunity to trade and many traders become less impatient to trade before the close. As a result, they submit fewer market orders and may even supply liquidity, which reduces spreads and volatility.

In addition, Pagano et al (2013) assert that the closing call auction can ameliorate transitory inefficiencies, evidenced by widening spreads and accentuated volatilities, at the close. By providing a venue that facilitates a more efficient order matching, the closing call auction mitigates the extent to which price discovery is perturbed by order imbalances caused by traders seeking to close out their positions by the end of the day. Pagano et al (2013) found supporting evidence that NASDAQ's closing call auction significantly reduced both spread and volatility for all market capitalisation groups.

Based on the above, I expect that the introduction of a closing call auction on Shenzhen will similarly result in more aggressive quote setting and hence lower price volatility in the continuous market that precedes the close.

Hypothesis 2: *The introduction of a closing call auction in Shenzhen narrowed the bid-ask spreads of closing prices.*

Hypothesis 3: *The introduction of a closing call auction in Shenzhen deceased volatility at the end of the continuous trading phase*.

However, given the proportionally smaller presence of institutional investors and a fully opaque call auction, the re-organisation of the end of day order flow may not be as substantial as what Kandel et al (2012) evidenced on Borsa Italiana and Paris Bourse after the closing call comes into effect.

Hypothesis 4: *The introduction of a closing call auction in Shenzhen moved only a small amount of trading volume from the last minutes of the continuous phase to the call auction.*

In addition to the papers already mentioned, there are other empirical studies that examined the market quality impact of closing call auctions. Chelley-Steeley (2009)

studied the impact of call introduction on the London Stock Exchange. She found an overall improvement in market quality, and the improvement was greatest at the open and for stocks with the lowest pre-call liquidity. The London call auction, however, was introduced as a parallel alternative trading venue to a dealer market, and the London experience thus cannot be used to study the effect on the limit order book. Comerton-Forde, Lau and McInish (2007) and Chang, Rhee, Stone and Tang (2008) used two different but complementary methodologies to arrive at the same conclusion that pricing efficiency in Singapore improved. Unfortunately for the Singaporean studies, opening and closing call auctions were introduced on the same month and the authors were unable to disentangle the impact of the closing auction from the opening auction.

So far, only Huang and Tsai (2008) have studied the impact of the closing call auction on market quality in a fully opaque context, but the stock market on which that study was based used the call method for both its normal and closing trading. Thus, Huang and Tsai (2008) is not directly comparable to China, nor the majority of the markets internationally that are based on continuous auctions. Nonetheless, Huang and Tsai (2008) found that when a fully opaque order book was used for the closing call auction on the Taiwan Stock Exchange, trading activity shifted away from the closing auction to the immediately preceding call auction intervals. Trading volume, order submission and market depths at the close declined. Huang and Tsai (2008) were able to sort their order book data by trader type and found the decline in order submission during the opaque call auction was mainly due to the actions of individual investors, closing their positions earlier rather than face an additional execution uncertainty risk during the closing call. Nevertheless, the noise in stock prices declined and the authors concluded that the efficiency of price discovery process improved. In contrast to the methodology used in this chapter, Huang and Tsai (2008) used five-minute time intervals to measure changes in various liquidity

measures, did not break their sample down to different liquidity groups, and declined to use the popular R-square price synchronicity measure despite calculating the relative return dispersion (RRD), which is based on the same market model.

Based on the above discussion, it can be seen that the outcomes of a closing call auction are crucially dependent on the institutional setting and market conditions.

4.3 Institutional detail

Just like the Shanghai Stock Exchange, the SZSE is based on the electronic Consolidated Open Limit Order Book (COLOB). A 10 minute opening call auction is held between 09:15 and 09:25, followed by the cooling periods from 9:25 am to 9:30 am, and two continuous auction sessions: the morning session from 9:30 am to 11:30 am and the afternoon session from 13:00 to 15:00. The market is closed on Saturdays and Sundays and other public holidays announced by the exchange.

There are no designated dealers (specialists) to intervene in trading in the market. Investors place their orders with the brokers in the form of either a market order or limit order, and only good-to-day limit orders are accepted by the trading system. At the end of the trading day, all orders are purged from the COLOB. The minimum tick size for all stocks is 0.01RMB. The quantity of stock purchased must be in round lots of 100, while there is no requirement on the quantity of sales. Shares can't be sold on the same day once they are bought. Floor trading among member brokers, and short selling are strictly prohibited. To curb sharp price movements, the limit of price change for each trading day is ±10% of the previous closing price, beyond which, trading will be halted for the rest of the day.

Prior to 1/7/2006, the closing price of stocks was determined by taking a volume-weighted average price of the trade prices during the one minute before the last trade (including the last trade) on that day. In the absence of any trade on a trading day, the previous closing price was taken as the closing price of that day. During the continuous trading session, the information of the best five offers and bids and their associated volume as well as the price and volume for the latest transaction on the stock exchanges was displayed on computer terminals viewable by investors on and off both exchanges.

From 1/7/2006, a closing call auction is held between 14:57-15:00. During the closing call pricing period 14:57-15:00, investors can place but not amend or cancel their orders. The buy or sell orders not executed during the continuous trading automatically enter the closing call auction. The closing price is generated from the call auction. In case no closing price is generated from the closing call auction, the trading volume-weighted average price of all the trades of the security one minute before the last trade (including the last trade) on that day is taken as the closing price. In the absence of trades on a trading day, the previous closing price is taken as the closing price of that day.

4.4 Data & sample

The data used in this study is obtained from the Thomson Reuters database. The data comprises intra-day trades and the best bid and ask prices for all stocks listed on the Shenzhen stock exchange. Details of all trades and changes in best bid and ask prices are time stamped to the nearest second.

Initially, the sample comprised of all A-shares listed on the Shenzhen stock exchange. To remove the effects of new IPO's, I excluded stocks that were listed after 01 July 2005. I also excluded stocks that suspended listing during the study period. A further 133 stocks

are excluded from the sample due to their inactive trading during the study period, resulting in a final sample size of 281 stocks.

The sample is partitioned into five roughly even quintile groups, based on average daily turnover, to examine how the impact of the introduction of the closing call differs across stocks with different levels of liquidity. Quintile 1 represents the most actively traded stocks, while quintile 5 is the least active SZSE shares during the study period.

The problem of pricing efficiency and information asymmetry for non-actively traded shares is particularly acute in China. About two-third of the outstanding Chinese stocks are state-owned and legal-person shares, which is neither transferrable nor tradeable on the open market. Although they can't directly deal with their shares, owners of illiquid shares exert a great deal of influence on corporate governance. They tend to dominate the board of directors and control inside information. By contrast, common traders receive very little information and these illiquid stocks are generally not followed by analysts. In London, Chelley-Steeley (2009) showed that low liquidity securities experienced greater improvements in price efficiency than stocks with high pre-call liquidity. But Chang et al (2008) found that gains were less for less liquid stocks in Singapore.

Like the previous two chapters, a period of five weeks before and after the disclosure of partial order information in the opening call auction of the SZSE is used in the study for analysis. This gives us a sufficient window to capture the immediate as well as the permanent effect of the change in opening call auction transparency.

To measure changes in market efficiency, I extend the sample period to 6 months before and 6 months after the event, a total of 240 trading days. This sample length, using Pagano and Schwartz's (2003) methodology, is consistent with the literature.

4.5 Methodology

This chapter examines the impact of the introduction of the closing call auction on market quality, focusing particularly on its effect on spread, volatility, trading activity and price efficiency.

4.5.1 Univariate comparisons

I begin by examining the changes in the intraday patterns of liquidity and volatility in the last thirty minutes of normal trading on the SZSE. I limit the investigation of the continuous market to the last half an hour because Kandel et al (2012) showed that the introduction of call auction had very little effect on the markets in Paris and Italy throughout most of the day, until during the very last minutes, where the effect was found to be very dramatic. The intraday patterns are assessed in 30 one-minute intervals between 14:30 and 15:00. Longer intervals (eg. 30 minutes), which other papers[36] have done, make it difficult to discern whether the changes are attributable to matters pertaining to the closing call per se, or some other attribute of the continuous market. This approach is compatible with that of Kandel et al (2012), Pagano et al (2013), Ibikunle (2015).

I analyse the changes in liquidity from both the price aspect (ie. quoted proportional spread, effective proportional spread) and quantity aspect (ie. dollar depth). The liquidity measures are calculated as follows:

$$PROPORTIONAL\ BID\text{-}ASK\ SPREAD\ (\%) = \frac{ask\ price - bid\ price}{bid - ask\ midpoint} \times 100$$

$$PROPORTIONAL\ EFFECTIVE\ SPREAD\ (\%) =$$

$$2 \times \frac{|transaction\ price - bid - ask\ midpoint\ immediately\ prior\ to\ the\ transaction|}{bid - ask\ midpoint} \times 100$$

[36] Pagano and Schwartz (2003), Aitken et al (2011)

DOLLAR DEPTH = $(best\ ask\ price \times best\ ask\ volume) + (best\ bid\ price \times best\ bid\ volume)$

Volatility is calculated by Parkinson's (1980)'s volatility measure:

VOLATILITY $_{idt}$ (%)= $(lnH_{idt} - lnL_{idt}) \times 100$

Where H_{idt} is the highest transaction price of stock *i*, for day *d*, interval *t*; and L_{idt} is the lowest transaction price of stock *i*, for day *d*, interval *t*.

Intraday patterns in trading activity are assessed as follows:

PROPORTIONAL [37] NUMBER OF TRADES = $\frac{Number\ of\ transacted\ trades\ during\ the\ time\ interval}{Number\ of\ trades\ for\ the\ whole\ day}$

PROPORTIONAL AVERAGE TRADE SIZE = $\frac{Average\ transacted\ value\ of\ individual\ trades\ during\ the\ time\ interval}{Average\ transacted\ value\ of\ individual\ trades\ for\ the\ whole\ day}$

PROPORTIONAL TURNOVER = $\frac{Total\ transacted\ value\ of\ individual\ trades\ during\ the\ time\ interval}{Total\ transacted\ value\ of\ individual\ trades\ for\ the\ whole\ day}$

If the introduction of the closing call auction causes trade volume to shift to the call auction as hypothesised, the proportional values of turnover at the end of the trading day will decline significantly as this volume is shifted to the closing call auction.

[37] In order to control for variations in trading activity across trading days and stocks

4.5.2 Multivariate analysis

To control for other changes in overall market conditions during the sample period, multivariate regressions are performed on spread and volatility. The bid-ask spread is affected by price volatility[38], market capitalisation[39], and trading activity[40]. Similarly, price volatility can be broken into spread, market capitalisation, volatility of the underlying price discovery process and the level of trading activity (Pagano et al 2013).

I conduct panel regression analysis on spread and volatility for one-minute intervals during the last thirty minutes of the trading day for the full sample group. For the endogeneity reasons as outlined in chapter 2, I solve the equations simultaneously:

$$pbas_{itd} = \beta_0 + \beta_1 volatility_{itd} + \beta_2 \ln(market\ capitalisation_i) + \beta_3\ proportional\ turnover_{itd} + \beta_4\ change_d + \sum_{n=5}^{7} \beta_n * five\ minute\ interval\ dummies_t + \sum_{n=8}^{10} \beta_n * change * five\ minute\ interval\ dummies_t \quad (1)$$

$$volatility_{itd} = \gamma_0 + \gamma_1 pbas_{itd} + \gamma_2 \ln(market\ capitalisation_i) + \gamma_3 std\_daily\_ret_i + \gamma_4 proportional\ turnover_{itd} + \gamma_5\ change_d + \sum_{n=6}^{8} \gamma_n * five\ minute\ interval\ dummies_t + \sum_{n=9}^{11} \gamma_n * change * five\ minute\ interval\ dummies_t \quad (2)$$

Where $pbas_{itd}$ is the average proportional bid-ask spread (%) for stock *i*, at time interval *t*, on day *d*. $volatility_{itd}$ is the Parkinson (1980) volatility (%) measure for stock *i*, time interval *t*, day *d*. $std\_daily\_ret_i$ is the standard deviation of close-to-close returns

[38] McInish and Wood (1992)
[39] Huberman and Halka (2001)
[40] Chordia, Roll and Subrahmanyam (2001)

measured over the study period, and represents volatility of the underlying price discovery process. $market\ capitalisation_i$ is the equity market capitalisation as at the close of trading on June 30 2006. $change_d$ is a dummy variable that equals to 1 if the observation is after 1 July 2006, and 0 otherwise. Also included are 3 five-minute time interval dummies to capture the sharp rise in spread and volatility in the last fifteen minutes of trading. The interaction variables $change * five\ minute\ interval\ dummies_t$ captures any additional changes in the intraday patterns as a result of the closing call introduction. The results are reported in Table 4.3.

4.5.3 Measuring price efficiency

4.5.3.1 Return Synchronicity

To measure market efficiency, I apply the methodology first employed by Pagano and Schwartz (2003) to study changes in market efficiency on the Paris Bourse. It is based on Cohen et al (1983), which uses a market model to compare short and long run relationship between individual stocks and the broader market index over different time intervals. The idea is that that frictions in the trading process would delay the adjustment of prices to new information and the resulting Ordinary Least Squares (OLS) estimators of beta would become biased or inefficient. An increase in the adjusted-R squares following the reform will indicate greater synchronicity in prices, a tighter fit between the individual asset returns and market returns, and hence improved price efficiency.

I use the Shenzhen A-share index as the market index for running the market model regressions. I calculate daily close-to-close returns for each stock and the A-share index using 12 different intervals: 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 15, and 20 days. Each stock's 12 adjusted R-squares in the 120 trading days pre-event period and 120 trading days post-

event period are calculated by performing a 'first pass regression' on the following market model:

$$R_{idLE} = \alpha_{iLE} + \beta_{iLE}\, R_{mdLE} + e_{idL,E} \qquad i=1,...n \quad L=1,...10,\ 15,\ 20 \quad E=1,2 \qquad (3)$$

where R_{idLE} is the close-to-close return for stock i on day d for time interval L, using either the pre or post-event returns (E). Correspondingly, R_{mdLE} is the market return on day d for time interval L, using either the pre or post-event returns (E). The adjusted R-square estimates are expected to be higher in the post-event period if the introduction of the closing call auction improved price discovery.

To assess whether the post-event R-squares are higher than pre-event R-squares, the adjusted R-square estimates from the first-pass regression are used as regressors to estimate the following second-pass regression:

$$AdjR^2_{iLE} = \beta_{i0} + \beta_{i1} ln(1 + L^{-1}) + \beta_{i2}\left(Dummy_{iE} \cdot ln(1 + L^{-1})\right) + \beta_{i3}(Dummy_{iE}) + u_{iLE} \qquad (4)$$

where $AdjR^2_{iLE}$ is the adjusted R-square for stock i, calculated using a L-day return interval during either the pre or post-event period (E). $Dummy_{iE}$ is set to 1 if the observation is in the post-event period, and 0 for the pre-event period. L is the return interval used in the first-pass regression.

The second-pass regression is written as such because Pagano and Schwartz (2003) determined that the transformed time interval, $ln(1+L^{-1})$, would provide the best linear fit between the R-square estimates from the first-pass regression and L. As L approaches infinity, the constant term becomes the asymptotic value of R-square. So if price synchronicity is improved in the post-event period, adjusted R-square will shift to a higher asymptotic or 'true' level, as reflected in positive and significant β_{i3} estimates. The

coefficient β_{i1} is expected to be negative as R-square of the market is expected to increase with return interval.

4.5.3.2 Relative Return Dispersion (RRD)

For robustness, I extend my study by examining another measure of market efficiency: the Relative return dispersion coefficient (RRD) presented in Amihud et al (1997). They argue that as market frictions weaken, the market quality improves and the residuals of the market model decline. Using one-day returns, the RRD coefficient is calculated as:

$$RRD_{Ed} = \left(\frac{1}{n}\right)\sum_{i=1}^{n} e_{iEd}^{2}$$

Where RRD_{Ed} is the average relative return dispersion coefficient on day *d*, obtained using all *i* stock samples. *n* is the number of stocks in the sample on day *d*. e_{iEd}^{2} is the squared market model (equation 3) residuals of security *i* on day *d*.

The RRD measure provides a complimentary approach to Cohen et al (1983). The R-square statistic captures the size of the market model residuals over time, for a particular stock. The RRD measure depicts the size of the market model residuals across stocks, for a particular trading day. Therefore, it captures the co-variation in the residuals across the sample stocks. Since the dispersion of returns for the individual stocks due to firm-specific information should be independent of the trading mechanism, systematic differences in RRD measure in the pre and post-call period indicate differences in efficiency (Chelley-Steeley, 2009). The RRD should fall after the introduction of a closing call auction, as the closing trading system is better able to cope with order imbalances, resulting in less correlated and smaller residuals across the sample on day *d*.

4.6 Results

4.6.1 Effect on liquidity

4.6.1.1 Intraday univariate analysis

[insert Table 4.1 here]

[insert Table 4.2 here]

Panels A–C in tables 4.1 and 4.2 document the change in intraday spread patterns during the last half an hour of the trading day, over the 5 week pre and post-event periods.

The results show a decrease in average quoted and effective spreads across every minute interval. The magnitude of the decrease is greater and more statistically significant in the earlier intervals than about 9 minutes before the commencement of the call auction. During the interval 1430 - 1431, quoted proportional spread fell 2.9%, but it merely dropped an average of 0.2% for the time interval 1454-1455, which is not a statistically significant change.

Interestingly, the quoted proportional spread in the post-event period peaks about two minutes before the commencement of the closing call auction. A minute before the closing auction, the quoted proportional spread drops and is again statistically significantly lower than in the same time period before the call auction. It is a sign of traders submitting competitive last-minute limit orders so that their trade can either be completed before the market moves into the call auction phase or their limit order gets rolled into the call auction and is executed as part of the closing price. Only limit orders are submitted during the closing call auction.

Also notable is that after the closing call auction was introduced, the closing spread is drastically reduced. Average quoted proportional spread fell 73.6% to a significantly

lower 0.0775%, average closing effective spread dropped 16.3% to 0.011 RMB and average proportional effective spread fell by 16% to 0.257%.

As a sign of their illiquidity, higher quintile stocks have higher average quoted and effective spreads. Quoted proportional spread and proportional effective spread generally fell across all quintiles during the assessed time intervals. However, the difference is generally statistically significant for the actively traded quintile groups than for the illiquid ones. For all five quintiles, closing quoted proportional spread and closing proportional effective spread is significantly lower in the post-event period, and quoted proportional spread peaks two minutes before the onset of the closing call auction.

Panel D in table 4.1 and 4.2 documents the intraday patterns of order book depth in the last 30 minutes, before and after the introduction of the closing call auction. As it can be seen, average dollar depth declined in the post-event period. Whilst this may be argued to be a direct result of the introduction of the closing call auction, it is more plausibly caused by the introduction of market orders on the SZSE from 01 July 2006. Market orders are used by liquidity-motivated traders who are no longer required to supply liquidity to the market by posting competitive limit orders. Limit orders supply market liquidity whereas market orders consume the liquidity supplied, hence there is less depth at the best bid and ask quotes.

The overall minute by minute fall is more statistically significant for some quintile groups than for others. The decline in dollar depth is mostly statistically significant for quintile 5, and somewhat significant for quintile 1. The changes are generally not statistically significant for quintiles 2, 3 and 4.

4.6.1.2 Multivariate analysis

Table 4.2 reports the coefficient estimates and *t*-statistics of the multivariate analysis of spread, controlling for other changes in overall market conditions during the sample period.

The parameter estimate for the *change* variable shows that overall, the call had a significant impact on reducing proportional bid-ask spread in the last 30 minutes of the trading day, at the 10% level of significance. Compared with before the introduction of the closing call auction, proportional bid-ask spread within the last 30 minutes of trading are, on average, 0.001% lower. Spread is inversely related to market capitalization and positively related to price volatility and trade turnover. The dummy interaction variables reveal that spread reduction is especially large in the last five minutes of the market. The marginal decline is 0.0063% and 0.0034% for the last 5 minutes and last 10 minutes, respectively.

The univariate and multivariate results combined reveal that closing call auction tangibly narrowed the closing bid-ask spreads, and reduced the overall immediacy cost of trading on the Shenzhen stock market. The hypothesis that closing call auction will result in more aggressive quote setting and narrower bid-ask spreads as the market approaches closure is supported.

4.6.2 Effect on volatility

4.6.2.1 Intraday univariate analysis

Panel E in table 4.1 and 4.2 presents the univariate minute by minute volatility patterns for the last half an hour of the trading day, over the 5 week pre and post-event periods.

The data shows that stock prices become increasingly volatile as the market approaches the end of its continuous trading. But with the availability of a closing call auction, the

peak of price volatility (0.04%), which occurs just before the close of continuous trading, is nearly half of the peak volatility during the pre-event period (0.07%). During the other one-minute time intervals, volatility in the post-event period is generally lower, and generally by a statistically significant amount. This observed pattern is consistent across all five quintile stock groups.

The only two intervals where the post-event volatility is noticeably higher than the pre-event period volatility is during the two minutes just before the post-event continuous market closes (14:55-14:56, 14:56-14:57). But that is due to imminent continuous market closure. The equivalent two minutes (14:58-14:59, 14:59-15:00) in the pre-event period generated significantly higher price volatility, averaging 0.05% and 0.07% respectively.

4.6.2.2 Multivariate analysis

[insert Table 4.3 here]

Table 4.3 reports the results of the multivariate analysis based on one-minute volatility estimates during the final 30 minutes of the trading day.

The parameter estimate for the *change* variable in equation (2) shows that, compared to prior to the introduction of the closing call auction, average one-minute interval volatilities fell by 0.005% in the 30 minutes lead up to the close. The final five minutes has an additional 0.021% less volatility, compared to the same time period, prior to 01 July 2006.

The multivariate regression also confirms that the closing 5 minutes have significantly higher volatility, compared to the rest of the trading day, and is consistent with the intraday pattern observed in table 4.1 and 4.2, Panel D. In Shenzhen, volatility increases with the spread, market cap size, the daily return volatility and average turnover.

In summary, these results support my initial hypothesis that closing call auctions will dampen the volatility accentuations that typically characterize order-book market closings. The effect is strongest during the minutes just prior to the close.

4.6.3 Effect on trading activity

Panels F-H in Table 4.1 and 4.2 present the univariate intraday patterns for proportional number of trades, proportional average trade size, and proportional turnover.

Panel F Table 4.1 shows that as the market approaches the end of its trading day, the proportional number of trade that gets transacted in each time interval increases. During the last 30 minutes of the trading day, this proportional value nearly doubles, from 0.48% during 14:30-1:431 interval to 0.83% in 14:59-15:00 in the pre-event study period. The less actively a stock is traded, the bigger proportion of its daily trades is transacted near the end of the trading day. This is to be expected, as traders in illiquid stocks will want to concentrate their trading during the parts of the day when liquidity is highest.

Similar to the proportional number of trades, the proportional size of the trades and the proportional turnover in each time interval also increase as the market approaches 15:00. At the end of continuous trading in the pre and post-event period, the average trade size is about 132% and 124%, respectively, of its daily average trade size. Proportional turnover in the last minute before the end of continuous trading is about double the turnover 30 minutes before at 15:30-15:31.

The effect of the introduction of the closing call auction is that about 1.4% of daily turnover migrated to the closing call. The daily percentage turnover slightly increases as stock liquidity decreases. This turnover is low but similar to other Asia-Pacific markets, which tend to have lower trading volumes in the closing call auctions than in other markets. (Pinfold and He, 2012)

In addition, there is a significant rise in the average proportional number of trades, average proportional trade size and average proportional turnover in the last 30 minutes, in the post-event study period. This evinces an increased aggressiveness in trading activity in the market just before the end of continuous trading by traders that want to avoid the call auction.

Therefore, the introduction of the closing call auction did not cause a substantial migration of trading activity away from the continuous market, and in fact made trading the continuous market just before the close even more intense. The lack of information transparency made the call auction too risky for the majority of traders, preferring to close their daily trading in the continuous auction market instead.

4.6.4 Price Efficiency

4.6.4.1 First pass results

[insert Table 4.4 here]

Table 4.4 reports the synchronicity of the price discovery, as judged by the adjusted R-square estimates of equation 3. The table reports the average adjusted R-squares for the full sample and then five quintile groups using the 12 time intervals, 240 trading days before and after the event. As commensurate with the literature[41], the magnitude of the average R-squares are higher in the actively traded stock groups and as the return horizon increases.

Overall, the results show that following the introduction of a closing call auction, the average adjusted R-squares increased for the actively traded stocks (Quintiles 1-3) but declined for the inactive stock groups (quintiles 4 and 5). The diminished levels of

[41] For example, Battig and Chelley-Steeley (2009). Also, Pinfold and He (2012) points out that illiquid stocks have stale prices, and this reduces the value of its R-squares. Nevertheless, improvements in R-squares represent improvements in pricing efficiencies for all stocks.

synchronicity for the inactively traded stocks suggest lower market quality and is consistent with the theory presented in chapter 2 that in a market with high adverse selection risk and information asymmetry, a fully opaque call auction can discourage participation and therefore meaningful price discovery.

4.6.4.2 Second-pass regression

The result of the second-pass regression is presented in Table 4.5. The asymptotic levels of R-square (β_{i0} and ($\beta_{i0} + \beta_{i3}$) for the pre and post-event period, respectively) are reported as R2CONSTANT. R2SLOPE is the second-pass slope parameter estimated as β_{i1} and (β_{i1}+β_{i2}) for the pre and post-event period, respectively.

[insert Table 4.5 here]

The second-pass regression results confirm the findings from the first-pass regression that the price quality of illiquid stocks declined, but the price quality of active liquid stocks improved in the post-event period. The magnitude of the post-call R2CONSTANT parameter rose at a statistically significant level for quintiles 1-3 and fell for quintiles 4 and 5.

The R2SLOPE parameter is negative and significant for all quintiles. In the post-call period, this parameter became even more negative. This suggests a strengthening of the relationship between R-square and lag length in the post-call period. (Chelley-Steeley, 2009)

In table 4.6, I also present the results of the second-pass regression in a frequency table. For each quintile, the stocks are divided into three categories of pricing efficiency change as measured by the dummy coefficient β_{i3}: statistically significant and negative, not statistically significant, and statistically significant and positive. The level of significance used is 5%.

[insert Table 4.6 here]

Table 4.6 shows that more than half of the stocks in quintiles 1 and 2 shifted to a higher asymptotic R-square level after the closing call auction was introduced. For the two least liquid quintiles, there were more declines in asymptotic R-square values than increases. Overall, the majority change in the R2CONSTANT parameter was a positive increase in the post-event period.

4.6.4.3 RRD results

Table 4.7 shows the mean values of the RRD statistic for the full sample, and then five quintile groups. The average RRD across the full sample is 0.00277 (median=0.001124) in the pre-event period and 0.000724 (median=0.000659) in the post-event period. This decrease in mean RRD is significant at 5% level of significance.

In addition, the RRD measure fell across all quintiles after the introduction of the closing call auction. The magnitude of the change appears to be roughly related to stock liquidity. The mean drop is greatest for the most actively traded group, and then becomes generally smaller as stock illiquidity increases. This pattern of change suggests that the actively traded stocks experience a greater improvement in market quality than illiquid securities.

[insert Table 4.7 here]

4.7 Conclusion

The introduction of the closing call auction did not cause a substantial migration of order flow away from the continuous market. Rather than observing very little trading before the close, the introduction of the call auction made trading in the continuous market the immediately preceded the closing call even more attractive and active. The risk of execution uncertainty, made worse by the lack of information disclosure during the call, and a ‘black box’ trading system that advantages informed traders, made traders that do

not need to trade at the closing price even keener to complete their orders before the closing call.

Nevertheless, the call auction's competitiveness and role in reducing order imbalances, lowered spreads and stabilised prices in the period both in the period leading up to the close and at the close. The decrease in the spread is most significant in the minutes just before the onset of the closing call auction.

The closing call auction did not improve the efficiency of all stocks. The results in Shenzhen showed that the closing call generally improved the efficiency of actively traded stocks' closing prices, but was detrimental to the price quality of less actively traded ones. This finding is in contrast with Chelley-Steeley (2009), which drew the opposite conclusion that closing call auctions was beneficial to the quality of illiquid stocks but did not enhance the market quality of high-liquid ones, and Pinfold and He (2012), which found that even highly illiquid stocks in New Zealand benefited from a closing call auction. London and New Zealand, unlike Shenzhen, had its full order book disclosed during the call and allowed orders placed in the closing auction to be withdrawn before the auction closed. This type of call auction structure reduced adverse selection risk to the participants in the auction and encouraged price discovery. The quality of Shenzhen's closing call auction system may be improved by adopting similar rules.

In view of the fact that it narrowed spreads, reduced market volatility and improved price efficiency (for some stocks), the closing call auction was a positive addition to the Chinese trading environment. It is arguable that the results would be even more enhanced if the closing call auction disclosed some information, such as the indicative auction prices and indicative auction volumes during the call. Given that Shanghai has now the

fifth largest stock market in the world by market capitalisation[42], the Shanghai Stock Exchange[43] should consider adopting a closing call auction as well.

[42] Source: http://www.world-exchanges.org/statistics

[43] I repeated the methodology used in this chapter on A-shares traded on the Shanghai Stock Exchange over the same time period. My results are available upon request.

Chapter 5: Conclusion

This dissertation contains three essays that investigate the impact of a stock market call auction reform on market quality. Call auctions play an integral role in price-setting and have become the most popular means to open and close daily trading in equity markets around the world. The performance of a call auction is entirely dependent on its market design and exchange trading rules. Nevertheless, the information transparency of the call auction is a still-not-settled and under-developed research area. Furthermore, the academic literature has tended to focus on developed Western markets. Very few studies have been published about emerging markets such as China, which has unique market characteristics that give new insight into the behaviour of uninformed individuals in financial markets. The conclusions and intraday data presented in this dissertation allow regulators and Chinese market participants to make decisions on how to best make use of this alternative trading platform.

The first essay in this dissertation uses the natural experiment offered by the Shanghai Stock Exchange to examine the relationship between the transparency of the opening call auction and the liquidity of the continuous market. The dynamics of the opening process and its impact on trading activity for the rest of the day is of interest to traders because traders can either cluster their trades during the non-trading period or withhold their orders until the market opens.

The results indicate that the dissemination of indicative trade information during the opening call session led to an overall improvement in liquidity costs. Bid-ask spreads narrowed because adverse selection risk fell significantly and there is less price volatility in the continuous market. This effect is greater for actively traded securities than illiquid

securities. The results also reveal a temporary decrease in trading volume in the first hour. The essay concludes that in an emerging market, where the market is dominated by individual investors, although improved transparency may discourage trading from informed investors, small non-institutional investors do benefit from better market transparency.

The second essay builds upon the first essay by examining the impact the introduction of opening call auction transparency in Shanghai, and the resulting decline in trading activity, had on the price discovery process of the continuous market, particularly within the first hour after market opening. Market efficiency is assessed on both dimensions of price discovery and noise.

The results reveal some migration in price discovery from the call auction to the continuous trading period. As a result, overall price discovery in the first hour of continuous trading rose. The proportional increase in this price discovery was observed to be greater for inactively traded stocks, than for actively traded stocks. Additionally, the continuous market became less noisy, even after controlling for trading activity. The essay suggests that this is due to the cancellation or amendment of otherwise unexecuted call auction orders. It is only possible if traders are able to 'look in' at the price discovery taking effect during the opening call auction, even if it prompts many informed investors to wait until the continuous market before disseminating their private information by trade. The essay concludes that a more transparency opening call auction is good for the efficiency of the Chinese stock market.

The third essay examines the effect of the introduction of a new closing call auction in Shenzhen on the quality of the market and on the trading behaviour of the Chinese market participants. The study employs high-frequency data to examine the effects of the closing call auction on spreads, volatility, turnover, trade size, and price discovery in one-minute intervals.

The results indicate that the closing call auction did not cause a substantial migration of trading activity from the continuous market to the call. Instead, the closing call auction generated a new peak in trading activity just prior to the closure of the continuous market, as traders sought to avoid the informationally opaque closing call auction. Bid-ask spreads also narrowed just before the end of continuous trading. Likewise, the quoted and effective spreads generated at the end of the call auction were substantially lower than pre-reform, when the closing price was generated by continuous trading prices.

In terms of closing price discovery, the results show that the closing call generally improved the efficiency of actively traded stocks' closing prices, but was detrimental to the price quality of less actively traded ones. This finding is in contrast with Chelley-Steeley (2009) and Pinfold and He (2012). In those two studies, the stock markets had its full order book disclosed during the call and allowed orders that were placed in the closing auction to be withdrawn before the auction closed. This type of call auction structure reduced adverse selection risk to the market participants and encouraged price discovery. It is suggested that the quality of Shenzhen's closing call auction system may be improved by adopting similar rules. Furthermore, the regulators of Shanghai Stock Exchange may use this study to support proposals to introduce closing call auctions as well.

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Tables

Table 2.1 Univariate test for five weeks before and after July 1, 2006

Panel A Entire sample

	Pre	Post	Difference
Number of trades in the first hour			
Mean	245.25	210.1	-35.15
Mean difference t-test			-26.75*
Quoted Proportional Spread (%)			
Mean	0.3221	0.3162	-0.006
Mean difference t-test			-3.941*
Effective Spread			
Mean	0.0259	0.0216	-0.0044
Mean difference t-test			-18.91*
Proportional Effective Spread (%)			
Mean	0.403	0.3325	-0.071
Mean difference t-test			-37.94*
Depth			
Mean	66900	53805	-13095
Mean difference t-test			-10.06*
Dollar Depth (RMB)			
Mean	295017	230726	-64291
Mean difference t-test			-9.57*
Time between trades (seconds)			
Mean	17.95	22.17	4.22
Mean difference t-test			13.34*
Total trading volume			
Mean	1983815	1410092	-573724
Mean difference t-test			16.02*
Ratio of transacted volume from call auction to trade volume during first hour			
Mean	0.0226	0.0213	-0.0013
Mean difference t-test			-0.5362
Volatility (standard deviation)			
Mean	0.0544	0.0479	-0.0065
Mean difference t-test			-7.599 *

This table contains the descriptive statistics for the first hour of daily trade: the number of trades, proportional quoted spread (%), effective spread, proportional effective spread (%), depth (sum of best bid and ask volume), time between trades (seconds), volatility (standard deviation), trading volume and the ratio of transacted call volume to trade volume. For each variable, the mean and mean changes for the five weeks before and after the structural change on July 1, 2006 are reported. A *t*-test reports whether the change in mean values between the pre and post-event period is statistically significant. The sample consist of 780 stocks included in Shanghai's A-share index.
* denotes significance at the 1% level

Table 2.1 Univariate test for five weeks before and after July 2006
Panel B to Panel F Sorted into quintiles

Panel B - Quintile 1	Trade Volume 1			Trade Volume 2			Trade Volume 3			Total		
	Pre	Post	Change	Pre	Post	Change	Pre	Post	Change	Pre	Post	Change
Number of stocks	125	125		26	26		5	5		156	156	
Number of trades in the first hour												
Mean	399.50	361.42	-38.07	323.39	262.91	-60.48	239.45	216.71	-22.74	385.79	344.08	-41.71
Mean difference t-test			-6.42			-4.99			-4.18			-7.82
Quoted Proportional Spread (%)												
Mean	0.2294	0.2218	-0.0076	0.1958	0.1911	-0.0048	0.2560	0.2565	0.0005	0.2240	0.2169	0.0070
Mean difference t-test			-17.1507			-3.2080			0.0373			-15.7281
Effective spread												
Mean	0.0183	0.0160	-0.0023	0.0441	0.0393	-0.0048	0.0779	0.0696	-0.0084	0.0230	0.0202	-0.0027
Mean difference t-test			-17.48			-7.47			-1.81			-16.97
Proportional Effective Spread (%)												
Mean	0.2795	0.2524	-0.2318	0.2457	0.2231	-0.4839	0.2865	0.3104	-0.8378	0.2741	0.2477	-0.0260
Mean difference t-test			-19.51			-9.92			-1.45			-21.68
Depth												
Mean	161541	146932	-14609	15408	13304	-2104	8530	7275	-1255	136196	123773	-12423
Mean difference t-test			-14.40			-15.24			1.44			-14.78
Dollar Depth (RMB)												
Mean	631729	576808	-54921	246762	218326	-28437	164366	231162	66796	564572	514845	-49727
Mean difference t-test			-17.44			-11.81			2.83			-18.82
Time between trades (seconds)												
Mean	9.34	10.43	1.08	11.49	14.29	2.81	14.96	16.52	1.55	9.74	11.11	1.37
Mean difference t-test			5.98			5.21			4.19			7.57
Ratio of transacted volume from call auction to trade volume during the first hour												
Mean	0.0125	0.0159	0.0034	0.0105	0.0124	0.0019	0.0079	0.0276	0.0197	0.0121	0.0153	0.0032
Mean difference t-test			4.07			1.05			1.98			4.28
Volatility												
Mean	0.0560	0.0486	-0.0074	0.1601	0.1287	-0.0314	0.2455	0.2126	-0.0329	0.0746	0.0630	-0.0115
Mean difference t-test			-3.70			-2.48			-2.01			-4.20

Panel C - Quintile 2

	Pre	Post	Change	Pre	Post	Change	Pre	Post	Change	Pre	Post	Change
Number of stocks	81	81		53	53		22	22		156	156	
Number of trades in the first hour												
Mean	317.90	266.03	-51.86	258.43	244.49	-13.93	198.69	153.81	-44.87	280.88	242.89	-37.99
Mean difference t-test			-6.49			-1.76			-4.16			-7.12
Quoted Proportional Spread (%)												
Mean	0.2780	0.2757	-0.0023	0.2271	0.2215	-0.0056	0.3111	0.3209	0.0098	0.2654	0.2636	-0.0020
Mean difference t-test			-3.62			-4.62			2.59			-21.31
Effective spread												
Mean	0.0160	0.0133	-0.0027	0.0326	0.0210	-0.0116	0.0921	0.0704	-0.0217	0.0324	0.0240	-0.0084
Mean difference t-test			-13.99			-7.20			-5.11			-10.24
Proportional Effective Spread (%)												
Mean	0.3527	0.3014	-0.0513	0.4364	0.2554	-0.1811	0.4093	0.3278	-0.0815	0.3891	0.2895	-0.1000
Mean difference t-test			-12.34			-7.84			-5.83			-11.87
Depth												
Mean	70765	70545	-220	22053	21542	-511	11201	9920	-1281	45815	45346	-468
Mean difference t-test			-0.46			-3.57			-5.98			-1.85
Dollar Depth (RMB)												
Mean	281633	271099	-10534	165370	163940	-1430	185690	179136	-6554	228117	222209	-5907
Mean difference t-test			-6.31			1.28			-1.42			-5.14
Time between trades (seconds)												
Mean	11.59	13.95	2.36	14.51	15.10	0.59	19.40	25.77	6.37	13.68	16.01	2.32
Mean difference t-test			6.46			0.96			4.35			6.19
Ratio of transacted volume from call auction to trade volume during the first hour												
Mean	0.0193	0.0201	0.0008	0.0150	0.0120	-0.0029	0.0161	0.0203	0.0043	0.0170	0.0172	0.0002
Mean difference t-test			0.30			-1.23			0.60			0.09
Volatility												
Mean	0.0363	0.0310	-0.0053	0.0603	0.0608	0.0005	0.1812	0.1498	-0.0314	0.0649	0.0579	-0.0070
Mean difference t-test			-4.90			0.14			-2.81			13.27

Panel D - Quintile 3

	Pre	Post	Change	Pre	Post	Change	Pre	Post	Change	Pre	Post	Change
Number of stocks	47	47		82	82		22	27		156	156	
Number of trades in the first hour												

Mean	283.21	226.83	-56.38	229.14	203.94	-25.21	192.17	147.25	-44.91	239.03	201.02	-38.01
Mean difference t-test			-4.89			-3.71			-4.33			-7.06
Quoted Proportional Spread (%)												
Mean	0.3548	0.3605	0.0057	0.2831	0.2727	-0.0105	0.2812	0.3203	0.0391	0.3044	0.3074	-0.0030
Mean difference t-test			4.67			-8.47			11.18			3.06
Effective spread												
Mean	0.0178	0.0124	-0.0055	0.0186	0.0157	-0.0028	0.0426	0.0407	-0.0019	0.0222	0.0194	-0.0028
Mean difference t-test			-13.67			-16.71			3.54			-15.80
Proportional Effective Spread (%)												
Mean	0.5124	0.3804	-0.1321	0.3490	0.2985	-0.0504	0.3214	0.3164	-0.0051	0.3934	0.3262	-0.0670
Mean difference t-test			-13.49			-18.04			-1.68			-19.93
Depth												
Mean	79750	86012	6262	32062	34005	1942	12042	10990	-1052	45690	42964	-2725
Mean difference t-test			5.97			8.01			-6.41			7.95
Dollar Depth (RMB)												
Mean	253595	261090	7494	157843	169811	11968	136219	120866	-15354	182948	188840	5891
Mean difference t-test			2.45			9.84			-8.79			5.05
Time between trades (seconds)												
Mean	13.19	16.45	3.25	16.25	18.20	1.95	19.70	28.30	8.60	15.93	19.42	3.49
Mean difference t-test			4.62			3.47			3.65			6.08
Ratio of transacted volume from call auction to trade volume during the first hour												
Mean	0.0279	0.0303	0.0024	0.0221	0.0180	-0.0041	0.0163	0.0151	-0.0012	0.0165	0.0163	-0.0002
Mean difference t-test			0.22			-0.80			-0.34			-0.16
Volatility												
Mean	0.0363	0.0310	-0.0053	0.0608	0.0603	-0.0005	0.1812	0.1498	-0.0314	0.0473	0.0407	-0.0066
Mean difference t-test			-3.97			-1.67			-3.67			-4.87

<u>*Panel E - Quintile 4*</u>

	Pre	Post	Change	Pre	Post	Change	Pre	Post	Change	Pre	Post	Change
Number of stocks	7	7		71	71		78	78		156	156	
Number of trades in the first hour												
Mean	226.60	209.25	-17.35	207.98	178.39	-29.59	164.42	139.24	-25.18	186.16	158.96	-27.20
Mean difference t-test			-5.29			-4.18			-4.66			-6.16
Quoted Proportional Spread (%)												
Mean	0.4849	0.3755	-0.1094	0.3448	0.3440	-0.0008	0.3353	0.4217	0.0864	0.3838	0.3418	-0.0420

Mean difference t-test			-12.25			-0.81			6.22			-5.94
Effective spread												
Mean	0.0410	0.0111	-0.0298	0.0160	0.0140	-0.0020	0.0401	0.0307	-0.0094	0.0285	0.0224	-0.0061
Mean difference t-test			-12.57			-12.10			-6.42			-8.14
Proportional Effective Spread (%)												
Mean	0.4067	0.3043	-0.1024	0.4215	0.3717	-0.0497	0.4758	0.3453	-0.1306	0.4610	0.3599	-0.1010
Mean difference t-test			-11.68			-12.83			-7.92			-11.66
Depth												
Mean	67042	111639	44597	40742	39040	-1702	113708	15960	-97748	78030	28282	-49747
Mean difference t-test			7.92			-6.79			-7.74			?
Dollar Depth (RMB)												
Mean	225610	232248	6638	146796	141843	-4954	620071	114253	-505818	387478	129030	-258448
Mean difference t-test			0.58			-5.57			-7.70			-7.75
Time between trades (seconds)												
Mean	16.83	17.14	0.31	17.86	21.02	3.16	23.39	29.03	5.64	20.65	25.03	4.38
Mean difference t-test			7.75			4.33			4.71			6.18
Ratio of transacted volume from call auction to trade volume during the first hour												
Mean	0.0219	0.0542	0.0324	0.0399	0.0314	-0.0085	0.0373	0.0342	-0.0032	0.0216	0.0208	-0.0007
Mean difference t-test			0.95			0.72			-1.36			-0.34
Volatility												
Mean	0.0231	0.0205	-0.0025	0.0301	0.0283	-0.0018	0.0611	0.0569	-0.0042	0.0457	0.0427	-0.0030
Mean difference t-test			-0.81			-1.67			-1.64			-1.91

<u>*Panel F - Quintile 5*</u>

	Pre	Post	Change	Pre	Post	Change	Pre	Post	Change	Pre	Post	Change
Number of stocks	3	3		23	23		130	130		156	156	
Number of trades in the first hour												
Mean	178.48	142.63	-35.84	167.99	118.16	-49.83	127.92	100.60	-27.33	134.41	103.57	-30.84
Mean difference t-test			-10.39			-6.45			-7.42			-9.16
Quoted Proportional Spread (%)												
Mean	0.6534	0.5874	-0.0660	0.4650	0.4725	0.0075	0.4255	0.4467	0.0213	0.4443	0.4530	0.0087
Mean difference t-test			-9.30			3.19			10.26			5.26
Effective spread												
Mean	0.0195	0.0105	-0.0090	0.0175	0.0130	-0.0045	0.0250	0.0237	-0.0013	0.0238	0.0220	-0.0018
Mean difference t-test			-8.25			-12.08			-6.19			-9.91

Proportional Effective Spread (%)												
Mean	0.4687	0.4308	-0.0381	0.6258	0.4780	-0.1475	0.6749	0.5450	-0.1299	0.4972	0.4387	-0.0590
Mean difference t-test			-11.30			-14.60			-24.83			-17.70
Depth												
Mean	159590	89239	-70351	72206	57971	-14235	23061	19581	-3480	35751	30329	-5422
Mean difference t-test			-11.84			-10.80			-15.44			-19.33
Dollar Depth (RMB)												
Mean	262175	172422	-89752	182548	152289	-30260	97895	88328	-9567	111971	98707	-13264
Mean difference t-test			-8.40			-8.97			-12.71			-16.04
Time between trades (seconds)												
Mean	20.00	24.97	4.96	22.33	31.23	8.90	31.21	40.90	9.69	29.78	39.31	9.54
Mean difference t-test			7.21			6.37			7.41			8.54
Ratio of transacted volume from call auction to trade volume during the first hour												
Mean	0.0219	0.0542	0.0324	0.0399	0.0314	-0.0085	0.0373	0.0342	-0.0032	0.0349	0.0355	0.0005
Mean difference t-test			1.62			-1.29			-0.25			0.10
Volatility												
Mean	0.0218	0.0133	-0.0085	0.0229	0.0200	-0.0029	0.0430	0.0383	-0.0047	0.0397	0.0354	-0.0043
Mean difference t-test			-6.37			-2.50			-3.24			-3.52

This table contains the descriptive statistics for the first hour of daily trade: the number of trades, proportional quoted spread (%), effective spread, proportional effective spread (%), depth (sum of best bid and ask volume), time between trades (seconds), volatility (standard deviation), and the ratio of transacted call volume to trade volume. For each variable, the mean and mean changes for the five weeks before and after the structural change on July 1, 2006 are reported. A *t*-test reports whether the change in mean values between the pre and post-event period is statistically significant. Actively traded A-shares are sorted into quintiles according to their average daily turnover during the study period. Within each quintile, they are further sorted according to their average trade volume. Quintile 1 represents the most liquid stocks, and quintile 5 contains the most illiquid. Similarly, trade volume 1 contains the largest trade volume stocks, and trade volume 3 the least.

Table 2.2 Simultaneous two-equation regression analysis

Panel A Summary statistics of regression variables

Variable	Mean	Median	Std Dev	Minimum	Maximum
peffspread (%)	0.39	0.29	1.39	0.00	118.89
depth	52553.02	19947.67	283912.95	110.00	15079976.22
volume	5443.49	3748.15	7728.42	1.00	584915.97
market capitalisation (Million RMB)	787.15	303.18	3680.92	50.50	86701.99
volatility (%)	4.42	2.63	6.22	0.00	216.12

Panel B Autocorrelation coefficients of variables

	1	2	3	4	5
peffspread	0.532	0.476	0.426	0.377	0.128
depth	0.288	0.221	0.190	0.170	0.156
Volume	0.318	0.280	0.261	0.149	0.135
market capitalisation	1.000	1.000	1.000	1.000	1.000
Volatility	0.231	0.216	0.170	0.104	0.038

1-first-order autocorrelation;
2-second-order autocorrelation;
3-third-order autocorrelation;
4-fourth-order autocorrelation;
5-fivth-order autocorrelation

Panel C Regression results for spread and depth in a simultaneous two-equation system

Dependent variable: peffspread		
Explanatory Variable	*Estimate*	*t-statistic*
Intercept	-0.0251	-5.71*
ln(Depth)	-0.0008	-2.96*
ln(Volume)	0.0007	2.95*
Market Capitalisation	-0.0010	-4.42*
volatility	0.0008	8.88*
Change	-0.0010	-3.99*
09:30 to 09:35	-0.0017	-14.48*
09:35 to 09:40	-0.0023	-15.29*
09:40 to 09:45	-0.0027	16.31*
09:45 to 09:50	-0.0029	-13.35*
09:50 to 09:55	-0.0031	13.05*
10:00 to 10:05	-0.0032	-13.45*
10:05 to 10:10	-0.0033	-13.49*
10:10 to 10:15	-0.0035	-11.27*
10:15 to 10:20	-0.0035	-12.34*
10:20 to 10:25	-0.0035	-12.29*
10:25 to 10:30	-0.0035	-11.56*
Adjusted R^2	0.0138	
Dependent variable: *ln*(depth$_{it}$)		
Explanatory Variable	*Estimate*	*t-statistic*
Intercept	-4.4987	-7.30*
Proportional Effective Spread	-2.8129	-5.05*
Market Capitalisation	0.4424	14.01*
volatility	-0.9877	-8.86*
Change	-0.0098	-10.50*
09:30 to 09:35	-2374	-17.89*
09:35 to 09:40	-0.3527	-12.18*
09:40 to 09:45	-0.4389	-14.64*
09:45 to 09:50	-0.4934	-16.03*
09:50 to 09:55	-0.5430	-16.93*
10:00 to 10:05	0.5858	18.03*
10:05 to 10:10	0.6176	18.39*
10:10 to 10:15	0.6441	18.78*
10:15 to 10:20	0.6600	17.61*
10:20 to 10:25	0.6733	18.01*
10:25 to 10:30	0.6700	1069*
Adjusted R^2	0.8283	

* denotes significance at the 1% level

This table presents the results of regression for spread and depth in a simultaneous two-equation system for 806 A-share stocks. The system consist of the following two equations:

$peffspread_{it} = \beta_0 + \beta_1 * \ln(depth_{it}) + \beta_2 * ln(volume_{it}) + \beta_3 *$ market capitalization$_i$ + $\beta_4 *$ volatility$_{it}$ + $\beta_5 *$ change$_{it}$ + $\sum_{n=1}^{11} \beta_n$ * time interval dummies + ε_{it}

$ln(depth_{it}) = \gamma_0 + \gamma_1 * peffspread_{it} + \gamma_2 *$ market capitalization$_i$ + γ_3 *volatility$_{it}$ *+ $\gamma_4 *$ change$_{it}$ + $\sum_{n=1}^{11} \gamma_n$ time interval dummies + ε_{it}

The sample period is from May 29, 2006 to Aug 7, 2006. *Depth* is the sum of order book volume at the best bid and ask prices. *peffspread* is the effective spread divided by transaction price. *Market capitalization* is equity market capitalization based on closing prices on June 30, 2006. *Volatility* is a Parkinson's volatility measure. *Change* is a dummy variable that is assigned a value of one if the observation is after July 1, 2006. The remaining variables are dummy five-minute time interval variables to control for the time-varying behaviour of proportional effective spread and depth.

Table 2.3 Components of the effective spread

	Estimated Adverse selection component of spread			Estimated Order Processing Component of spread		
	Before	After	Change	Before	After	Change
Full Sample (806 stocks)						
Mean	0.7294	0.4180	-0.3114	0.1101	0.4819	0.3718
Median	0.8037	0.4331	-0.3745	0.0781	0.4862	0.3888
Mean difference t-test			-33.10*			88.16*
Quintile 1 (162 stocks)						
Mean	0.7663	0.3812	-0.3850	0.09406	0.5350	0.4409
Median	0.8377	0.4160	-0.4432	0.06664	0.5296	0.4569
Mean difference t-test			-18.35*			57.28 *
Quintile 2 (161 stocks)						
Mean	0.7496	0.4170	-0.3326	0.10899	0.49596	0.38697
Median	0.8327	0.4308	-0.3947	0.08861	0.50004	0.40517
Mean difference t-test			-15.43 *			49.15*
Quintile 3 (161 stocks)						
Mean	0.7506	0.4132	-0.3373	0.1101	0.4871	0.3770
Median	0.8284	0.4207	-0.4042	0.0771	0.4944	0.3963
Mean difference t-test			-16.86*			41.65*
Quintile 4 (160 stocks)						
Mean	0.7191	0.4325	-0.2866	0.1073	0.4586	0.3512
Median	0.8020	0.4348	-0.3557	0.0667	0.4611	0.3659
Mean difference t-test			-13.65*			36.96*
Quintile 5 (162 stocks)						
Mean	0.6619	0.4459	-0.2160	0.1297	0.4330	0.3032
Median	0.7054	0.4447	-0.2489	0.0904	0.4321	0.3238
Mean difference t-test			-11.13*			32.03*

We use the regression models from Lin Sanger Booth (1994) to estimate the components of effective bid-ask spread in the first hour of daily trading for each of the 806 sample stocks:

$$\Delta Q_{t+1} = \lambda z_t + e_{t+1}$$

$$\Delta P_{+1} = - \gamma z_t + \mu_{t+1}$$

where $\Delta Q_{t+1} = Q_{t+1} - Q_t$; Q_t is the logarithm of the quoted bid-ask midpoint at time t; $z_t = P_t - Q_t$; Pt is the logarithm of trade price at time t; λ is the adverse selection component of effective spread and γ is the order processing cost component. The before period extends from May 29 to June 30, 2006, and the after period covers July 1 to August 7, 2006.

* denotes significance at the 1% level

Table 2.4 Five-minute interval intraday data five days before and five days after the regime change

	Proportional Spread (%)		Depth		Parkinson's Volatility (%)		Volume		Proportional Volume (%)	
Time	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post
Panel A: Morning Session										
9:30	0.3823	0.3692	22427	24363	0.0068	0.0066	9422	9633	0.1298	0.1254
9:35	0.2964	0.3017	32677	29232	0.0031	0.0041	7771	7720	0.1086	0.1029
9:40	0.2691	0.2700	37796	32614	0.0026	0.0027	7142	7484	0.1080	0.1028
9:45	0.2564	0.2535	42781	37788	0.0024	0.0020	7612	7572	0.1154	0.1044
9:50	0.2502	0.2455	48499	41892	0.0020	0.0019	7764	7716	0.1191	0.1056
9:55	0.2447	0.2377	50567	45066	0.0017	0.0018	7483	7630	0.1144	0.1062
10:00	0.2444	0.2370	51468	44495	0.0017	0.0017	7374	7261	0.1199	0.1042
10:05	0.2417	0.2352	52224	45945	0.0015	0.0015	7115	7072	0.1165	0.1011
10:10	0.2383	0.2332	53035	49836	0.0016	0.0014	7446	7242	0.1197	0.1034
10:15	0.2413	0.2307	50907	54472	0.0018	0.0012	8403	6892	0.1305	0.1016
10:20	0.2378	0.2291	51774	61140	0.0016	0.0011	7136	7650	0.1168	0.1126
10:25	0.2367	0.2297	55970	63328	0.0012	0.0012	6947	6950	0.1149	0.1036
10:30	0.2375	0.2271	57292	62689	0.0013	0.0013	7001	7851	0.1130	0.1118
10:35	0.2372	0.2281	60510	64378	0.0011	0.0012	6601	7556	0.1087	0.1085
10:40	0.2368	0.2279	61801	68770	0.0010	0.0010	6676	7137	0.1119	0.1044
10:45	0.2370	0.2262	62934	75392	0.0011	0.0011	6480	7104	0.1094	0.1056
10:50	0.2380	0.2257	61209	73657	0.0011	0.0011	6341	7276	0.1084	0.1064
10:55	0.2364	0.2292	61943	68729	0.0012	0.0011	6485	6967	0.1080	0.1066
11:00	0.2366	0.2265	65854	72777	0.0010	0.0011	6556	7142	0.1027	0.1080
11:05	0.2338	0.2271	67057	74482	0.0009	0.0011	6515	7156	0.1062	0.1071
11:10	0.2357	0.2277	68872	75037	0.0010	0.0010	6573	7430	0.1102	0.1074
11:15	0.2363	0.2267	71754	73197	0.0011	0.0011	7161	7745	0.1156	0.1081
11:20	0.2379	0.2293	68659	71919	0.0009	0.0009	6725	7412	0.1098	0.1038
11:25	0.2357	0.2301	69504	69312	0.0008	0.0009	6415	6942	0.1046	0.1024

Table 2.4, continued

	Proportional Spread (%)		Depth		Parkinson's Volatility (%)		Volume		Proportional Volume (%)	
Time	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post
Panel B: Afternoon Session										
13:00	0.2379	0.2331	65866	65716	0.0011	0.0012	10588	10115	0.1589	0.1505
13:05	0.2317	0.2253	64321	66083	0.0008	0.0009	6891	6709	0.1062	0.0992
13:10	0.2310	0.2251	66850	68934	0.0009	0.0009	6918	6777	0.1114	0.1005
13:15	0.2313	0.2237	67244	68761	0.0009	0.0008	7176	6858	0.1106	0.1012
13:20	0.2299	0.2219	68120	69080	0.0009	0.0009	7129	7171	0.1088	0.1038
13:25	0.2298	0.2232	72531	69155	0.0009	0.0008	6770	7586	0.1112	0.1103
13:30	0.2303	0.2228	72935	71291	0.0008	0.0009	6608	6703	0.1063	0.1021
13:35	0.2307	0.2212	70773	76692	0.0009	0.0009	6312	6671	0.1066	0.1042
13:40	0.2290	0.2219	71077	73695	0.0010	0.0013	6592	8097	0.1116	0.1180
13:45	0.2291	0.2243	74400	70062	0.0008	0.0012	6459	7949	0.1068	0.1186
13:50	0.2292	0.2228	74576	66540	0.0009	0.0013	6802	7683	0.1095	0.1178
13:55	0.2278	0.2252	77623	69590	0.0008	0.0011	7054	7071	0.1104	0.1092
14:00	0.2274	0.2234	80299	70901	0.0008	0.0009	6848	6995	0.1103	0.1079
14:05	0.2284	0.2223	74161	69867	0.0010	0.0009	7186	7255	0.1149	0.1102
14:10	0.2284	0.2229	69752	71343	0.0009	0.0010	6833	7238	0.1152	0.1140
14:15	0.2299	0.2209	74568	72566	0.0009	0.0010	6633	7474	0.1164	0.1197
14:20	0.2289	0.2217	79402	74558	0.0009	0.0009	6703	7534	0.1147	0.1129
14:25	0.2288	0.2211	82969	73486	0.0010	0.0010	6777	7369	0.1152	0.1132
14:30	0.2277	0.2205	82244	71802	0.0009	0.0009	7122	7226	0.1181	0.1108
14:35	0.2275	0.2178	81938	75351	0.0009	0.0011	7068	7507	0.1203	0.1169
14:40	0.2271	0.2195	82901	79824	0.0009	0.0010	7264	7775	0.1251	0.1193
14:45	0.2260	0.2171	80862	77186	0.0010	0.0009	7610	8112	0.1301	0.1274
14:50	0.2256	0.2176	75072	74265	0.0010	0.0011	8404	8107	0.1413	0.1312
14:55	0.2270	0.2210	64958	69775	0.0015	0.0014	9367	8933	0.1607	0.1439

This table reports the mean values for proportional spread, depth, volatility, volume and proportional volume in each five-minute time interval, five trading days before and then five trading days after the regime change. The sample size is 188 shares. It excludes A-shares that experienced share splits during 2006, stocks that didn't trade during the ten day period, and stocks that resumed trading at 10.30am.

Table 2.5 Univariate test for shorter or longer time period before and after July 1, 2006

Panel A Ten weeks before and after July 1, 2006

	Pre	Post	Difference
Number of trades in the first hour			
Mean	260.25	185.26	-74.99
Mean difference t-test			-31.88 *
Quoted Proportional Spread (%)			
Mean	0.325	0.311	-0.014
Mean difference t-test			-8.271*
Effective Spread			
Mean	0.0272	0.0211	-0.0061
Mean difference t-test			-28.64 *
Proportional Effective Spread (%)			
Mean	0.414	0.328	-0.086
Mean difference t-test			-38.34*
Depth			
Mean	71238	61783	-9155
Mean difference t-test			-6.77*
Dollar Depth (RMB)			
Mean	325689	268955	-56734
Mean difference t-test			-5.48*
Time between trades (seconds)			
Mean	18.82	21.38	2.56
Mean difference t-test			7.64*
Total trading volume			
Mean	1913872	1586585	-327287
Mean difference t-test			9.36*
Ratio of transacted volume from call auction to trade volume during first hour			
Mean	0.0229	0.0210	-0.0019
Mean difference t-test			-1.359
Volatility (standard deviation)			
Mean	0.0589	0.0482	-0.107
Mean difference t-test			-8.729 *

Panel B Two weeks before and after 1 July 2006

	Pre	Post	Difference
Number of trades in the first hour			
Mean	243.7	209.2	-34.5
Mean difference t-test			24.19*
Quoted Proportional Spread (%)			
Mean	0.321	0.315	-0.006
Mean difference t-test			7.46*
Effective Spread			
Mean	0.023	0.021	-0.002
Mean difference t-test			-6.89 *
Proportional Effective Spread (%)			
Mean	0.396	0.313	-0.083
Mean difference t-test			-14.07 *
Depth			
Mean	70992	61936	-9056
Mean difference t-test			-5.89*
Dollar Depth (RMB)			
Mean	306784	270416	-36368
Mean difference t-test			-5.68*
Time between trades (seconds)			
Mean	16.38	21.56	5.18
Mean difference t-test			15.29*
Total trading volume			
Mean	1962352	1506935	-455417
Mean difference t-test			14.86*
Ratio of transacted volume from call auction to trade volume during first hour			
Mean	0.0205	0.0182	-0.0023
Mean difference t-test			-1.085
Volatility (standard deviation)			
Mean	0.052	0.046	-0.006
Mean difference t-test			-4.06*

Table 2.6 Market transparency reform and liquidity in A-shares that had (and had not) reformed the split share structure

Panel A Sample of A-shares that had reformed the split share structure

	Pre	Post	Difference
Number of trades in the first hour			
Mean	280.32	225.52	-54.8
Mean difference t-test			-34.26*
Quoted Proportional Spread (%)			
Mean	0.3175	0.3102	-0.0073
Mean difference t-test			-10.25*
Effective Spread			
Mean	0.0251	0.0204	-0.0047
Mean difference t-test			-22.35*
Proportional Effective Spread (%)			
Mean	0.404	0.323	-0.081
Mean difference t-test			-41.32*
Depth			
Mean	66348	51632	-14716
Mean difference t-test			-11.86*
Dollar Depth (RMB)			
Mean	286538	213684	-127146
Mean difference t-test			-9.48*
Time between trades (seconds)			
Mean	16.38	21.02	4.64
Mean difference t-test			15.19*
Total trading volume			
Mean	2234568	1823698	-410870
Mean difference t-test			10.96*
Ratio of transacted volume from call auction to trade volume during first hour			
Mean	0.0232	0.0217	-0.0015
Mean difference t-test			-0.875
Volatility (standard deviation)			
Mean	0.0532	0.0461	-0.0071
Mean difference t-test			-6.387 *

Panel B Sample of A-shares that had not reformed the share split structure

	Pre	**Post**	**Difference**
Number of trades in the first hour			
Mean	238.18	206.35	-31.83
Mean difference t-test			-19.68*
Quoted Proportional Spread (%)			
Mean	0.3254	0.3209	-0.0045
Mean difference t-test			-4.923*
Effective Spread			
Mean	0.0263	0.0224	-0.0039
Mean difference t-test			-15.96*
Proportional Effective Spread (%)			
Mean	0.401	0.337	-0.064
Mean difference t-test			-31.67*
Depth			
Mean	67236	57889	-9347
Mean difference t-test			-7.65*
Dollar Depth (RMB)			
Mean	299871	244268	-55603
Mean difference t-test			-5.39*
Time between trades (seconds)			
Mean	18.68	22.81	4.13
Mean difference t-test			11.48*
Total trading volume			
Mean	1923658	1330976	-592682
Mean difference t-test			15.38*
Ratio of transacted volume from call auction to trade volume during first hour			
Mean	0.0223	0.0212	-0.0011
Mean difference t-test			-0.3689
Volatility (standard deviation)			
Mean	0.0574	0.0513	-0.0061
Mean difference t-test			-7.599 *

Table 3.1 Weighted Price Contribution by time period and trading volume quintile

Quintile	1500 – 0925			9.25-9.30			09.30-10.30			1030-1500		
	Pre	Post	Change	Pre	Post	Change	Pre	Post	Change	Pre	Post	Change
Highest	0.1944	0.1066	-0.0878	0.0272	0.0174	-0.0098	0.2944	0.3350	0.0405	0.4838	0.5409	0.0570
Mean difference t-test			-0.0878			-1.8742***			2.2739**			
2	0.2111	0.1024	-0.1087	0.0229	0.0216	-0.0013	0.2744	0.3163	0.0418	0.4915	0.5595	0.0680
Mean difference t-test			-5.4688*			-0.2598***			2.7557*			
3	0.2252	0.1268	-0.0985	0.0300	0.0124	-0.0176	0.2527	0.2970	0.0442	0.4919	0.5638	0.0718
Mean difference t-test			-3.2711*			-2.4552**			2.2203**			
4	0.1790	0.1325	-0.0465	0.0255	0.0080	-0.0175	0.2309	0.2983	0.0673	0.5644	0.5610	-0.0034
Mean difference t-test			-2.2161**			-2.8045*			4.2136*			
Lowest	0.2031	0.0864	-0.1167	0.0186	0.0161	-0.0026	0.2169	0.3055	0.0885	0.5612	0.5919	0.0307
Mean difference t-test			-5.4558*			-0.3714			5.6123*			
Overall	0.2026	0.1109	-0.0916	0.0249	0.0151	-0.0098	0.2539	0.3104	0.0565	0.5186	0.5634	0.0448
Mean difference t-test			-8.842*			-3.5369*			7.4099*			8.6589*

*, ** and *** denote significance level at 1%, 5% and 10% respectively.

This table reports the mean weighted price contribution (WPC) for 780 stocks that comprise Shanghai's A-share index between 29 May 2006 and 04 Aug 2006, sorted into quintiles based on their average trade volume during the study period. Quintile 1 represents the most liquid stocks, and quintile 5 contains the most illiquid. The daily close to close return is divided into four time periods: the opening call auction (previous close to opening call), the opening trade (the opening call auction just after 0925am to the first continuous trade after 0930am), first 60minutes of the trading day, and the remainder of the trading day.

For each time period *t*, the weighted price contribution is calculated for each stock and then averaged across stocks:

$$WPC_t = \sum_{d=1}^{D} \left(\frac{|ret_d|}{\sum_{d=1}^{D} |ret_d|} \right) \times \left(\frac{ret_{t,d}}{ret_d} \right)$$

where ret_d is the close-to-close on day *d*, and $ret_{t,d}$ is the logarithmic return for period *t* on day *d*.

Mean changes in the WPC following the reform on 01 July 2006 are also reported. A *t*-test reports whether the change in mean values between the pre and post-event periods are statistically significant.

Table 3.2 Mean WPC across the trading day

Time	Pre	Post
0925-0930	0.0249	0.0152
0930-0945	0.1208	0.1316
0945-1000	0.0586	0.0912
1000-1015	0.0484	0.0405
1015-1030	0.0447	0.0540
1030-1045	0.0162	0.0542
1045-1100	0.0629	0.0301
1100-1115	0.0435	0.0587
1115-1135	0.0629	0.0844
1300-1315	0.0376	0.0242
1315-1330	0.0110	0.0287
1330-1345	0.0254	0.0211
1345-1400	0.0249	0.0152
1400-1415	0.1208	0.1316
1415-1430	0.0586	0.0912
1430-1445	0.0484	0.0405
1445-1500	0.0447	0.0540

This table reports the mean Weighted Price Contribution (WPC) for 780 stocks on the SSE in 15-minute time intervals. The sample period is five weeks before and five weeks after the regime change on 01 July 2006.

Table 3.3 Weighted Price Contribution per trade by time period and trading volume quintile

Quintile	1500-0925			0930-1030		
	Pre	Post	Change	Pre	Post	Change
Highest	0.6127	0.4778	-0.1350	6.5672	7.4862	0.9189
Mean difference t-test			-1.1721			2.3452**
2	0.5241	0.5203	-0.0038	5.8430	6.9668	1.1237
Mean difference t-test			-0.035			3.6014*
3	0.5578	0.3340	-0.2238	4.9608	6.6459	1.6851
Mean difference t-test			-1.8632 ***			5.0071*
4	0.5223	0.1925	-0.3298	4.7911	6.2659	1.4747
Mean difference t-test			-2.7452 *			4.2473*
Lowest	0.4418	0.3108	-0.131	4.4943	6.1551	1.6607
Mean difference t-test			-0.9538			5.2942*
Overall	0.5318	0.3671	-0.1647	5.3313	6.7040	1.3726
Mean difference t-test			-3.0543 *			8.9882*

* denotes significance at 0.01 level
** denotes significance at 0.05 level
*** denotes significance at 0.10 level

The weighted price contribution per trade (WPCT) is computed by dividing the WPC for each time period by the weighted fraction of trades occurring in that interval. The WPCT for each stock at time period t is defined as:

$$WPCT_i = \frac{\sum_{d=1}^{D}\left(\frac{|ret_d|}{\sum_{d=1}^{D}|ret_d|}\right)\times\left(\left[\frac{ret_{t,d}}{ret_d}\right]\right)}{\sum_{d=1}^{D}\left(\frac{|ret_d|}{\sum_{d=1}^{D}|ret_d|}\right)\times\left(\frac{tr_{t,d}}{tr_d}\right)} \qquad (2)$$

where $tr_{t,d}$ is the number of executed trades during time period t on day d, and tr_d is the total number of trades on day d.

The five week pre-event sample period runs from 29 May 2006 to 30 June 2006, and the post-event sample period is from 01 July 2006 to 04 August 2006. 780 stocks that comprise Shanghai's A-share index are sorted into quintiles based on their average trade volume during the study period. Quintile 1 represents the most liquid stocks, and quintile 5 contains the most illiquid.

Mean changes in the WPCT are also reported. A *t*-test reports whether the change in mean values between the pre and post-event periods are statistically significant.

Table 3.4 Volatility Regression

Explanatory Variable	*Estimate*	*t-statistic*
intercept	0.0081	49.12
$\ln(market\_cap_i)$	-0.0012	-132.41
$\ln(turnover_{i,t,d})$	0.0017	288.75
$effspread_{i,t,d}$	0.0162	29.29
change	-0.0006	-41.3
09:30 to 09:35	0.0064	169.58
09:35 to 09:40	0.0031	82.35
09:40 to 09:45	0.0014	38.43
09:45 to 09:50	0.0007	20.04
09:50 to 09:55	0.0003	8.46
10:00 to 10:05	-0.0002	-4.36
10:05 to 10:10	-0.0003	-8.49
10:10 to 10:15	-0.0005	-12.92
10:15 to 10:20	-0.0006	-17.29
10:20 to 10:25	-0.0007	-19.58
10:25 to 10:30	-0.0037	-95.45
Adjusted R^2	0.2797	

All variables are significant at 1% level

Table 3.4 presents the result from the following volatility regression:

$$Volatility_{i,t,d} = \beta_0 + \beta_1 * \ln(market\_cap_i) + \beta_2 * \ln(turnover_{i,t,d}) + \beta_3 * effspread_{i,t,d} + \beta_4 * change + \sum_{n=5}^{15} \beta_n * \text{time interval dummies} + \varepsilon_{it}$$

Based on a sample of 780 A-share stocks from 29 May 2006 to 7 Aug 2006. $Volatility_{i,t,d}$ is the Parkinson (1980)[44] 'High Low Range Volatility' for stock *i*, at 5-minute interval *t*, on day *d*. $market\_cap_i$ is the equity market capitalization for stock *i* based on closing prices on 30 June 2006. $turnover_{i,t,d}$ is the total turnover for stock *i*, during time interval *t*, on day *d*. $effspread_{i,t,d}$ is the mean effective spread[45] for stock *i*, during time interval *t*, on day *d*., *Change* is a dummy variable that takes a value of one after the reform to the opening call system, and a value of zero if otherwise. Also included are 11 five-minute time interval dummies for the first hour of trading, to capture the time varying characteristics of these volatility measures.

[44] As shown by Parkinson (1980), this volatility measurement properly scaled, not only is an unbiased estimator of volatility but is five times more efficient than the classic estimator of volatility.

[45] Effective spread=2x$|\text{transaction price} - \text{bidask midpoint immediately prior to the transaction}|$

Table 4.1 Intraday univariateest for 5 weeks before and 5 weeks after 01 July 2006 – Full sample

Time	Pre	Post	Change	Time	Pre	Post	Change	Time	Pre	Post	Change
number of stocks	281	281									
Panel A: Proportional bid-ask spread (%)											
14:30-14:31	0.2909	0.2829	-0.0085**	14:40-14:41	0.2841	0.2804	-0.0043	14:50-14:51	0.2806	0.2803	-0.0005
14:31-14:32	0.2936	0.2848	-0.0084**	14:41-14:42	0.2860	0.2788	-0.0074**	14:51-14:52	0.2789	0.2803	0.0009
14:32-14:33	0.2963	0.2827	-0.0133***	14:42-14:43	0.2838	0.2789	-0.0061*	14:52-14:53	0.2803	0.2777	-0.0025
14:33-14:34	0.2944	0.2830	-0.0112**	14:43-14:44	0.2867	0.2794	-0.0075**	14:53-14:54	0.2800	0.2781	-0.0023
14:34-14:35	0.2884	0.2807	-0.0081**	14:44-14:45	0.2820	0.2806	-0.0026	14:54-14:55	0.2797	0.2797	-0.0006
14:35-14:36	0.2882	0.2804	-0.0088**	14:45-14:46	0.2831	0.2791	-0.0038	14:55-14:56	0.2821	0.2812	-0.0011
14:36-14:37	0.2891	0.2799	-0.0095**	14:46-14:47	0.2814	0.2766	-0.0048	14:56-14:57	0.2811	0.2496	-0.0317***
14:37-14:38	0.2848	0.2799	-0.0052	14:47-14:48	0.2810	0.2785	-0.0024	14:57-14:58	0.2824	.	.
14:38-14:39	0.2874	0.2810	-0.0064*	14:48-14:49	0.2788	0.2801	0.0009	14:58-14:59	0.2891	.	.
14:39-14:40	0.2838	0.2793	-0.0049	14:49-14:50	0.2813	0.2805	-0.0011	14:59-close	0.2923	0.0775	-0.2151***
Panel B: Effective spread											
14:30-14:31	0.0137	0.0133	-0.0004	14:40-14:41	0.0132	0.0125	-0.00043*	14:50-14:51	0.0130	0.0128	-3.8E-05
14:31-14:32	0.0134	0.0130	-0.0002	14:41-14:42	0.0133	0.0126	-0.00035	14:51-14:52	0.0128	0.0128	0.0002
14:32-14:33	0.0133	0.0128	-0.0002	14:42-14:43	0.0131	0.0126	-0.00034	14:52-14:53	0.0128	0.0126	6.43E-05
14:33-14:34	0.0134	0.0127	-0.0004**	14:43-14:44	0.0133	0.0127	-0.00047	14:53-14:54	0.0129	0.0127	-6.9E-05
14:34-14:35	0.0132	0.0126	-0.0004**	14:44-14:45	0.0130	0.0127	-0.00022	14:54-14:55	0.0131	0.0128	-1.5E-05
14:35-14:36	0.0131	0.0126	-0.0004	14:45-14:46	0.0129	0.0127	-1.9E-05	14:55-14:56	0.0132	0.0130	5.15E-05
14:36-14:37	0.0132	0.0125	-0.0005**	14:46-14:47	0.0129	0.0126	-6.2E-05	14:56-14:57	0.0134	0.0130	-6E-05
14:37-14:38	0.0131	0.0126	-0.0003	14:47-14:48	0.0130	0.0126	-5.2E-05	14:57-14:58	0.0133	.	.
14:38-14:39	0.0131	0.0128	-6.8E-05	14:48-14:49	0.0128	0.0126	-5.3E-05	14:58-14:59	0.0138	.	.
14:39-14:40	0.0130	0.0126	-0.0003	14:49-14:50	0.0128	0.0127	-2.6E-05	14:59-close	0.0142	0.0115	-0.0023

Time	Pre	Post	Change	Time	Pre	Post	Change	Time	Pre	Post	Change
Panel C: Proportional effective spread (%)											
14:30-14:31	0.2956	0.2836	-0.0117**	14:40-14:41	0.2878	0.2764	-0.0115***	14:50-14:51	0.2852	0.2819	-0.0032
14:31-14:32	0.2909	0.2823	-0.0087**	14:41-14:42	0.2875	0.2773	-0.0102***	14:51-14:52	0.2828	0.2827	0.0004
14:32-14:33	0.2901	0.2809	-0.0075**	14:42-14:43	0.2865	0.2778	-0.0098***	14:52-14:53	0.2835	0.2805	-0.0028
14:33-14:34	0.2926	0.2804	-0.0119***	14:43-14:44	0.2899	0.2808	-0.0094*	14:53-14:54	0.2847	0.2803	-0.0041
14:34-14:35	0.2897	0.2790	-0.0109***	14:44-14:45	0.2870	0.2800	-0.0075**	14:54-14:55	0.2864	0.2841	-0.0022
14:35-14:36	0.2880	0.2789	-0.0101**	14:45-14:46	0.2842	0.2791	-0.0047	14:55-14:56	0.2882	0.2865	-0.0007
14:36-14:37	0.2877	0.2769	-0.0108***	14:46-14:47	0.2841	0.2765	-0.0077**	14:56-14:57	0.2903	0.2891	-1.3E-06
14:37-14:38	0.2877	0.2789	-0.0078**	14:47-14:48	0.2846	0.2779	-0.0059	14:57-14:58	0.2899	.	.
14:38-14:39	0.2870	0.2814	-0.0059	14:48-14:49	0.2815	0.2795	-0.0028	14:58-14:59	0.2999	.	.
14:39-14:40	0.2844	0.2775	-0.0079**	14:49-14:50	0.2832	0.2795	-0.0043	14:59-close	0.3078	0.2575	-0.0492***
Panel D: Dollar depth											
14:30-14:31	572006	538128	-123376**	14:40-14:41	596443	599548	-73746	14:50-14:51	607918	582186	-91402**
14:31-14:32	610937	551820	-131371**	14:41-14:42	600484	596044	-95492*	14:51-14:52	636472	623976	-95080
14:32-14:33	599384	540581	-118130**	14:42-14:43	588212	555963	-105911*	14:52-14:53	631741	586704	-118809**
14:33-14:34	594900	582535	-109066*	14:43-14:44	602401	575089	-90683	14:53-14:54	645772	564902	-156029**
14:34-14:35	608227	561918	-144318**	14:44-14:45	587062	585475	-93567**	14:54-14:55	613516	576389	-134890***
14:35-14:36	616309	576583	-101186*	14:45-14:46	614377	598191	-84139*	14:55-14:56	632654	585100	-147716***
14:36-14:37	641868	567277	-138709**	14:46-14:47	616983	562625	-87075*	14:56-14:57	639554	530990	-185773***
14:37-14:38	619966	567202	-134969**	14:47-14:48	618699	561103	-121638**	14:57-14:58	622319	.	.
14:38-14:39	612991	548754	-129338**	14:48-14:49	611858	581349	-102078**	14:58-14:59	642914	.	.
14:39-14:40	577332	568083	-91836**	14:49-14:50	637453	595701	-142162**	14:59-close	654914	522588	-108843**

Time	Pre	Post	Change	Time	Pre	Post	Change	Time	Pre	Post	Change
Panel E: Parkinson's volatility (%)											
14:30-14:31	0.0266	0.0200	-0.0069***	14:40-14:41	0.0279	0.0205	-0.0070***	14:50-14:51	0.0272	0.0249	-0.0018
14:31-14:32	0.0247	0.0209	-0.0039***	14:41-14:42	0.0263	0.0193	-0.0063***	14:51-14:52	0.0287	0.0267	-0.0010
14:32-14:33	0.0240	0.0196	-0.0037***	14:42-14:43	0.0267	0.0203	-0.0066***	14:52-14:53	0.0303	0.0250	-0.0052**
14:33-14:34	0.0257	0.0205	-0.0055***	14:43-14:44	0.0264	0.0209	-0.0051***	14:53-14:54	0.0298	0.0284	-0.0015
14:34-14:35	0.0264	0.0206	-0.0059*	14:44-14:45	0.0265	0.0201	-0.0062***	14:54-14:55	0.0316	0.0289	-0.0029
14:35-14:36	0.0269	0.0202	-0.0070***	14:45-14:46	0.0271	0.0223	-0.0037**	14:55-14:56	0.0328	0.0333	0.0004
14:36-14:37	0.0262	0.0189	-0.0076***	14:46-14:47	0.0269	0.0207	-0.0045***	14:56-14:57	0.0348	0.0466	0.0122***
14:37-14:38	0.0272	0.0212	-0.0060***	14:47-14:48	0.0288	0.0247	-0.0041	14:57-14:58	0.0384	.	.
14:38-14:39	0.0253	0.0211	-0.0045**	14:48-14:49	0.0273	0.0261	-0.0013	14:58-14:59	0.0532	.	.
14:39-14:40	0.0236	0.0209	-0.0032**	14:49-14:50	0.0267	0.0242	-0.0028*	14:59-close	0.0776	0.0000	-0.0770***
Panel F: Proportional number of trades (%)											
14:30-14:31	0.4820	0.5137	0.0309***	14:40-14:41	0.4957	0.5319	0.0347***	14:50-14:51	0.5540	0.6062	0.0541***
14:31-14:32	0.4738	0.5099	0.0356***	14:41-14:42	0.4909	0.5278	0.0367***	14:51-14:52	0.5577	0.6190	0.0615***
14:32-14:33	0.4861	0.5122	0.0263***	14:42-14:43	0.5027	0.5294	0.0259***	14:52-14:53	0.5767	0.6174	0.0432***
14:33-14:34	0.4908	0.5194	0.0287***	14:43-14:44	0.5047	0.5556	0.0518***	14:53-14:54	0.5822	0.6513	0.0697***
14:34-14:35	0.4902	0.5218	0.0312***	14:44-14:45	0.5227	0.5431	0.0217***	14:54-14:55	0.6132	0.6496	0.0389***
14:35-14:36	0.4796	0.5292	0.0518***	14:45-14:46	0.5092	0.5589	0.0511***	14:55-14:56	0.6171	0.6856	0.0687***
14:36-14:37	0.4929	0.5236	0.0307***	14:46-14:47	0.5345	0.5578	0.0251***	14:56-14:57	0.6420	0.8889	0.2481***
14:37-14:38	0.4900	0.5302	0.0406***	14:47-14:48	0.5188	0.5837	0.0666***	14:57-14:58	0.6479	.	.
14:38-14:39	0.4972	0.5220	0.0241***	14:48-14:49	0.5356	0.5851	0.0498***	14:58-14:59	0.6991	.	.
14:39-14:40	0.4829	0.5300	0.0480***	14:49-14:50	0.5388	0.5904	000.0557***	14:59-close	0.8338	0.2088	-0.6259***

Time	Pre	Post	Change	Time	Pre	Post	Change	Time	Pre	Post	Change
Panel G: Proportional average trade size											
14:30-14:31	0.9972	1.0172	0.0129	14:40-14:41	1.0165	1.0356	0.0206	14:50-14:51	1.0942	1.1137	0.0224
14:31-14:32	0.9584	0.9758	0.0185	14:41-14:42	0.9880	1.0327	0.0454	14:51-14:52	1.1094	1.1265	0.0290
14:32-14:33	0.9982	0.9743	-0.0220	14:42-14:43	0.9750	1.0057	0.0252	14:52-14:53	1.1348	1.1317	0.0110
14:33-14:34	0.9699	0.9672	0.0002	14:43-14:44	1.0228	1.0068	-0.0201	14:53-14:54	1.1184	1.1259	0.0067
14:34-14:35	1.0001	1.0088	0.0148	14:44-14:45	1.0146	1.0323	0.0231	14:54-14:55	1.1695	1.2163	0.0628**
14:35-14:36	0.9756	0.9882	0.0119	14:45-14:46	1.0340	1.0670	0.0450*	14:55-14:56	1.1759	1.2474	0.0658**
14:36-14:37	1.0104	0.9814	-0.0318	14:46-14:47	1.0459	1.0575	0.0180	14:56-14:57	1.2229	1.2486	0.0291
14:37-14:38	0.9984	0.9997	0.0001	14:47-14:48	1.0909	1.0824	-0.0066	14:57-14:58	1.2824	.	.
14:38-14:39	0.9636	1.0009	0.0385	14:48-14:49	1.0470	1.0765	0.0430*	14:58-14:59	1.3346	.	.
14:39-14:40	0.9406	1.0254	0.0817***	14:49-14:50	1.0625	1.0911	0.0283	14:59-close	1.3254	9.2497	7.9292***
Panel H: Proportional turnover (%)											
14:30-14:31	0.5055	0.5377	0.0287	14:40-14:41	0.5119	0.5490	0.0343*	14:50-14:51	0.6230	0.6896	0.0693***
14:31-14:32	0.4709	0.5124	0.0421*	14:41-14:42	0.4936	0.5559	0.0646***	14:51-14:52	0.6339	0.7110	0.0821***
14:32-14:33	0.4980	0.5140	0.0176	14:42-14:43	0.5154	0.5401	0.0216	14:52-14:53	0.6542	0.7051	0.0623***
14:33-14:34	0.4827	0.5221	0.0403***	14:43-14:44	0.5228	0.5726	0.0484***	14:53-14:54	0.6672	0.7429	0.0773***
14:34-14:35	0.5011	0.5352	0.0320	14:44-14:45	0.5446	0.5852	0.0436***	14:54-14:55	0.7265	0.7894	0.0774***
14:35-14:36	0.4934	0.5372	0.0453**	14:45-14:46	0.5352	0.6084	0.0789***	14:55-14:56	0.7430	0.8632	0.1182***
14:36-14:37	0.5167	0.5316	0.0136	14:46-14:47	0.5579	0.5931	0.0397***	14:56-14:57	0.7899	1.1156	0.3295***
14:37-14:38	0.4927	0.5460	0.0551***	14:47-14:48	0.5785	0.6485	0.0732***	14:57-14:58	0.8393	.	.
14:38-14:39	0.4966	0.5385	0.0433***	14:48-14:49	0.5764	0.6597	0.0905***	14:58-14:59	0.9457	.	.
14:39-14:40	0.4771	0.5501	0.0719***	14:49-14:50	0.5897	0.6613	0.0732***	14:59-close	1.1239	1.4207	0.2998***

***, ** and * denote significance level at 1%, 5% and 10% respectively.

This table presents the univariate mean comparisons of the intraday patterns between 14:30 and 15:00 of: proportional bid-ask spread (%), effective spread, proportional effective spread (%), dollar depth, Parkinson's volatility (%), proportional number of trades (%), proportional average trade size, and proportional turnover (%). The pre-period is from 29 May to 30 June 2006. The post-period runs from 01 July to 04 August 2006.

Table 4.2 Intraday univariate test for 5 weeks before and 5 weeks after 01 July 2006 – Quintiles

	Quintile 1			Quintile 2			Quintile 3			Quintile 4			Quintile 5		
Time	Pre	Post	Diff.	Pre	Post	Diff.	Pre	Post	Diff.	Pre	Post	Diff.	Pre	Post	Diff.
number of stocks	56	56		56	56		56	56		56	56		57	57	
Panel A: Proportional bid-ask spread (%)															
14:30-14:31	0.2035	0.1951	-0.0084*	0.2627	0.2619	-0.0008	0.2949	0.2778	-0.0171***	0.3095	0.3079	-0.0017	0.3878	0.3732	-0.0145
14:31-14:32	0.2014	0.1969	-0.0044	0.2607	0.2653	0.0046	0.3000	0.2797	-0.0203***	0.3125	0.3081	-0.0043	0.3937	0.3765	-0.0172
14:32-14:33	0.2021	0.1962	-0.0058	0.2601	0.2645	0.0044	0.3007	0.2788	-0.0219***	0.3183	0.3043	-0.0140	0.4022	0.3734	-0.0288*
14:33-14:34	0.2026	0.1939	-0.0086**	0.2580	0.2624	0.0043	0.2972	0.2795	-0.0177***	0.3135	0.3036	-0.0099	0.4022	0.3785	-0.0238
14:34-14:35	0.1986	0.1914	-0.0071*	0.2578	0.2599	0.0022	0.2957	0.2768	-0.0189***	0.3147	0.3087	-0.0060	0.3799	0.3691	-0.0108
14:35-14:36	0.2008	0.1901	-0.0107**	0.2603	0.2562	-0.0041	0.2948	0.2771	-0.0177***	0.3076	0.3082	0.0006	0.3831	0.3711	-0.0120
14:36-14:37	0.1990	0.1900	-0.0090**	0.2535	0.2540	0.0004	0.2962	0.2756	-0.0206***	0.3065	0.3075	0.0010	0.3921	0.3730	-0.0191
14:37-14:38	0.1994	0.1902	-0.0092**	0.2549	0.2566	0.0017	0.2949	0.2744	-0.0205***	0.3084	0.3102	0.0019	0.3691	0.3693	0.0002
14:38-14:39	0.1987	0.1931	-0.0056	0.2568	0.2566	-0.0002	0.2913	0.2758	-0.0155***	0.3076	0.3063	-0.0013	0.3848	0.3753	-0.0095
14:39-14:40	0.1997	0.1929	-0.0069*	0.2573	0.2532	-0.0041	0.2880	0.2750	-0.0130**	0.3072	0.3072	-0.0001	0.3707	0.3702	-0.0005
14:40-14:41	0.1997	0.1944	-0.0052	0.2575	0.2512	-0.0063	0.2871	0.2744	-0.0127**	0.3068	0.3022	-0.0046	0.3739	0.3810	0.0072
14:41-14:42	0.1988	0.1945	-0.0043	0.2569	0.2524	-0.0045	0.2877	0.2738	-0.0139**	0.3070	0.3064	-0.0005	0.3801	0.3666	-0.0135
14:42-14:43	0.2006	0.1934	-0.0072*	0.2562	0.2512	-0.0050	0.2845	0.2702	-0.0143***	0.3092	0.3043	-0.0049	0.3747	0.3757	0.0010
14:43-14:44	0.2002	0.1916	-0.0086**	0.2572	0.2528	-0.0045	0.2902	0.2721	-0.0180***	0.3047	0.3004	-0.0043	0.3820	0.3800	-0.0021
14:44-14:45	0.1971	0.1932	-0.0040	0.2547	0.2533	-0.0014	0.2861	0.2762	-0.0099*	0.3065	0.3055	-0.0010	0.3713	0.3742	0.0030
14:45-14:46	0.2008	0.1928	-0.0079	0.2516	0.2537	0.0021	0.2847	0.2714	-0.0133***	0.3084	0.2969	-0.0115	0.3699	0.3813	0.0113
14:46-14:47	0.1980	0.1915	-0.0065	0.2513	0.2524	0.0011	0.2841	0.2725	-0.0116**	0.3060	0.2967	-0.0093	0.3693	0.3715	0.0022
14:47-14:48	0.1980	0.1916	-0.0064	0.2523	0.2518	-0.0005	0.2833	0.2754	-0.0079	0.3019	0.2966	-0.0053	0.3694	0.3771	0.0077
14:48-14:49	0.1989	0.1880	-0.0109**	0.2566	0.2559	-0.0007	0.2813	0.2776	-0.0037	0.2998	0.3034	0.0037	0.3619	0.3775	0.0156
14:49-14:50	0.1980	0.1910	-0.0070*	0.2526	0.2558	0.0032	0.2827	0.2812	-0.0015	0.3059	0.3012	-0.0047	0.3718	0.3761	0.0043
14:50-14:51	0.1980	0.1899	-0.0081**	0.2488	0.2551	0.0063	0.2842	0.2781	-0.0061	0.3075	0.2976	-0.0099	0.3690	0.3841	0.0150
14:51-14:52	0.1974	0.1903	-0.0071*	0.2513	0.2625	0.0111	0.2852	0.2817	-0.0034	0.3012	0.2988	-0.0024	0.3647	0.3709	0.0061
14:52-14:53	0.1953	0.1912	-0.0041	0.2524	0.2633	0.0109	0.2820	0.2736	-0.0083	0.3048	0.2958	-0.0090	0.3689	0.3668	-0.0021

14:53-14:54	0.1979	0.1897	-0.0082**	0.2514	0.2604	0.0091	0.2816	0.2774	-0.0042	0.3042	0.2987	-0.0054	0.3698	0.3671	-0.0027
14:54-14:55	0.1962	0.1902	-0.0059	0.2523	0.2615	0.0092	0.2846	0.2777	-0.0069	0.3050	0.2965	-0.0085	0.3665	0.3754	0.0089
14:55-14:56	0.1978	0.1920	-0.0058	0.2540	0.2599	0.0059	0.2850	0.2798	-0.0052	0.3080	0.2972	-0.0108	0.3699	0.3801	0.0102
14:56-14:57	0.1990	0.1672	-0.0317***	0.2555	0.2264	-0.0291***	0.2849	0.2484	-0.0365***	0.3032	0.2655	-0.0376***	0.3670	0.3434	-0.0236**
14:57-14:58	0.1995	.	.	0.2594	.	.	0.2852	.	.	0.3049	.	.	0.3668	.	.
14:58-14:59	0.1996	.	.	0.2603	.	.	0.2906	.	.	0.3097	.	.	0.3872	.	.
14:59-close	0.2052	0.0351	-0.1701***	0.2622	0.0525	-0.2097***	0.2907	0.0689	-0.2218***	0.3176	0.0882	-0.2293***	0.3876	0.1434	-0.2442***

	Quintile 1			Quintile 2			Quintile 3			Quintile 4			Quintile 5		
Time	Pre	Post	Diff.	Pre	Post	Diff.	Pre	Post	Diff.	Pre	Post	Diff.	Pre	Post	Diff.
Panel B: Effective spread															
14:30-14:31	0.0140	0.0129	-0.0010*	0.0131	0.0137	0.0006	0.0135	0.0125	-0.0010	0.0129	0.0133	0.0004	0.0137	0.0124	-0.0012*
14:31-14:32	0.0137	0.0133	-0.0004	0.0129	0.0133	0.0005	0.0139	0.0124	-0.0015	0.0129	0.0129	0.0000	0.0127	0.0130	0.0003
14:32-14:33	0.0136	0.0130	-0.0005	0.0128	0.0130	0.0002	0.0132	0.0122	-0.0011**	0.0130	0.0129	-0.0001	0.0124	0.0128	0.0004*
14:33-14:34	0.0134	0.0129	-0.0005**	0.0126	0.0128	0.0002	0.0135	0.0125	-0.0010*	0.0128	0.0129	0.0001	0.0135	0.0126	-0.0009
14:34-14:35	0.0133	0.0125	-0.0008*	0.0128	0.0126	-0.0002	0.0132	0.0122	-0.0010**	0.0131	0.0133	0.0003	0.0130	0.0126	-0.0005
14:35-14:36	0.0133	0.0126	-0.0007*	0.0128	0.0125	-0.0003	0.0133	0.0120	-0.0012**	0.0126	0.0132	0.0006	0.0128	0.0127	-0.0002
14:36-14:37	0.0131	0.0127	-0.0004	0.0123	0.0120	-0.0003	0.0136	0.0119	-0.0017**	0.0130	0.0130	0.0001	0.0127	0.0127	-0.0001
14:37-14:38	0.0133	0.0126	-0.0007	0.0124	0.0123	-0.0001	0.0133	0.0121	-0.0013*	0.0127	0.0134	0.0007	0.0126	0.0126	0.0000
14:38-14:39	0.0132	0.0129	-0.0003	0.0127	0.0125	-0.0002	0.0131	0.0122	-0.0009***	0.0128	0.0130	0.0003	0.0126	0.0134	0.0008
14:39-14:40	0.0133	0.0128	-0.0005	0.0127	0.0123	-0.0004	0.0130	0.0121	-0.0009*	0.0130	0.0130	0.0001	0.0123	0.0125	0.0002
14:40-14:41	0.0135	0.0129	-0.0006	0.0127	0.0122	-0.0005*	0.0131	0.0120	-0.0011**	0.0128	0.0130	0.0002	0.0127	0.0126	-0.0001
14:41-14:42	0.0133	0.0130	-0.0003	0.0126	0.0124	-0.0002	0.0132	0.0122	-0.0010***	0.0132	0.0132	0.0000	0.0127	0.0124	-0.0003
14:42-14:43	0.0136	0.0129	-0.0007	0.0128	0.0124	-0.0004	0.0129	0.0119	-0.0010**	0.0130	0.0130	0.0000	0.0125	0.0130	0.0004
14:43-14:44	0.0137	0.0125	-0.0011*	0.0129	0.0124	-0.0005	0.0133	0.0119	-0.0014**	0.0130	0.0131	0.0001	0.0129	0.0134	0.0005
14:44-14:45	0.0133	0.0127	-0.0006	0.0125	0.0127	0.0002	0.0131	0.0121	-0.0010*	0.0127	0.0129	0.0002	0.0128	0.0129	0.0000
14:45-14:46	0.0134	0.0128	-0.0006	0.0122	0.0126	0.0005	0.0127	0.0121	-0.0006***	0.0128	0.0128	0.0000	0.0125	0.0131	0.0006
14:46-14:47	0.0131	0.0128	-0.0003	0.0124	0.0125	0.0001	0.0126	0.0122	-0.0004	0.0126	0.0126	0.0000	0.0126	0.0129	0.0004
14:47-14:48	0.0131	0.0127	-0.0004	0.0124	0.0124	0.0000	0.0127	0.0128	0.0001	0.0123	0.0125	0.0002	0.0128	0.0126	-0.0001
14:48-14:49	0.0131	0.0124	-0.0007	0.0128	0.0127	-0.0001	0.0125	0.0123	-0.0002	0.0125	0.0128	0.0002	0.0125	0.0130	0.0005
14:49-14:50	0.0131	0.0126	-0.0005	0.0126	0.0125	0.0000	0.0125	0.0127	0.0002	0.0128	0.0129	0.0001	0.0125	0.0126	0.0001
14:50-14:51	0.0132	0.0126	-0.0006	0.0123	0.0128	0.0005**	0.0128	0.0127	-0.0001	0.0131	0.0127	-0.0004	0.0129	0.0133	0.0004
14:51-14:52	0.0130	0.0127	-0.0003	0.0123	0.0134	0.0010**	0.0129	0.0126	-0.0003	0.0125	0.0128	0.0002	0.0123	0.0129	0.0006
14:52-14:53	0.0129	0.0126	-0.0002	0.0122	0.0132	0.0010**	0.0127	0.0119	-0.0009*	0.0126	0.0127	0.0001	0.0126	0.0129	0.0003
14:53-14:54	0.0132	0.0126	-0.0006	0.0125	0.0130	0.0005	0.0127	0.0124	-0.0004	0.0130	0.0126	-0.0004	0.0124	0.0129	0.0005
14:54-14:55	0.0131	0.0128	-0.0003	0.0128	0.0129	0.0002	0.0130	0.0123	-0.0006	0.0128	0.0127	-0.0001	0.0128	0.0135	0.0008
14:55-14:56	0.0131	0.0128	-0.0003	0.0130	0.0129	-0.0001	0.0133	0.0127	-0.0007	0.0128	0.0130	0.0002	0.0126	0.0137	0.0011
14:56-14:57	0.0135	0.0131	-0.0005	0.0130	0.0128	-0.0002	0.0135	0.0123	-0.0012	0.0127	0.0132	0.0004	0.0128	0.0139	0.0011

14:57-14:58	0.0135	.	.	0.0128	.	.	0.0135	.	.	0.0128	.	.	0.0123	.	.
14:58-14:59	0.0136	.	.	0.0128	.	.	0.0140	.	.	0.0136	.	.	0.0134	.	.
14:59-close	0.0141	0.0123	-0.0018***	0.0132	0.0112	-0.0020***	0.0142	0.0110	-0.0032**	0.0139	0.0115	-0.0023***	0.0142	0.0118	-0.0023***

	Quintile 1			Quintile 2			Quintile 3			Quintile 4			Quintile 5		
Time	Pre	Post	Diff.	Pre	Post	Diff.	Pre	Post	Diff.	Pre	Post	Diff.	Pre	Post	Diff.
Panel C: Proportional effective spread (%)															
14:30-14:31	0.2116	0.1983	-0.0133***	0.2703	0.2691	-0.0012	0.2964	0.2821	-0.0143*	0.3056	0.3117	0.0061	0.3928	0.3576	-0.0351**
*14:31-14:32	0.2091	0.1997	-0.0094**	0.2669	0.2644	-0.0025	0.2991	0.2810	-0.0181**	0.3104	0.3065	-0.0039	0.3709	0.3613	-0.0095
14:32-14:33	0.2075	0.1978	-0.0097**	0.2645	0.2640	-0.0005	0.3004	0.2784	-0.0220***	0.3098	0.3074	-0.0024	0.3631	0.3601	-0.0030
14:33-14:34	0.2074	0.1966	-0.0108**	0.2600	0.2644	0.0044	0.2992	0.2784	-0.0208***	0.3091	0.3037	-0.0054	0.3860	0.3595	-0.0264**
14:34-14:35	0.2028	0.1939	-0.0089**	0.2627	0.2582	-0.0045	0.2977	0.2774	-0.0203***	0.3127	0.3095	-0.0033	0.3746	0.3573	-0.0173*
14:35-14:36	0.2056	0.1938	-0.0118***	0.2620	0.2566	-0.0054	0.2969	0.2743	-0.0226***	0.3037	0.3076	0.0039	0.3757	0.3613	-0.0144
14:36-14:37	0.2028	0.1941	-0.0087*	0.2565	0.2526	-0.0039	0.2989	0.2739	-0.0251***	0.3084	0.3060	-0.0024	0.3714	0.3575	-0.0139
14:37-14:38	0.2039	0.1933	-0.0106**	0.2600	0.2569	-0.0031	0.2955	0.2765	-0.0191***	0.3044	0.3097	0.0053	0.3702	0.3601	-0.0116
14:38-14:39	0.2041	0.1970	-0.0071	0.2634	0.2584	-0.0051	0.2959	0.2747	-0.0212****	0.3077	0.3060	-0.0017	0.3658	0.3712	0.0054
14:39-14:40	0.2056	0.1963	-0.0093**	0.2628	0.2541	-0.0087	0.2892	0.2771	-0.0122**	0.3078	0.3050	-0.0027	0.3610	0.3543	-0.0067
14:40-14:41	0.2067	0.1973	-0.0094**	0.2633	0.2511	-0.0122**	0.2945	0.2752	-0.0194***	0.3037	0.3010	-0.0027	0.3715	0.3575	-0.0140
14:41-14:42	0.2062	0.1980	-0.0082*	0.2601	0.2537	-0.0064	0.2925	0.2739	-0.0186***	0.3091	0.3061	-0.0030	0.3680	0.3531	-0.0149
14:42-14:43	0.2097	0.1961	-0.0135***	0.2624	0.2546	-0.0078	0.2886	0.2700	-0.0186***	0.3094	0.3032	-0.0062	0.3677	0.3646	-0.0031
14:43-14:44	0.2086	0.1940	-0.0147***	0.2639	0.2557	-0.0082	0.2932	0.2725	-0.0207***	0.3099	0.3061	-0.0038	0.3751	0.3755	0.0004
14:44-14:45	0.2057	0.1951	-0.0106**	0.2606	0.2573	-0.0032	0.2919	0.2765	-0.0154**	0.3064	0.3053	-0.0011	0.3725	0.3651	-0.0074
14:45-14:46	0.2082	0.1960	-0.0122**	0.2561	0.2564	0.0002	0.2854	0.2718	-0.0136***	0.3077	0.2985	-0.0092	0.3614	0.3724	0.0110
14:46-14:47	0.2015	0.1951	-0.0064	0.2578	0.2555	-0.0022	0.2879	0.2748	-0.0131**	0.3043	0.2955	-0.0088	0.3703	0.3624	-0.0079
14:47-14:48	0.2029	0.1937	-0.0092**	0.2566	0.2538	-0.0029	0.2853	0.2818	-0.0035	0.2999	0.2961	-0.0038	0.3736	0.3637	-0.0099
14:48-14:49	0.2017	0.1917	-0.0100**	0.2614	0.2579	-0.0034	0.2861	0.2787	-0.0074	0.3016	0.3006	-0.0009	0.3620	0.3693	0.0073
14:49-14:50	0.2036	0.1946	-0.0090**	0.2607	0.2589	-0.0018	0.2850	0.2827	-0.0023	0.3049	0.3018	-0.0031	0.3640	0.3610	-0.0055
14:50-14:51	0.2037	0.1933	-0.0104**	0.2552	0.2624	0.0072	0.2872	0.2820	-0.0052	0.3061	0.2989	-0.0072	0.3748	0.3743	-0.0005
14:51-14:52	0.2033	0.1935	-0.0098**	0.2575	0.2708	0.0132	0.2897	0.2826	-0.0071	0.2995	0.3024	0.0029	0.3629	0.3654	0.0025
14:52-14:53	0.2017	0.1956	-0.0061	0.2556	0.2671	0.0115	0.2859	0.2734	-0.0125**	0.3036	0.2971	-0.0065	0.3701	0.3696	-0.0005
14:53-14:54	0.2047	0.1948	-0.0099**	0.2587	0.2665	0.0077	0.2870	0.2798	-0.0072	0.3090	0.2972	-0.0118	0.3646	0.3652	0.0006
14:54-14:55	0.2068	0.1959	-0.0109**	0.2597	0.2642	0.0045	0.2894	0.2810	-0.0084	0.3050	0.2992	-0.0059	0.3706	0.3803	0.0097
14:55-14:56	0.2042	0.1987	-0.0055	0.2686	0.2639	-0.0047	0.2907	0.2858	-0.0049	0.3090	0.3032	-0.0058	0.3659	0.3829	0.0170*
14:56-14:57	0.2070	0.2012	-0.0059	0.2685	0.2646	-0.0039	0.2934	0.2851	-0.0082	0.3063	0.3083	0.0020	0.3718	0.3875	0.0157

14:57-14:58	0.2073	.	.	0.2699	.	.	0.2968	.	.	0.3051	.	.	0.3655	.	.
14:58-14:59	0.2111	.	.	0.2730	.	.	0.2995	.	.	0.3168	.	.	0.3930	.	.
14:59-close	0.2178	0.1874	-0.0304***	0.2776	0.2354	-0.0422***	0.3037	0.2568	-0.0469***	0.3251	0.2750	-0.0501***	0.4106	0.3346	-0.0760***

	Quintile 1			Quintile 2			Quintile 3			Quintile 4			Quintile 5		
Time	Pre	Post	Diff.	Pre	Post	Diff.	Pre	Post	Diff.	Pre	Post	Diff.	Pre	Post	Diff.
Panel D: Dollar depth															
14:30-14:31	1065644	631120	-434523*	558099	579349	21250	554696	421619	-133077	343471	330367	-13105	264217	205636	-58581
14:31-14:32	1153186	716123	-437063	594014	566278	-27736	543892	419223	-124669	371486	354674	-16812	258018	206023	-51995**
14:32-14:33	1101549	719247	-382302*	570792	526078	-44714	528765	393539	-135226	399894	415068	15174	255830	210937	-44893*
14:33-14:34	1110053	729134	-380919	618474	565732	-52741	545792	430993	-114799	364158	421118	56960	274293	219492	-54802*
14:34-14:35	1117920	671771	-446149**	721224	541646	-179579	510976	460589	-50386	400599	388827	-11773	255535	219891	-35644
14:35-14:36	1081509	732174	-349335	648519	594598	-53922	537365	433563	-103802	364648	420180	55532	275795	220569	-55226
14:36-14:37	1179279	735529	-443750*	647579	576142	-71437	565477	424262	-141215	369386	384673	15287	270221	216277	-53943*
14:37-14:38	1145415	728791	-416624	650517	609509	-41008	604859	462886	-141973	370095	382413	12318	296830	208438	-88392
14:38-14:39	1064191	740624	-323567*	672143	598298	-73844	559910	447959	-111951	361027	285210	-75817	267372	204673	-62699**
14:39-14:40	961709	716375	-245335*	635552	580971	-54581	540170	447858	-92312	398010	396448	-1562	256815	190958	-65857**
14:40-14:41	1025874	773697	-252177	587117	639036	51919	560274	456145	-104128	390745	396906	6161	254790	184231	-70559**
14:41-14:42	1072839	714257	-358582*	605560	597419	-8141	586008	484704	-101304	391138	407247	16109	245923	219152	-26771***
14:42-14:43	1095241	721320	-373921*	563828	566250	2421	537092	457499	-79594	372318	354840	-17477	264374	202602	-61771
14:43-14:44	1120651	754330	-366321	575744	572451	-3293	527650	489780	-37870	376529	376484	-45	253367	206698	-46669**
14:44-14:45	1039058	763602	-275456	598884	552916	-45968	537620	506055	-31566	422694	335518	-87177	235512	206689	-28823*
14:45-14:46	1049508	740624	-308884*	610383	590220	-20163	530138	507270	-22868	416144	394130	-22014	248707	201284	-47423
14:46-14:47	1075576	753062	-322514*	618586	550806	-67780	502580	501632	-947	405414	418946	13531	265010	206828	-58182**
14:47-14:48	1129343	784660	-344683	629339	509336	-120004	557860	490438	-67422	402621	374066	-28555	249732	200904	-48828**
14:48-14:49	1113025	749355	-363670**	588291	557062	-31229	569048	530587	-38461	432970	413129	-19841	253306	195327	-57979**
14:49-14:50	1237910	801138	-436771*	624206	552666	-71539	564843	507667	-57176	433323	361400	-71923	261137	186530	-74607***
14:50-14:51	1090322	783718	-306604*	621531	562852	-58679	501001	495458	-5543	408933	395607	-13326	272269	199085	-73184***
14:51-14:52	1192517	839439	-353078	614139	592266	-21874	582346	482486	-99860	401083	481058	79975	286208	205392	-80816***
14:52-14:53	1188314	778822	-409493**	635904	571908	-63996	508413	478754	-29659	423625	384255	-39371	260925	208218	-52707**
14:53-14:54	1279309	766390	-512919*	625321	567724	-57597	531459	484511	-46948	447193	338246	-108947	266964	211434	-55530**
14:54-14:55	1178038	770933	-407104**	618030	533586	-84444	533096	498185	-34911	420585	339346	-81239	290036	222090	-67945**
14:55-14:56	1197236	754762	-442475**	639323	537846	-101476	535772	486497	-49275	422083	348687	-73396	283762	210475	-73286*
14:56-14:57	1172303	717284	-455019***	632982	506198	-126784	538714	419692	-119022	441436	311667	-129769	292467	192660	-99808**

14:57-14:58	1190937	.	.	659788	.	.	555724	.	.	405617	.	.	266232	.	.
14:58-14:59	1263773	.	.	637694	.	.	550564	.	.	435845	.	.	269176	.	.
14:59-close	1290261	1090373	-199889	659536	621458	-38078	534538	440587	-93951	402030	278830	-123200	281679	192234	-89445***

	Quintile 1			Quintile 2			Quintile 3			Quintile 4			Quintile 5		
Time	Pre	Post	Diff.	Pre	Post	Diff.	Pre	Post	Diff.	Pre	Post	Diff.	Pre	Post	Diff.
Panel E: Parkinson's volatility (%)															
14:30-14:31	0.0260	0.0206	-0.0054**	0.0327	0.0257	-0.0071	0.0271	0.0214	-0.0057*	0.0248	0.0186	-0.0062**	0.0230	0.0128	-0.0102**
14:31-14:32	0.0249	0.0224	-0.0024	0.0285	0.0288	0.0002	0.0281	0.0218	-0.0063*	0.0214	0.0172	-0.0042	0.0208	0.0142	-0.0066*
14:32-14:33	0.0237	0.0217	-0.0019	0.0291	0.0249	-0.0042	0.0251	0.0195	-0.0056**	0.0207	0.0182	-0.0024	0.0180	0.0138	-0.0042*
14:33-14:34	0.0253	0.0203	-0.0050**	0.0267	0.0260	-0.0007	0.0290	0.0190	-0.0100***	0.0250	0.0210	-0.0041	0.0242	0.0158	-0.0084*
14:34-14:35	0.0240	0.0191	-0.0050***	0.0271	0.0239	-0.0032	0.0262	0.0209	-0.0053**	0.0234	0.0206	-0.0028	0.0315	0.0182	-0.0133
14:35-14:36	0.0253	0.0196	-0.0058***	0.0303	0.0261	-0.0043	0.0277	0.0222	-0.0055**	0.0242	0.0200	-0.0043	0.0281	0.0131	-0.0150***
14:36-14:37	0.0247	0.0196	-0.0050**	0.0240	0.0211	-0.0028	0.0302	0.0186	-0.0117***	0.0249	0.0217	-0.0032	0.0281	0.0129	-0.0152***
14:37-14:38	0.0251	0.0209	-0.0042**	0.0278	0.0256	-0.0022	0.0365	0.0203	-0.0161**	0.0221	0.0212	-0.0010	0.0244	0.0180	-0.0067
14:38-14:39	0.0251	0.0216	-0.0035	0.0255	0.0213	-0.0042*	0.0295	0.0188	-0.0107***	0.0250	0.0186	-0.0064*	0.0219	0.0235	0.0016
14:39-14:40	0.0228	0.0211	-0.0017	0.0265	0.0230	-0.0035	0.0222	0.0218	-0.0004	0.0243	0.0206	-0.0037	0.0240	0.0165	-0.0075**
14:40-14:41	0.0260	0.0206	-0.0054***	0.0266	0.0210	-0.0056**	0.0275	0.0204	-0.0071***	0.0231	0.0202	-0.0029	0.0319	0.0172	-0.0147
14:41-14:42	0.0250	0.0191	-0.0059***	0.0280	0.0225	-0.0055**	0.0256	0.0184	-0.0072***	0.0219	0.0203	-0.0016	0.0258	0.0145	-0.0113***
14:42-14:43	0.0238	0.0196	-0.0041**	0.0295	0.0219	-0.0076**	0.0262	0.0198	-0.0064***	0.0280	0.0221	-0.0059	0.0272	0.0181	-0.0090**
14:43-14:44	0.0232	0.0217	-0.0015	0.0329	0.0241	-0.0087*	0.0253	0.0199	-0.0053*	0.0230	0.0177	-0.0053***	0.0249	0.0201	-0.0048
14:44-14:45	0.0298	0.0209	-0.0089*	0.0288	0.0257	-0.0031	0.0286	0.0209	-0.0077***	0.0244	0.0188	-0.0056**	0.0209	0.0147	-0.0062***
14:45-14:46	0.0253	0.0213	-0.0040	0.0298	0.0267	-0.0032	0.0266	0.0206	-0.0061***	0.0233	0.0219	-0.0014	0.0230	0.0194	-0.0037
14:46-14:47	0.0243	0.0213	-0.0030	0.0260	0.0242	-0.0018	0.0298	0.0225	-0.0072**	0.0235	0.0204	-0.0031	0.0234	0.0155	-0.0079**
14:47-14:48	0.0258	0.0206	-0.0053***	0.0283	0.0246	-0.0038	0.0269	0.0267	-0.0003	0.0237	0.0247	0.0010	0.0389	0.0269	-0.0120
14:48-14:49	0.0275	0.0206	-0.0069**	0.0277	0.0354	0.0078	0.0355	0.0236	-0.0120**	0.0232	0.0238	0.0007	0.0237	0.0273	0.0037
14:49-14:50	0.0240	0.0223	-0.0017	0.0300	0.0288	-0.0012	0.0302	0.0234	-0.0068**	0.0247	0.0240	-0.0008	0.0254	0.0213	-0.0044
14:50-14:51	0.0225	0.0199	-0.0026	0.0306	0.0297	-0.0009	0.0306	0.0277	-0.0029	0.0249	0.0236	-0.0013	0.0250	0.0239	-0.0011
14:51-14:52	0.0260	0.0223	-0.0036	0.0290	0.0383	0.0093	0.0343	0.0252	-0.0091**	0.0245	0.0248	0.0003	0.0237	0.0219	-0.0018
14:52-14:53	0.0266	0.0211	-0.0054*	0.0285	0.0332	0.0047	0.0331	0.0252	-0.0078***	0.0277	0.0249	-0.0028	0.0352	0.0201	-0.0151
14:53-14:54	0.0264	0.0229	-0.0036	0.0352	0.0380	0.0028	0.0313	0.0286	-0.0027	0.0303	0.0256	-0.0047	0.0267	0.0274	0.0007
14:54-14:55	0.0295	0.0225	-0.0070**	0.0345	0.0393	0.0048	0.0372	0.0279	-0.0093**	0.0327	0.0277	-0.0050	0.0251	0.0269	0.0018
14:55-14:56	0.0288	0.0308	0.0020	0.0341	0.0382	0.0041	0.0360	0.0306	-0.0054	0.0356	0.0277	-0.0079	0.0296	0.0384	0.0089
14:56-14:57	0.0333	0.0376	0.0043	0.0359	0.0520	0.0161**	0.0413	0.0480	0.0066	0.0314	0.0436	0.0122***	0.0303	0.0517	0.0214***

14:57-14:58	0.0310	.	.	0.0424	.	.	0.0447	.	.	0.0351	.	.	0.0369	.	.
14:58-14:59	0.0390	.	.	0.0523	.	.	0.0481	.	.	0.0471	.	.	0.0777	.	.
14:59-close	0.0663	0.0000	-0.0663***	0.0721	0.0000	-0.0721***	0.0632	0.0000	-0.0632***	0.0616	0.0000	-0.0616***	0.1210	0.0000	-0.1210***

	Quintile 1			Quintile 2			Quintile 3			Quintile 4			Quintile 5		
Time	Pre	Post	Diff.	Pre	Post	Diff.	Pre	Post	Diff.	Pre	Post	Diff.	Pre	Post	Diff.
Panel F: Proportional number of trades (%)															
14:30-14:31	0.4308	0.4443	0.0134**	0.4454	0.4612	0.0158	0.4760	0.5024	0.0264**	0.4986	0.5232	0.0246**	0.5655	0.6390	0.0735***
14:31-14:32	0.4206	0.4427	0.0221***	0.4400	0.4596	0.0196*	0.4670	0.4898	0.0228**	0.4894	0.5250	0.0357***	0.5557	0.6329	0.0772***
14:32-14:33	0.4266	0.4407	0.0141**	0.4470	0.4608	0.0138	0.4574	0.4853	0.0279**	0.4907	0.5388	0.0481***	0.6070	0.6345	0.0276
14:33-14:34	0.4284	0.4478	0.0194***	0.4485	0.4606	0.0121	0.4661	0.5097	0.0436***	0.5067	0.5407	0.0340**	0.6014	0.6389	0.0375
14:34-14:35	0.4313	0.4456	0.0143***	0.4472	0.4691	0.0219**	0.4797	0.5098	0.0300***	0.5101	0.5371	0.0271*	0.5829	0.6448	0.0619**
14:35-14:36	0.4258	0.4557	0.0299***	0.4381	0.4742	0.0361***	0.4680	0.5163	0.0483***	0.4929	0.5444	0.0515***	0.5609	0.6535	0.0925***
14:36-14:37	0.4326	0.4507	0.0180***	0.4603	0.4757	0.0154	0.4721	0.5109	0.0388***	0.5175	0.5344	0.0170	0.5819	0.6455	0.0636***
14:37-14:38	0.4271	0.4632	0.0361***	0.4494	0.4834	0.0340***	0.4624	0.5110	0.0486***	0.4843	0.5433	0.0591***	0.6290	0.6499	0.0291
14:38-14:39	0.4360	0.4537	0.0177***	0.4510	0.4760	0.0249**	0.4939	0.5060	0.0121	0.5213	0.5203	-0.0010	0.5727	0.6527	0.0800***
14:39-14:40	0.4295	0.4591	0.0295***	0.4393	0.4819	0.0426***	0.4678	0.5193	0.0515***	0.5038	0.5276	0.0238**	0.5668	0.6612	0.0944***
14:40-14:41	0.4404	0.4596	0.0192***	0.4618	0.4839	0.0220*	0.4792	0.5221	0.0429***	0.5026	0.5365	0.0339***	0.5876	0.6565	0.0689***
14:41-14:42	0.4355	0.4620	0.0264***	0.4526	0.4768	0.0242**	0.4732	0.5042	0.0311***	0.5075	0.5456	0.0380***	0.5876	0.6506	0.0631****
14:42-14:43	0.4367	0.4636	0.0269***	0.4600	0.4839	0.0239**	0.4858	0.5017	0.0159	0.5283	0.5371	0.0088	0.6076	0.6612	0.0535**
14:43-14:44	0.4417	0.4760	0.0342***	0.4550	0.5010	0.0459***	0.4910	0.5322	0.0413***	0.5230	0.5766	0.0535***	0.6094	0.6928	0.0834***
14:44-14:45	0.4606	0.4664	0.0058	0.4692	0.4831	0.0139	0.4954	0.5345	0.0391***	0.5425	0.5584	0.0159	0.6406	0.6764	0.0357
14:45-14:46	0.4436	0.4822	0.0385***	0.4656	0.5071	0.0415***	0.5027	0.5376	0.0349***	0.5272	0.5881	0.0608***	0.6061	0.6852	0.0790**
14:46-14:47	0.4643	0.4746	0.0104*	0.4841	0.5049	0.0208*	0.5178	0.5514	0.0336*	0.5452	0.5866	0.0414***	0.6528	0.6748	0.0220
14:47-14:48	0.4522	0.4847	0.0324***	0.4734	0.5282	0.0547***	0.5085	0.5747	0.0661***	0.5452	0.6016	0.0564***	0.6121	0.7343	0.1221***
14:48-14:49	0.4720	0.4964	0.0245***	0.4941	0.5205	0.0264**	0.5266	0.5790	0.0524***	0.5567	0.6194	0.0627***	0.6333	0.7157	0.0824***
14:49-14:50	0.4642	0.5038	0.0397***	0.4961	0.5400	0.0439***	0.5363	0.5796	0.0434***	0.5592	0.6111	0.0518***	0.6297	0.7210	0.1029***
14:50-14:51	0.4729	0.5097	0.0368***	0.5121	0.5525	0.0405***	0.5494	0.6002	0.0508***	0.5732	0.6445	0.0714***	0.6547	0.7254	0.0707***
14:51-14:52	0.4792	0.5158	0.0366***	0.5139	0.5661	0.0522***	0.5520	0.6069	0.0549***	0.5937	0.6325	0.0389**	0.6523	0.7761	0.1239***
14:52-14:53	0.4888	0.5233	0.0346***	0.5335	0.5586	0.0251**	0.5723	0.6113	0.0390***	0.5952	0.6595	0.0642***	0.6843	0.7391	0.0547**
14:53-14:54	0.4925	0.5347	0.0422***	0.5284	0.5976	0.0693***	0.5778	0.6395	0.0617***	0.6212	0.6803	0.0591***	0.6890	0.8047	0.1156***
14:54-14:55	0.5074	0.5362	0.0288***	0.5565	0.6025	0.0460***	0.6072	0.6384	0.0313***	0.6452	0.6991	0.0539***	0.7416	0.7761	0.0345
14:55-14:56	0.5075	0.5585	0.0510***	0.5649	0.6238	0.0589***	0.6148	0.6756	0.0608***	0.6561	0.7212	0.0652***	0.7426	0.8494	0.1068***
14:56-14:57	0.5216	0.7300	0.2084***	0.5857	0.8158	0.2301***	0.6486	0.8933	0.2447***	0.6925	0.9436	0.2511***	0.7575	1.0627	0.3052***

14:57-14:58	0.5301	.	.	0.5860	.	.	0.6554	.	.	0.6986	.	.	0.7618	.	.
14:58-14:59	0.5519	.	.	0.6315	.	.	0.7099	.	.	0.7541	.	.	0.8407	.	.
14:59-close	0.6804	0.0998	-0.5806***	0.7587	0.1368	-0.6219***	0.8437	0.1790	-0.6647***	0.9220	0.2354	-0.6865***	0.9639	0.3872	-0.5767***

	Quintile 1			Quintile 2			Quintile 3			Quintile 4			Quintile 5		
Time	Pre	Post	Diff.	Pre	Post	Diff.	Pre	Post	Diff.	Pre	Post	Diff.	Pre	Post	Diff.
Panel G: Proportional average trade size															
14:30-14:31	0.9386	1.0154	0.0768**	0.9792	1.0695	0.0903	1.0373	0.9608	-0.0765	0.9465	1.0239	0.0774	1.1200	1.0185	-0.1015
14:31-14:32	0.9519	0.9649	0.0130	0.9357	0.9076	-0.0281	1.0135	0.9415	-0.0720	0.9753	0.9667	-0.0086	0.9299	1.1153	0.1854*
14:32-14:33	1.0044	0.9663	-0.0381	0.9648	0.9564	-0.0084	1.0251	0.9866	-0.0385	1.0414	1.0036	-0.0377	0.9684	0.9804	0.0120
14:33-14:34	0.9041	0.9181	0.0140	0.9477	1.0335	0.0858	1.0209	0.9720	-0.0489	1.0197	0.9861	-0.0336	0.9548	0.9442	-0.0106
14:34-14:35	0.9283	1.0261	0.0979*	0.9949	0.9908	-0.0040	0.9786	0.9830	0.0045	0.9371	1.0775	0.1404	1.1508	0.9893	-0.1615
14:35-14:36	0.9276	0.9563	0.0286	0.9700	1.0032	0.0332	1.0633	0.9937	-0.0696	0.9040	1.0130	0.1090*	1.0125	0.9716	-0.0409
14:36-14:37	1.0020	0.9694	-0.0326	1.0173	1.0309	0.0136	1.0672	0.9722	-0.0949*	1.0440	0.9994	-0.0446	0.9518	0.9510	-0.0008
14:37-14:38	0.9345	1.0589	0.1244**	1.0531	0.9931	-0.0600	1.0383	0.9569	-0.0814	1.0126	0.9506	-0.0619	0.9745	1.0345	0.0566
14:38-14:39	0.9596	0.9894	0.0298	0.9318	1.0060	0.0742	0.9877	1.0419	0.0542	0.9733	1.0022	0.0290	0.9824	0.9726	-0.0097
14:39-14:40	0.9616	0.9667	0.0051	0.9402	1.0417	0.1015***	0.9474	0.9815	0.0341	0.9591	1.0753	0.1162**	0.9178	1.0690	0.1512*
14:40-14:41	0.9852	0.9631	-0.0221	0.9631	0.9560	-0.0071	0.9524	1.0432	0.0908	1.0525	1.1752	0.1227	1.1288	1.0442	-0.0846
14:41-14:42	0.9426	1.0654	0.1228*	0.9523	1.0012	0.0488	1.0184	1.0614	0.0429	0.9419	1.0412	0.0993	1.0900	1.0053	-0.0848
14:42-14:43	0.9448	1.0134	0.0686*	0.9705	0.9771	0.0065	1.0594	0.9560	-0.1034*	0.9722	1.0312	0.0589	0.9543	1.0481	0.0938
14:43-14:44	0.9784	1.0510	0.0726	1.0015	0.9752	-0.0263	1.0462	1.0063	-0.0398	1.0326	0.9774	-0.0552	1.0833	1.0320	-0.0512
14:44-14:45	0.9343	1.0172	0.0829**	0.9730	1.0344	0.0614	1.1196	1.0327	-0.0869	1.0281	1.0308	0.0026	1.0080	1.0507	0.0427
14:45-14:46	0.9873	1.0833	0.0960**	1.0509	1.0532	0.0024	1.0445	1.0327	-0.0118	1.0608	1.1078	0.0470	0.9919	1.0827	0.0907
14:46-14:47	0.9981	1.0713	0.0732	1.0219	1.0469	0.0250	1.0612	1.0403	-0.0209	1.0459	1.0227	-0.0232	1.1015	1.1188	0.0173
14:47-14:48	1.0803	1.1407	0.0604	1.0422	1.0205	-0.0217	1.0581	1.0831	0.0250	1.0858	1.0887	0.0029	1.1834	1.0854	-0.0980
14:48-14:49	1.0616	1.1017	0.0402	1.0767	1.0319	-0.0449	1.0619	1.0423	-0.0196	1.0075	1.1250	0.1175*	0.9906	1.1110	0.1204**
14:49-14:50	1.0752	1.1127	0.0375	1.0376	1.0574	0.0198	1.0890	1.1860	0.0970	1.1113	1.0058	-0.1055*	1.0296	1.1100	0.0795
14:50-14:51	1.0881	1.0938	0.0057	1.0375	1.1590	0.1214*	1.1162	1.1550	0.0388	1.1142	1.0889	-0.0252	1.1165	1.0885	-0.0280
14:51-14:52	1.1003	1.1903	0.0900*	1.0666	1.1834	0.1168**	1.1305	1.0564	-0.0741	1.1197	1.1875	0.0678	1.0941	1.0402	-0.0539
14:52-14:53	1.1204	1.2402	0.1199***	1.1244	1.1643	0.0399	1.1575	1.1075	-0.0500	1.0712	1.1228	0.0516	1.1604	1.0404	-0.1200
14:53-14:54	1.1714	1.1899	0.0185*	1.1397	1.1678	0.0282	1.1586	1.1718	0.0132	1.1278	1.0868	-0.0410	1.0122	1.0267	0.0145
14:54-14:55	1.2261	1.2963	0.0702**	1.2103	1.1854	-0.0250	1.1717	1.2163	0.0446	1.1192	1.1814	0.0622	1.0664	1.2268	0.1604**
14:55-14:56	1.2612	1.3110	0.0498**	1.2322	1.2095	-0.0227	1.2296	1.2994	0.0698	1.0903	1.1022	0.0119	1.0913	1.3088	0.2175***
14:56-14:57	1.3295	1.3216	-0.0080***	1.2550	1.2398	-0.0152	1.2187	1.2809	0.0623	1.2174	1.1758	-0.0416	1.0952	1.2412	0.1461**

14:57-14:58	1.3697	.	.	1.2842	.	.	1.3299	.	.	1.2620	.	.	1.1768	.	.
14:58-14:59	1.5357	.	.	1.3679	.	.	1.3953	.	.	1.2309	.	.	1.1646	.	.
14:59-close	1.4440	13.7381	12.2941	1.3375	11.2702	9.9327***	1.3157	9.3082	7.9924***	1.1808	7.3166	6.1359***	1.3542	4.7266	3.3724***

	Quintile 1			Quintile 2			Quintile 3			Quintile 4			Quintile 5		
Time	Pre	Post	Diff.	Pre	Post	Diff.	Pre	Post	Diff.	Pre	Post	Diff.	Pre	Post	Diff.
Panel H: Proportional turnover (%)															
14:30-14:31	0.4273	0.4746	0.0473**	0.4547	0.5052	0.0506*	0.5419	0.5025	-0.0395	0.4916	0.5495	0.0579*	0.6331	0.6604	0.0273
14:31-14:32	0.4082	0.4411	0.0329	0.4260	0.4424	0.0164	0.4925	0.4825	-0.0100	0.4846	0.5295	0.0449	0.5504	0.6753	0.1249
14:32-14:33	0.4405	0.4418	0.0013	0.4479	0.4637	0.0158	0.4910	0.4782	-0.0128	0.5179	0.5583	0.0404	0.5937	0.6367	0.0430
14:33-14:34	0.4036	0.4333	0.0297*	0.4312	0.4958	0.0645**	0.4823	0.5221	0.0399	0.5305	0.5454	0.0149	0.5661	0.6237	0.0576
14:34-14:35	0.4165	0.4628	0.0462**	0.4673	0.4890	0.0217	0.4803	0.5091	0.0287	0.4985	0.5507	0.0522*	0.6524	0.6638	0.0115
14:35-14:36	0.4102	0.4504	0.0401*	0.4449	0.4946	0.0497*	0.5167	0.5114	-0.0053	0.4804	0.5664	0.0860**	0.6051	0.6611	0.0560
14:36-14:37	0.4523	0.4550	0.0028	0.4945	0.5096	0.0150	0.4970	0.5042	0.0072	0.5697	0.5629	-0.0068	0.5829	0.6321	0.0492
14:37-14:38	0.4095	0.4954	0.0859***	0.4840	0.5062	0.0221	0.4875	0.4952	0.0077	0.4953	0.5453	0.0499*	0.5991	0.6885	0.1015*
14:38-14:39	0.4397	0.4555	0.0158	0.4362	0.4893	0.0531**	0.4976	0.5439	0.0464*	0.5273	0.5406	0.0132	0.5839	0.6639	0.0800
14:39-14:40	0.4319	0.4541	0.0222	0.4313	0.5018	0.0705***	0.4639	0.5333	0.0694***	0.5135	0.5637	0.0503	0.5517	0.7015	0.1498***
14:40-14:41	0.4516	0.4404	-0.0112	0.4453	0.4886	0.0433	0.4811	0.5495	0.0684**	0.5369	0.6176	0.0806**	0.6514	0.6494	-0.0020
14:41-14:42	0.4292	0.4960	0.0669**	0.4480	0.4929	0.0449**	0.4982	0.5379	0.0397	0.4938	0.5786	0.0848**	0.5974	0.6837	0.0863
14:42-14:43	0.4307	0.4784	0.0477***	0.4718	0.4925	0.0207	0.5285	0.4926	-0.0359	0.5502	0.5612	0.0110	0.6142	0.6780	0.0637
14:43-14:44	0.4440	0.5113	0.0673***	0.4666	0.5028	0.0361	0.5102	0.5538	0.0436	0.5531	0.5835	0.0304	0.6499	0.7145	0.0645
14:44-14:45	0.4427	0.4847	0.0420**	0.4750	0.5328	0.0579**	0.5836	0.5707	-0.0129	0.5880	0.6073	0.0193	0.6340	0.7394	0.1054**
14:45-14:46	0.4477	0.5249	0.0772***	0.5072	0.5506	0.0434	0.5265	0.5721	0.0456	0.5735	0.6594	0.0860**	0.6109	0.7522	0.1414***
14:46-14:47	0.4775	0.5064	0.0290	0.4965	0.5446	0.0481**	0.5695	0.5856	0.0161	0.5666	0.6011	0.0346	0.6758	0.7402	0.0643
14:47-14:48	0.4969	0.5602	0.0633***	0.5057	0.5675	0.0618*	0.5517	0.6372	0.0854***	0.6079	0.6684	0.0605*	0.7243	0.8190	0.0948
14:48-14:49	0.5159	0.5637	0.0478*	0.5622	0.5680	0.0058	0.5623	0.6426	0.0804***	0.5868	0.6926	0.1058**	0.6403	0.8511	0.2108***
14:49-14:50	0.5105	0.5842	0.0737***	0.5267	0.5838	0.0572**	0.6132	0.6854	0.0722*	0.6366	0.6369	0.0002	0.6743	0.8290	0.1565***
14:50-14:51	0.5287	0.5770	0.0483***	0.5459	0.6574	0.1116***	0.6422	0.6983	0.0561	0.6659	0.7284	0.0625*	0.7319	0.8000	0.0681
14:51-14:52	0.5381	0.6299	0.0918***	0.5697	0.6888	0.1191***	0.6314	0.6578	0.0264	0.6799	0.7781	0.0982**	0.7431	0.8183	0.0752
14:52-14:53	0.5548	0.6561	0.1013***	0.6096	0.6672	0.0577*	0.6640	0.6771	0.0131	0.6473	0.7698	0.1225***	0.7577	0.7695	0.0118
14:53-14:54	0.5844	0.6437	0.0593**	0.6353	0.7222	0.0869***	0.6953	0.7632	0.0679*	0.7163	0.7625	0.0462	0.7071	0.8326	0.1255***
14:54-14:55	0.6273	0.6994	0.0721***	0.7070	0.7312	0.0242	0.7228	0.7717	0.0489	0.7567	0.8058	0.0491	0.7661	0.9568	0.1906***
14:55-14:56	0.6535	0.7519	0.0984***	0.7190	0.7680	0.0490	0.7836	0.9022	0.1186**	0.7310	0.8129	0.0818*	0.8369	1.0776	0.2407***
14:56-14:57	0.7067	0.9791	0.2725***	0.7650	1.0275	0.2625***	0.8201	1.1437	0.3236***	0.8433	1.1214	0.2781***	0.8109	1.3182	0.5074***

14:57-14:58	0.7334	.	.	0.7671	.	.	0.8695	.	.	0.8967	.	.	0.9244	.	.
14:58-14:59	0.8529	.	.	0.8915	.	.	1.0149	.	.	0.9714	.	.	0.9999	.	.
14:59-close	0.9981	1.2735	0.2754***	1.0641	1.3675	0.3034***	1.1455	1.4767	0.3312***	1.1460	1.5175	0.3715***	1.2559	1.4746	0.2187***

***, ** and * denote significance level at 1%, 5% and 10% respectively.

This table presents the univariate mean comparisons of the intraday patterns between 14:30 and 15:00 of: proportional bid-ask spread (%), effective spread, proportional effective spread (%), dollar depth, Parkinson's volatility (%), proportional number of trades (%), proportional average trade size, and proportional turnover (%). The pre-period is from 29 May to 30 June 2006. The post-period runs from 01 July to 04 August 2006. The sample stocks are sorted into quintiles according to their average daily turnover during the study period. Quintile 1 represents the most liquid stocks, and quintile 5 contains the most illiquid. The difference in means between the pre and post-event period are recorded.

Table 4.3 Multivariate regressions of spread and volatility during the closing minutes

Dependent variable: $pbas_{itd}$		
Explanatory Variable	*Estimate*	*t-statistic*
Intercept	1.6920	324.16***
volatility	0.4208	155.15***
ln(Market Capitalisation)	-0.0673	-275.31***
Proportional turnover	0.3745	13.32***
Change	-0.0010	-1.72*
14:55 to close	-0.0083	-9.81***
14:50 to 14:55	0.0065	7.78***
14:45 to 14:50	0.0049	5.85***
Change × 14:55 to close	-0.0062	-4.75***
Change × 14:50 to 14:55	-0.0033	-2.82***
Change × 14:45 to 14:50	-0.0013	-1.1**
Adjusted R^2	0.2426	
Dependent variable: $volatility_{itd}$		
Explanatory Variable	*Estimate*	*t-statistic*
Intercept	-0.2367	-63.56***
Pbas	0.1621	155.27***
ln(Market Capitalisation)	0.0097	57.43***
Std_daily_ret	0.0099	5.95***
Proportional turnover	2.0593	120.66***
Change	-0.0052	-13.99***
14:55 to close	0.0098	18.64***
14:50 to 14:55	0.0008	1.7*
14:45 to 14:50	-0.00005	-0.1
Change × 14:55 to close	-0.0206	-25.19***
Change × 14:50 to 14:55	0.00062	0.85
Change × 14:45 to 14:50	0.0009	1.2
Adjusted R^2	0.1187	

***, ** and * denote significance level at 1%, 5% and 10% respectively.

This table presents the results of the simultaneous regressions for spread and volatility for 281 A-share stock listed on the Shenzhen stock exchange during 29 May - 04 August 2006. The system consists of the following two equations:

$$pbas_{itd} = \beta_0 + \beta_1 volatility_{itd} + \beta_2 \ln(market\ capitalisation_i) + \beta_3\ proportional\ turnover_{itd} + \beta_4\ change_d + \sum_{n=5}^{7} \beta_n * five\ minute\ interval\ dummies_t + \sum_{n=8}^{10} \beta_n * change * five\ minute\ interval\ dummies_t$$

$$volatility_{itd} = \gamma_0 + \gamma_1 pbas_{itd} + \gamma_2 \ln(market\ capitalisation_i) + \gamma_3 std\_daily\_ret_i + \gamma_4 proportional\ turnover_{itd} + \gamma_5\ change_d + \sum_{n=6}^{8} \gamma_n * five\ minute\ interval\ dummies_t + \sum_{n=9}^{11} \gamma_n * change * five\ minute\ interval\ dummies_t$$

Where $pbas_{itd}$ is the average proportional bid-ask spread (%) for stock *i*, at time interval *t*, on day *d*. $volatility_{itd}$ is the Parkinson (1980) volatility (%) measure for stock *i*, time interval *t*, day *d*. $std\_daily\_ret_i$ is the standard deviation of close-to-close returns measured over the study period, and represents volatility of the underlying price discovery process. $market\ capitalisation_i$ is the equity market capitalisation as at the close of trading on June 30 2006. $change_d$ is a dummy variable that equals to 1 if the observation is after 1 July 2006, and 0 otherwise. Also included are 3 five-minute time interval dummies to capture the sharp rise in spread and volatility in the last fifteen minutes of trading. The interaction variables $change * five\ minute\ interval\ dummies_t$ captures any additional changes in the intraday patterns as a result of the closing call introduction.

Table 4.4 First Pass Regression

	Full sample					Quintile 1					Quintile 2				
L	Pre	Post	Diff	% Diff	T-stat	Pre	Post	Diff	% Diff	T-stat	Pre	Post	Diff	% Diff	T-stat
1	0.2428	0.2881	0.0453	18.64	3.729*	0.2136	0.3471	0.1335	62.48	5.29*	0.2337	0.3100	0.0764	32.68	2.9*
2	0.2618	0.2770	0.0152	5.79	1.18	0.2295	0.3361	0.1067	46.49	3.78*	0.2566	0.2991	0.0425	16.55	1.62
3	0.2780	0.2706	-0.0074	-2.66	-0.54	0.2453	0.3450	0.0997	40.63	3.28*	0.2722	0.2941	0.0219	8.04	0.81
4	0.2897	0.2737	-0.0160	-5.52	-1.09	0.2553	0.3525	0.0973	38.11	2.94*	0.2846	0.3044	0.0198	6.95	0.68
5	0.2946	0.2854	-0.0092	-3.12	-0.6	0.2600	0.3627	0.1028	39.53	3.01*	0.2970	0.3272	0.0302	10.18	0.99
6	0.3059	0.3064	0.0005	0.17	0.03	0.2706	0.3798	0.1092	40.34	3.06*	0.3182	0.3547	0.0365	11.47	1.14
7	0.3031	0.3178	0.0147	4.85	0.92	0.2651	0.3887	0.1236	46.61	3.39*	0.3174	0.3726	0.0552	17.40	1.69
8	0.2935	0.3257	0.0322	10.96	1.99*	0.2659	0.3976	0.1317	49.52	3.55*	0.3160	0.3878	0.0718	22.71	2.14*
9	0.2860	0.3275	0.0415	14.51	2.56*	0.2671	0.4030	0.1359	50.89	3.71*	0.3154	0.3967	0.0813	25.79	2.36*
10	0.2759	0.3279	0.0519	18.81	3.23*	0.2717	0.4076	0.1359	50.00	3.78*	0.3024	0.3998	0.0974	32.20	2.85*
15	0.2645	0.3464	0.0819	30.96	4.69*	0.2725	0.4654	0.1928	70.75	4.97*	0.2933	0.4193	0.1259	42.94	3.31*
20	0.2801	0.3537	0.0736	26.26	3.93*	0.2659	0.4661	0.2002	75.28	4.83*	0.3134	0.4251	0.1117	35.65	2.58*

	Quintile 3					Quintile 4					Quintile 5				
L	Pre	Post	Diff	% Diff	T-stat	Pre	Post	Diff	% Diff	T-stat	Pre	Post	Diff	% Diff	T-stat
1	0.2717	0.3013	0.0296	10.89	1.03	0.3052	0.2716	-0.0337	-11.03	-1.23	0.1907	0.2117	0.0210	11.02	0.88
2	0.2685	0.2814	0.0129	4.79	0.44	0.3264	0.2669	-0.0596	-18.25	-1.94	0.2286	0.2026	-0.0260	-11.36	-1.04
3	0.2714	0.2699	-0.0014	-0.52	-0.05	0.3466	0.2572	-0.0894	-25.79	-2.78*	0.2549	0.1882	-0.0666	-26.14	-2.47*
4	0.2788	0.2714	-0.0074	-2.65	-0.22	0.3615	0.2574	-0.1040	-28.78	-3.14*	0.2688	0.1844	-0.0844	-31.39	-2.87*
5	0.2781	0.2807	0.0026	0.94	0.08	0.3654	0.2661	-0.0993	-27.18	-2.92*	0.2730	0.1921	-0.0810	-29.65	-2.63*
6	0.2927	0.3015	0.0088	3.00	0.24	0.3807	0.2868	-0.0939	-24.66	-2.74*	0.2681	0.2112	-0.0570	-21.24	-1.77
7	0.2941	0.3112	0.0172	5.84	0.47	0.3800	0.2955	-0.0845	-22.23	-2.45*	0.2598	0.2228	-0.0370	-14.24	-1.11
8	0.2798	0.3158	0.0360	12.85	0.98	0.3636	0.2989	-0.0647	-17.80	-1.84	0.2431	0.2300	-0.0131	-5.38	-0.38
9	0.2742	0.3141	0.0399	14.55	1.08	0.3502	0.2963	-0.0538	-15.38	-1.51	0.2242	0.2291	0.0049	2.18	0.14
10	0.2565	0.3126	0.0561	21.87	1.53	0.3398	0.2930	-0.0468	-13.76	-1.32	0.2104	0.2280	0.0176	8.37	0.52
15	0.2435	0.3243	0.0807	33.15	1.95	0.3097	0.3000	-0.0097	-3.12	-0.26	0.2044	0.2251	0.0207	10.12	0.59
20	0.2718	0.3382	0.0663	24.40	1.53	0.3258	0.3047	-0.0211	-6.47	-0.53	0.2246	0.2364	0.0118	5.24	0.33

* denotes significance at 5% level.

This table reports the average adjusted R-square estimates over the period 120 trading days before and 120 trading days after 01 July 2006 using the regression from equation 3:

$$R_{idLE} = \alpha_{iLE} + \beta_{iLE} R_{mdLE} + e_{idL,E} \qquad i=1,...n \quad L=1,...10,\ 15,\ 20 \quad E=1,2$$

where R_{idLE} is the close-to-close return for stock *i* on day *d* for time interval *L*, using either the pre or post-event returns (*E*). Correspondingly, R_{mdLE} is the market return on day *d* for time interval *L*, using either the pre or post-event returns (*E*). Diff is the difference in mean adjusted R-squares between the pre and post-event periods. The sample stocks are sorted into quintiles according to their average daily turnover during the study period. Quintile 1 represents the most liquid stocks, and quintile 5 contains the most illiquid.

Table 4.5 Second Pass Regression

	Full sample			Quintile 1			Quintile 2		
	Pre	Post	Change	Pre	Post	Change	Pre	Post	Change
Constant									
parameter	0.2952	0.3300	0.0348	0.2774	0.4225	0.1451	0.3217	0.3984	0.0768
t-stat	22.7864	26.5181	2.0909*	9.1721	18.0604	3.8985*	10.4941	16.0529	2.1882*
Slope									
parameter	-0.0662	-0.1034	-0.0372	-0.0980	-0.1665	-0.0685	-0.1355	-0.1954	-0.0599
t-stat	-3.1680	-6.4622	-1.4871	-2.0499	-4.6305	-1.1502	-2.8121	-5.4512	-1.0299

	Quintile 3			Quintile 4			Quintile 5		
	Pre	Post	Change	Pre	Post	Change	Pre	Post	Change
Constant									
parameter	0.2727	0.3533	0.0806	0.3583	0.2952	-0.0630	0.2467	0.2023	-0.0444
t-stat	10.9556	11.2010	3.0653*	11.6622	10.6321	-1.7547	9.3236	9.2759	-2.7126*
Slope									
parameter	0.0034	-0.0549	-0.0582	-0.0576	-0.0591	-0.0015	-0.0439	-0.0423	0.0016
t-stat	0.0710	-1.4405	-0.9270	-1.1650	-1.8167	-0.0288	-1.0864	-1.3095	0.0356

* denotes significance at 5% level.

This table reports the parameter estimates from the following second-pass regression:

$$AdjR^2_{iLE} = \beta_{i0} + \beta_{i1} ln(1 + L^{-1}) + \beta_{i2}\left(Dummy_{iE} \cdot ln(1 + L^{-1})\right) + \beta_{i3}(Dummy_{iE}) + u_{iLE} \qquad i=1,...n \quad L=1,...10, 15, 20 \quad E=1,2$$

where $AdjR^2_{iLE}$ is the adjusted R-square for stock i, calculated using a L-day return interval during either the pre or post-event period (E). $Dummy_{iE}$ is set to 1 if the observation is in the post-event period, and 0 for the pre-event period. L is the return interval used in the first-pass regression. u_{iLE} is the stochastic error term. The sample stocks are sorted into quintiles according to their average daily turnover during the study period. Quintile 1 represents the most liquid stocks, and quintile 5 contains the most illiquid. The slope captures the relationship between the first-pass adjusted R-square and the transformed return intervals. The constant can be thought of as an asymptotic R-square.

Table 4.6 R-squared regression dummy coefficient

Quintile	negative and significant		not statistically sig		positive and significant	
	freq count	% of total freq	freq count	% of total freq	freq count	% of total freq
1	14	25	6	10.7143	36	64.2857
2	19	33.9286	8	14.2857	29	51.7857
3	20	35.7143	12	21.4286	24	42.8571
4	30	53.5714	11	19.6429	15	26.7857
5	20	35.0877	21	36.8421	16	28.0702
overall	103	36.6548	58	20.6406	120	42.7046

This frequency table presents the results of β_{i3}in the second-pass regression:

$AdjR^2_{iLE} = \beta_{i0} + \beta_{i1} ln(1 + L^{-1}) + \beta_{i2}\left(Dummy_{iE} \cdot ln(1 + L^{-1})\right) + \beta_{i3}(Dummy_{iE}) + u_{iLE}$ i=1,...n L=1,...10, 15, 20 E=1,2

where $AdjR^2_{iLE}$ is the adjusted R-square for stock i, calculated using a L-day return interval during either the pre or post-event period (E). $Dummy_{iE}$ is set to 1 if the observation is in the post-event period, and 0 for the pre-event period. L is the return interval used in the first-pass regression. u_{iLE} is the stochastic error term.

For the full sample and each quintile, β_{i3} is classified as: statistically significant and negative, not statistically significant, and statistically significant and positive. The level of significance is 5%.

Table 4.7 RRD

	Full sample			Quintile 1			Quintile 2		
	Pre	Post	Change	Pre	Post	Change	Pre	Post	Change
mean	0.0028	0.0007	-0.0021	0.0125	0.0007	-0.0118	0.0029	0.0008	-0.0021
median	0.0011	0.0007	-0.0004	0.0012	0.0005	-0.0007	0.0012	0.0005	-0.0006
s.d.	0.0123	0.0004	0.0229	0.0676	0.0004	0.0675	0.0087	0.0008	0.0088
t-stat	2.42	22.11	-2.11*	1.38	11.31	-1.31	2.48	7.37	-1.75

	Quintile 3			Quintile 4			Quintile 5		
	Pre	Post	Change	Pre	Post	Change	Pre	Post	Change
mean	0.0031	0.0006	-0.0025	0.0011	0.0008	-0.0003	0.0012	0.0007	-0.0005
median	0.0012	0.0005	-0.0008	0.0008	0.0006	-0.0002	0.0008	0.0006	-0.0002
s.d.	0.0111	0.0004	0.0112	0.0013	0.0006	0.0016	0.0014	0.0003	0.0015
t-stat	2.07	11.25	-1.64	6.45	10.51	-1.54	6.45	15.58	-2.46*

*significant at the 5% level

This table contains the RRD statistics calculated for the pre and post-event periods for the full sample and five liquidity sorted groups according to average daily turnover. Quintile 1 represents the most active. Quintile 5 is the least active. The RRD is calculated using 120 trading days prior and 120 trading days subsequent to the introduction of the closing call auction. The Relative Return Dispersion (RRD) coefficient is calculated as:

$$RRD_{Ed} = \left(\frac{1}{n}\right)\sum_{i=1}^{n} e_{iEd}^{2}$$

Where RRD_{Ed} is the average relative return dispersion coefficient on day d, obtained using all *i* stock samples. *n* is the number of stocks in the sample on day *d*. e_{iEd}^{2} is the squared market model (equation 3) residuals of security *i* on day *d*.

Figures

Figure 2.1 The intraday proportional bid-Ask spread

This figure depicts the average proportional bid-ask spreads (%) across each five-minute time interval for 723 A-share stocks during five trading days before and five trading days after July 1, 2006.

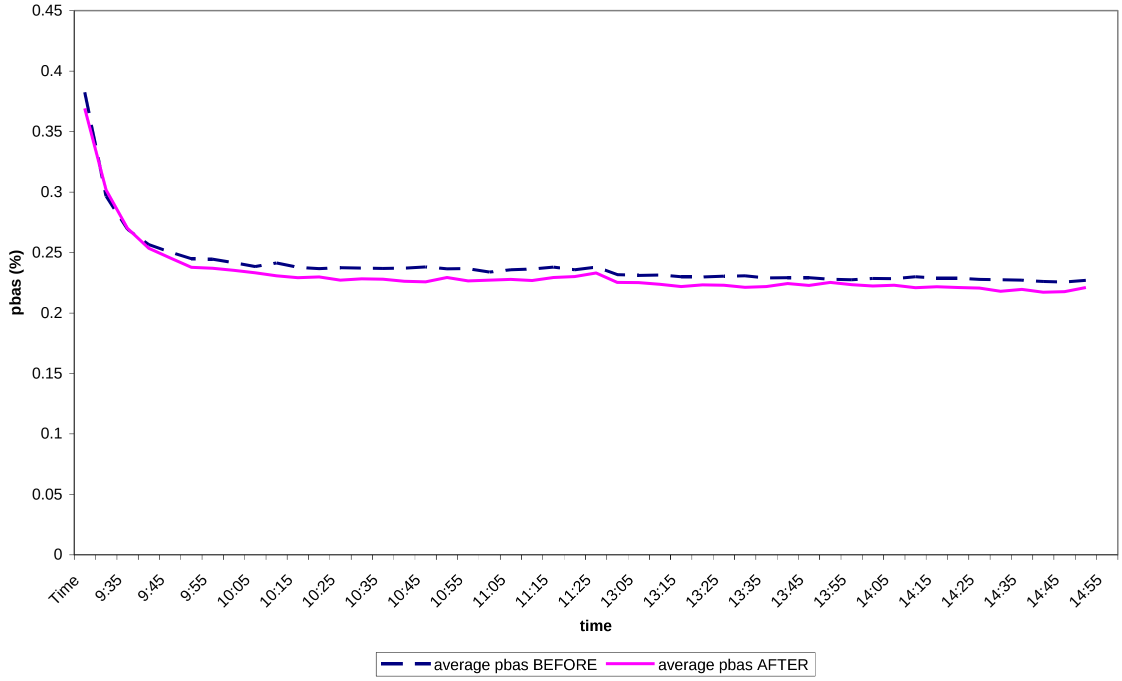


Figure 2.2 The intraday depth

This figure depicts the average depth across each five-minute time interval for 723 A-share stocks during five trading days before and five trading days after July 1, 2006. Depth is the sum of the volume at the best bid and ask quotes.

Figure 2.3 The intraday volatility

This figure depicts the average volatility across each five-minute time interval for 723 A-share stocks during five trading days before and five trading days after July 1, 2006. *Volatility* is a Parkinson's volatility measure.

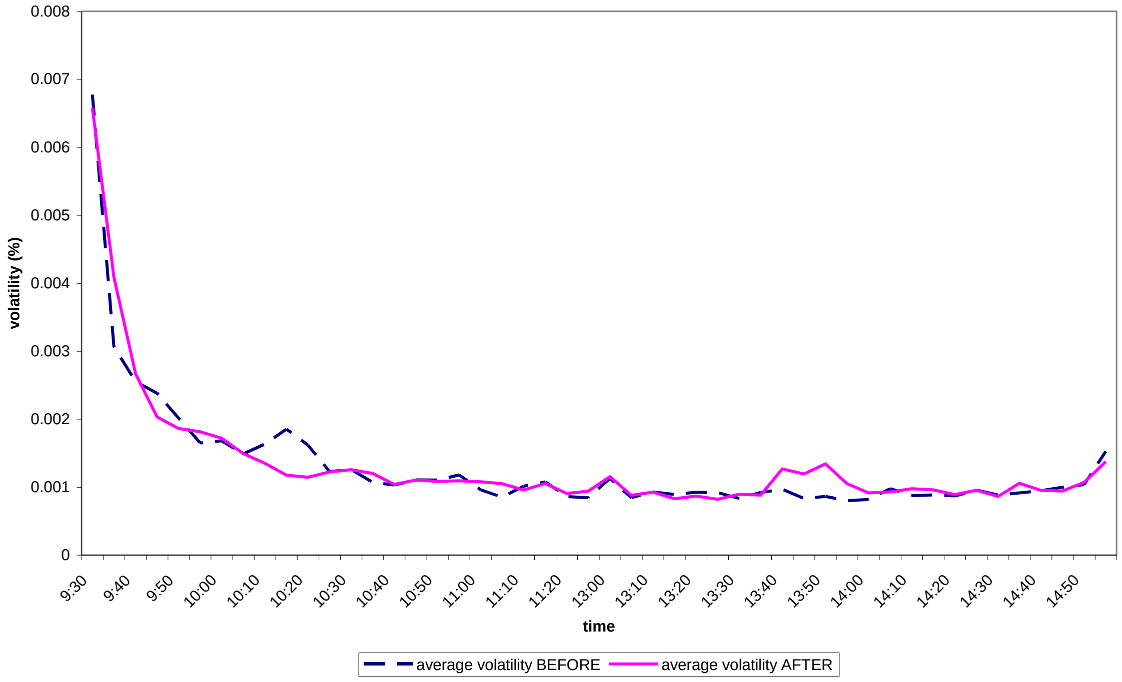


Figure 2.4 The intraday volume

This figure depicts the average volume across each five-minute time interval for 723 A-share stocks during five trading days before and five trading days after July 1, 2006.

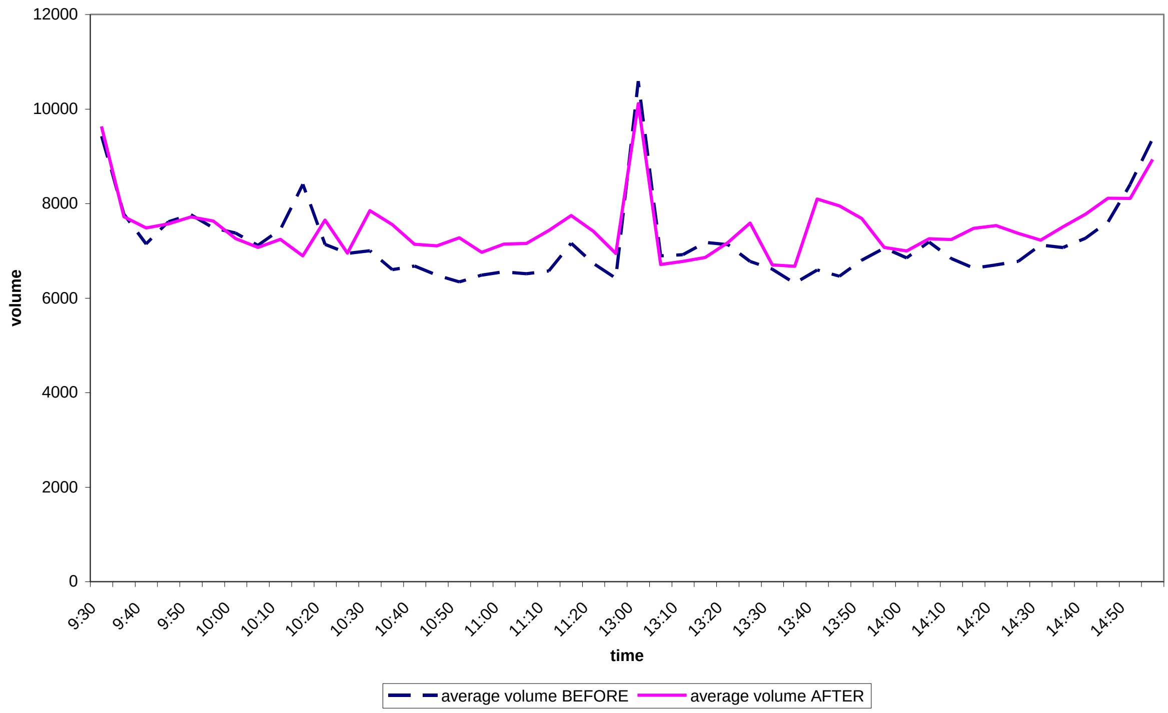


Figure 2.5 The intraday proportional volume

This figure depicts the average proportional volume across each five-minute time interval for 723 A-share stocks during five trading days before and five trading days after July 1, 2006. Proportional volume is the ratio of individual transacted volume divided by daily volume.

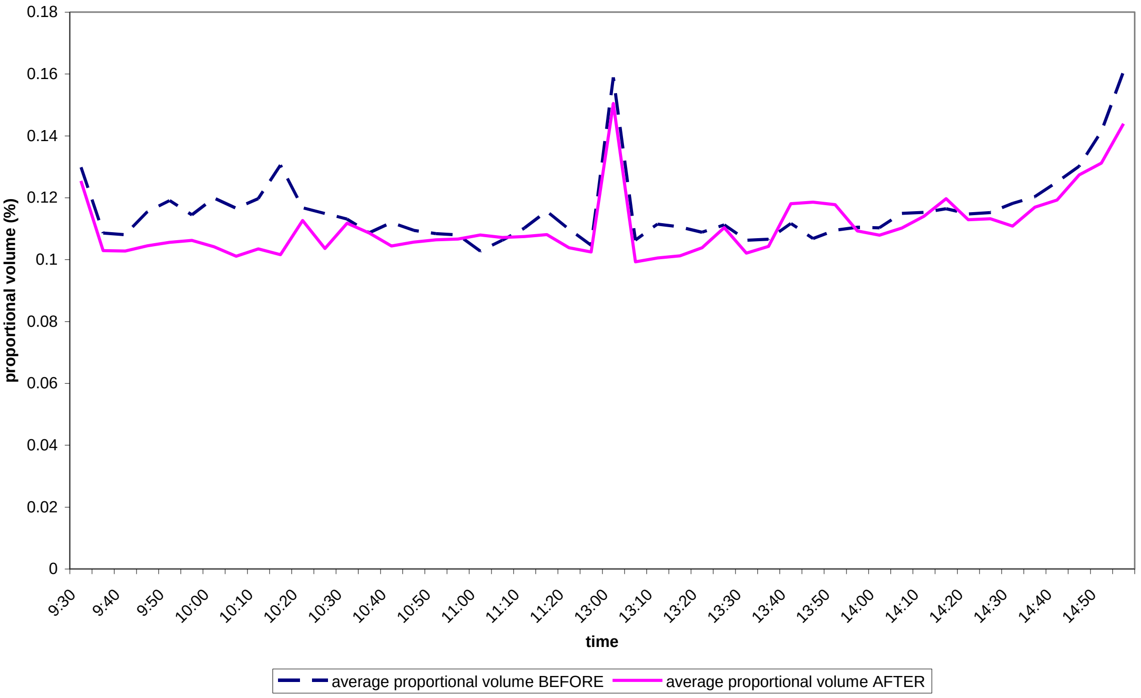


Figure 3.1 Mean WPC across the trading day

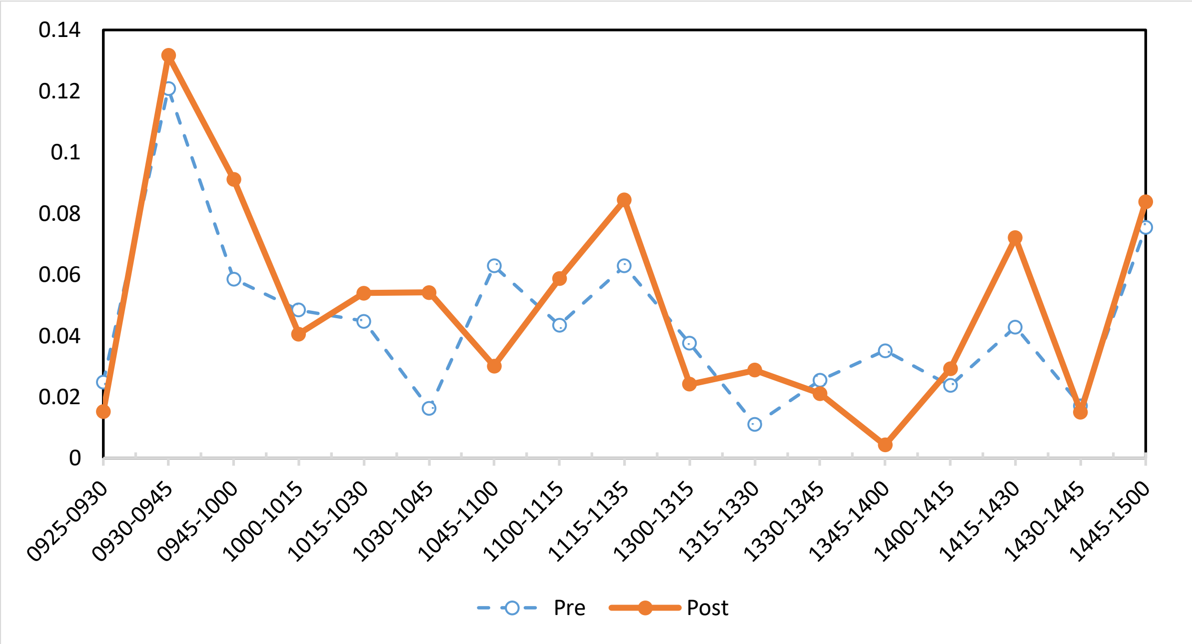
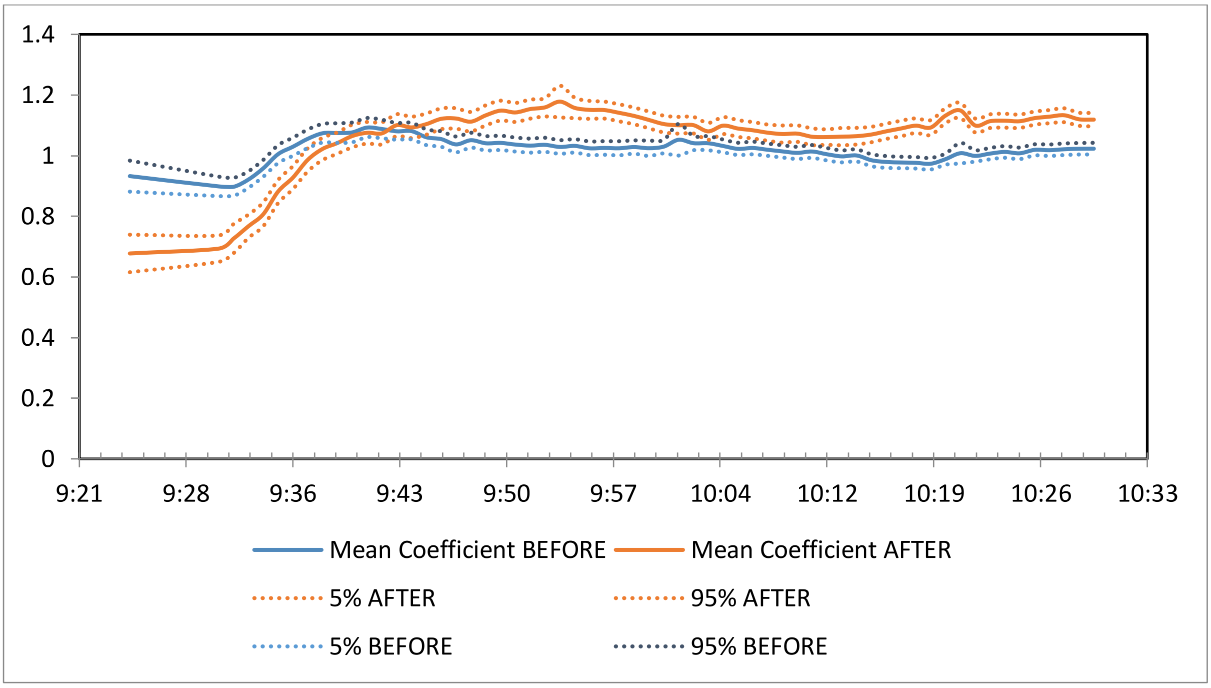
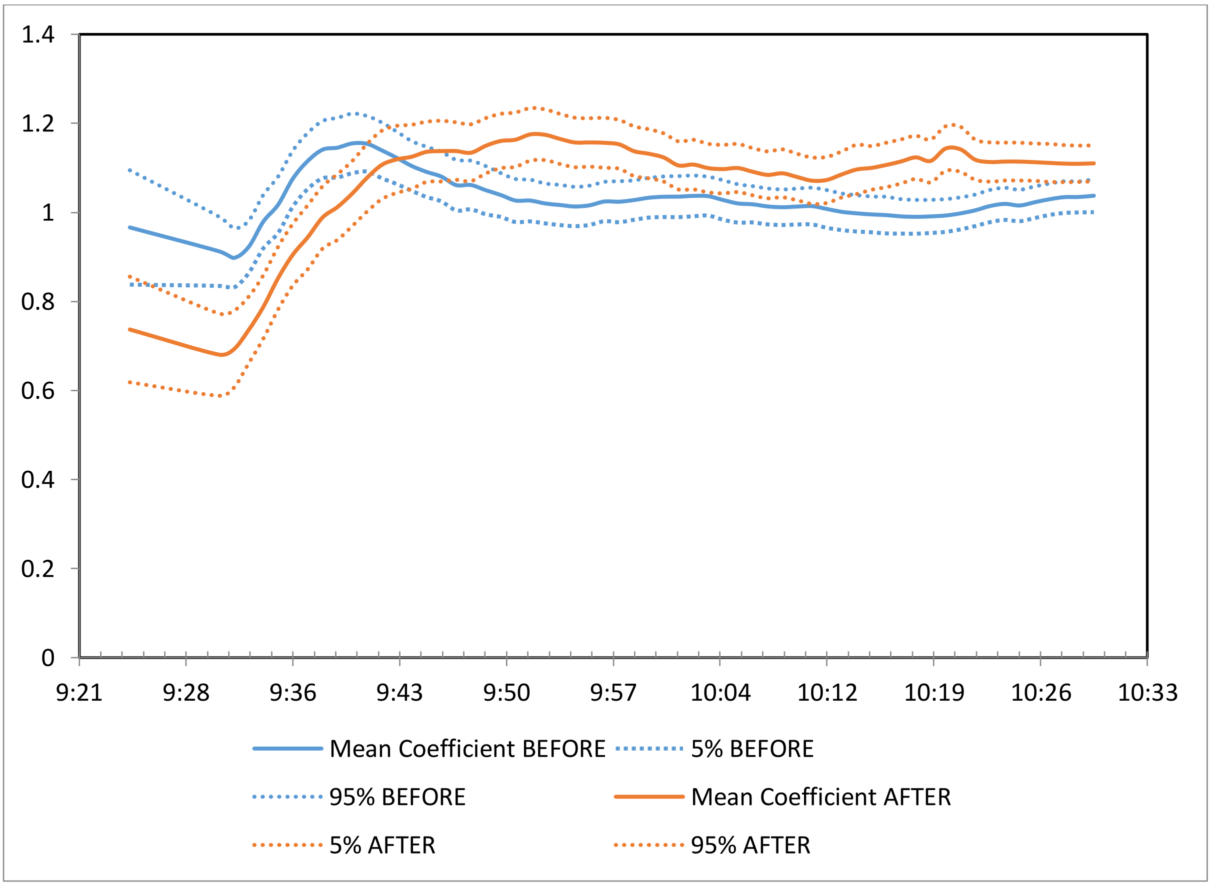


Figure 3.2 β estimates of unbiasedness regressions.

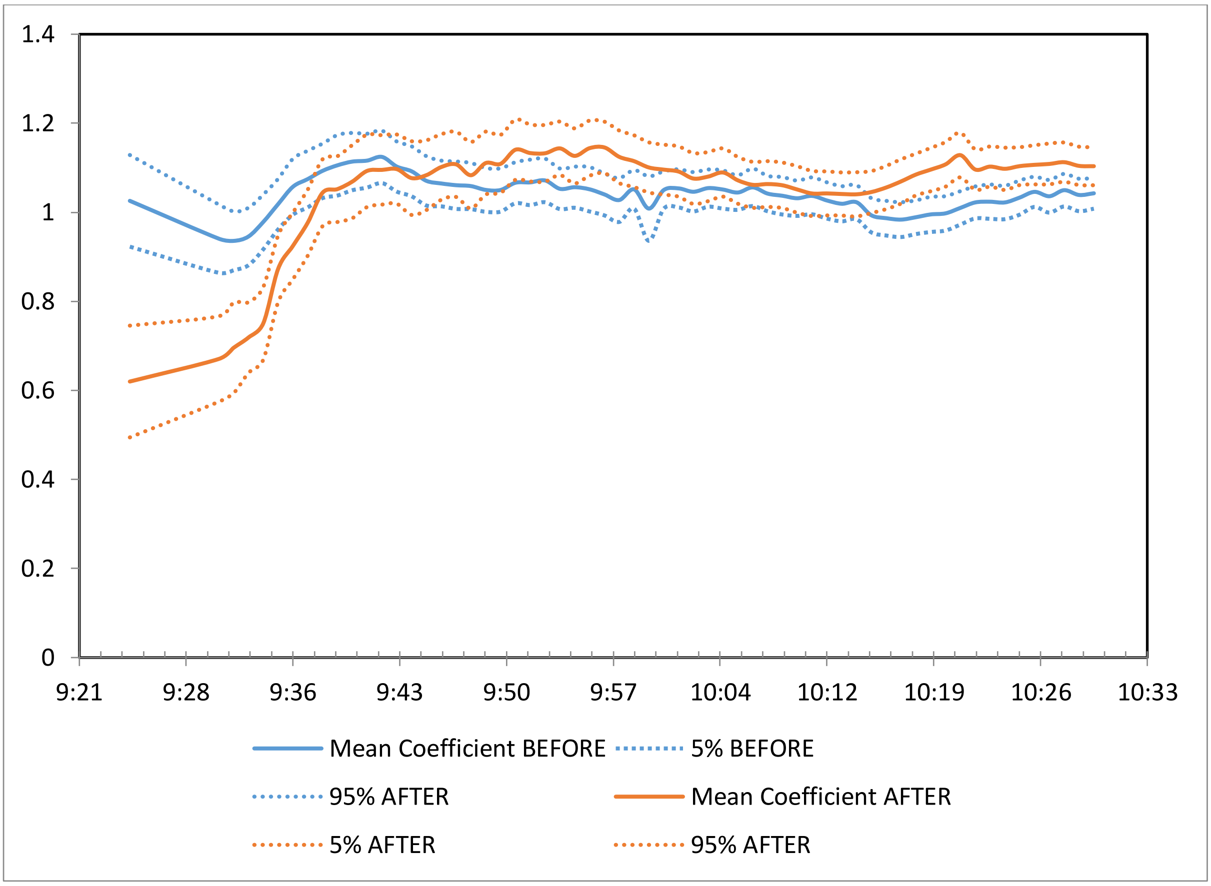
Graph 1 Overall



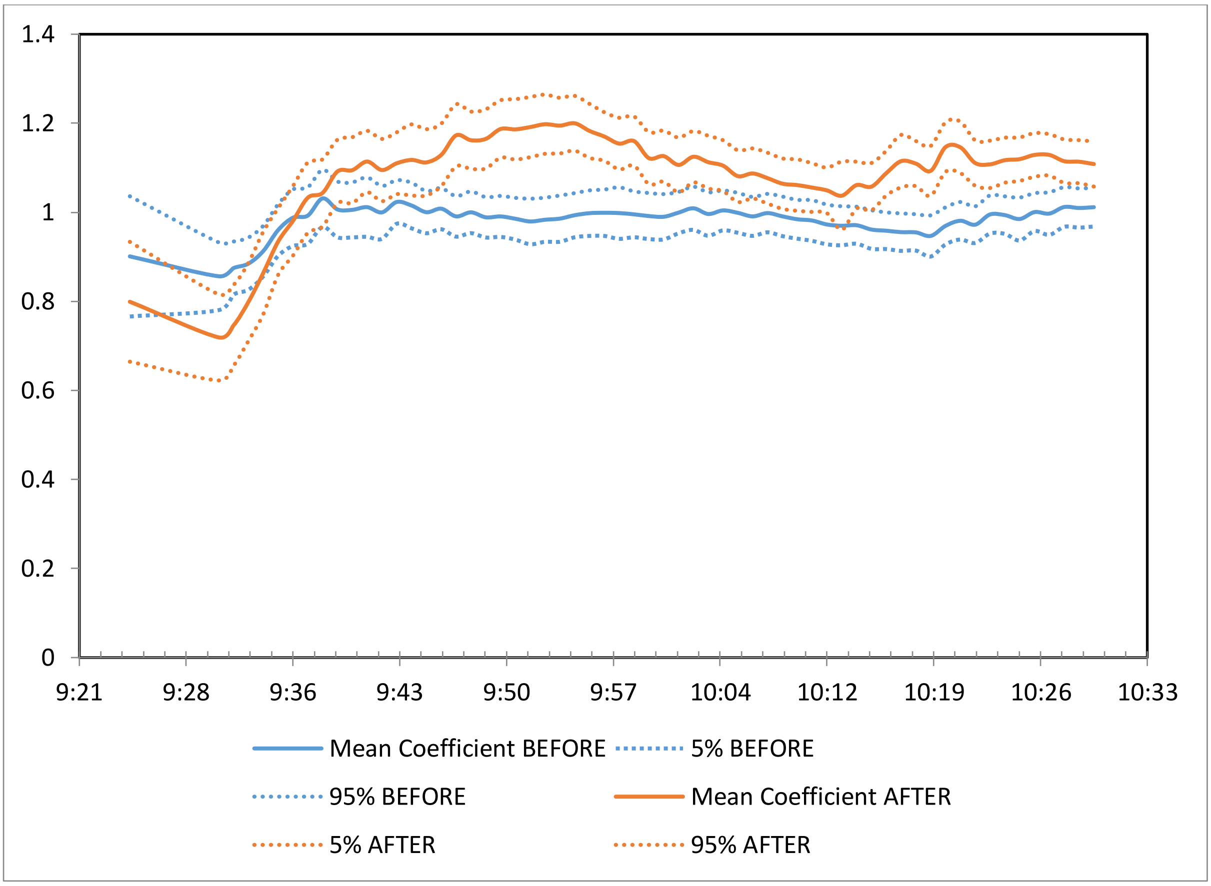
Graph 2 Quintile 1 (highest)



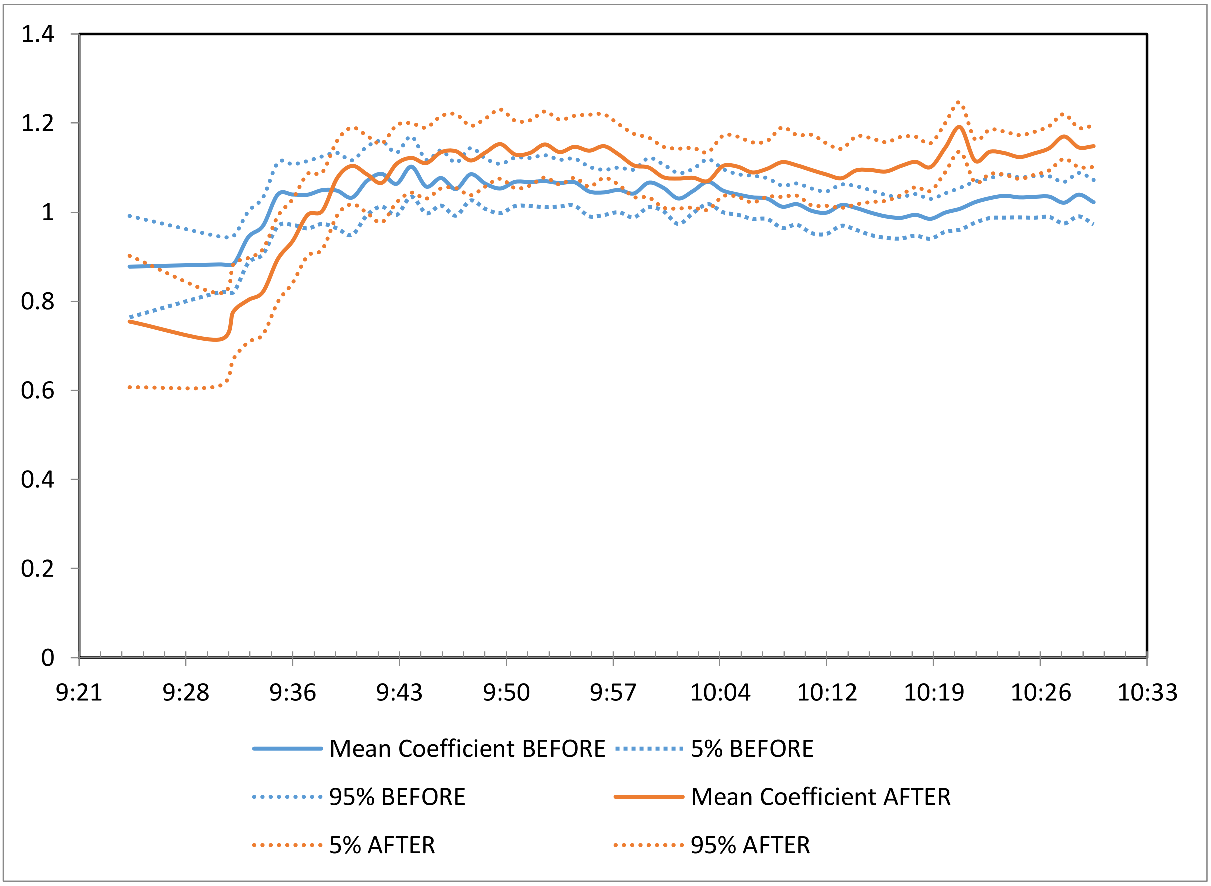
Graph 3 Quintile 2



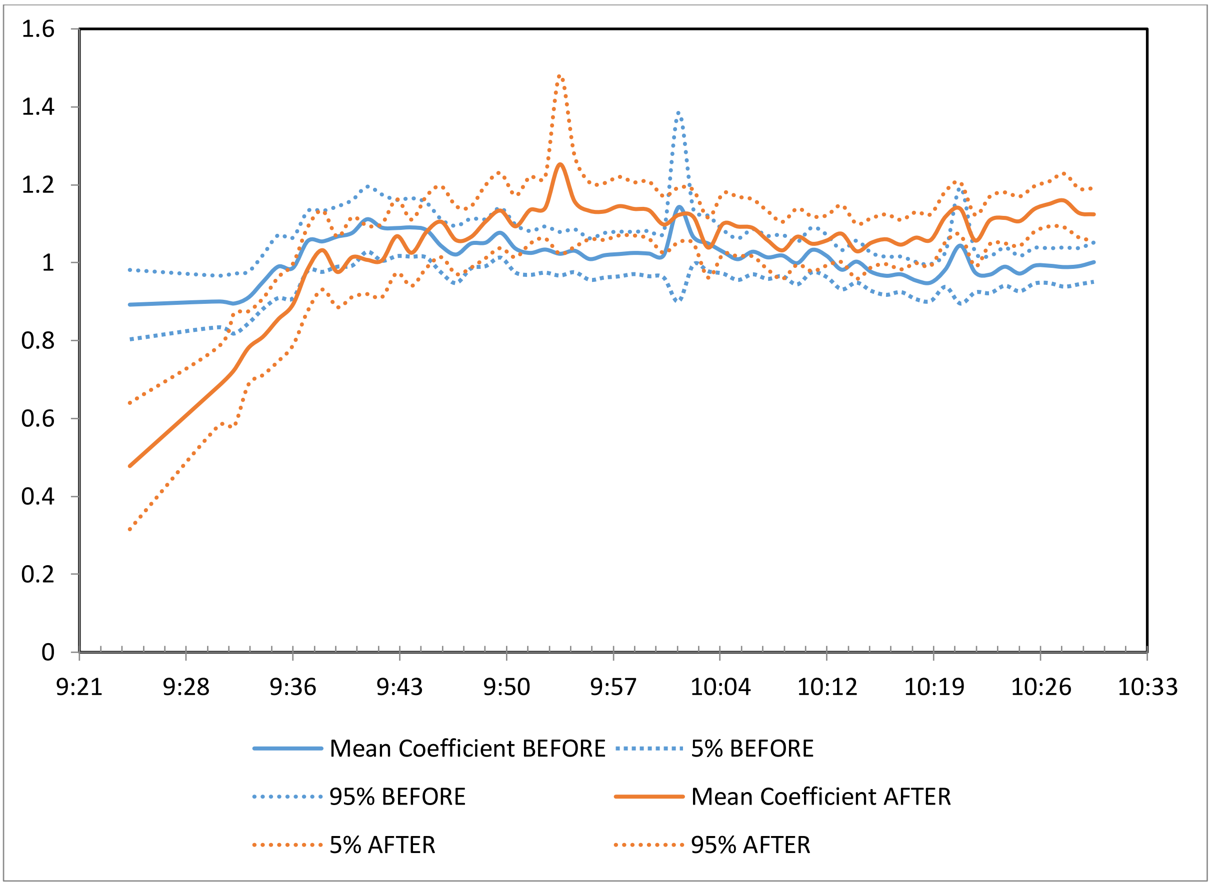
Graph 4 Quintile 3



Graph 5 Quintile 4



Graph 6 Quintile 5



Unbiasedness regressions are performed for each 1 minute period from 0925 to 1030 for 780 A-share stocks listed on the SSE. For each stock and each one minute time period, I regress the daily close-to-close return (ret_{cc}) on the return from the previous close to the end of that time period i (ret_{ci}):

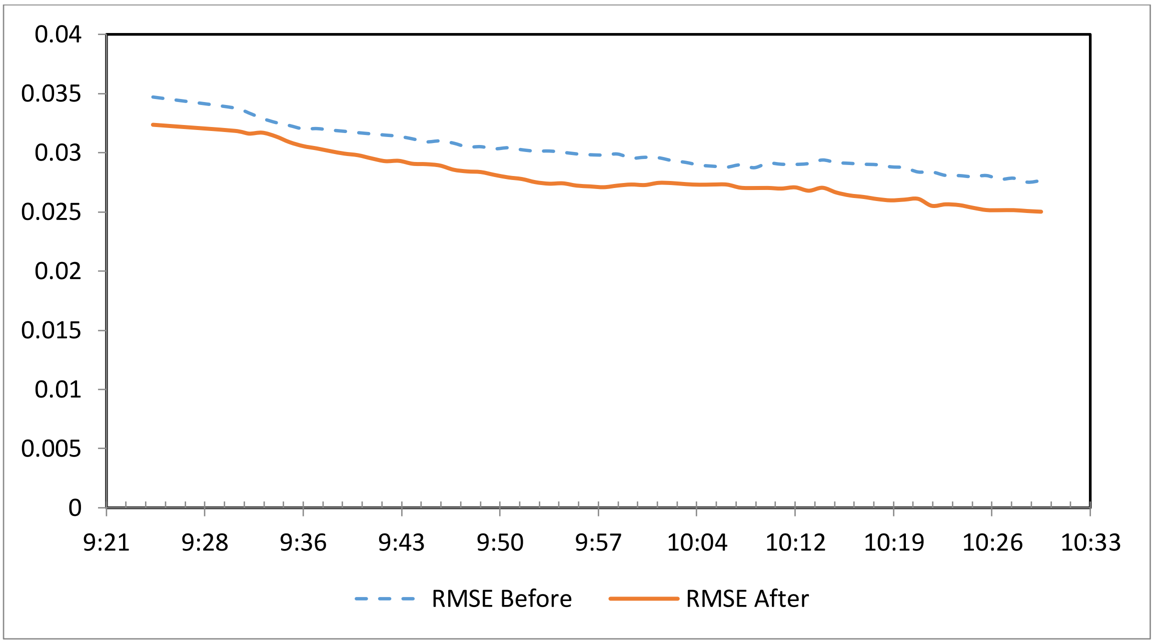
$$ret_{cc} = \alpha + \beta \times ret_{ci} + \varepsilon_i$$

The five week pre-event sample period runs from 29 May 2006 to 30 June 2006, and the post-event sample period is from 01 July 2006 to 04 August 2006. Sample stocks are further sorted into quintiles based on their average trade volume during the study period. Quintile 1 represents the most liquid stocks, and quintile 5 contains the most illiquid.

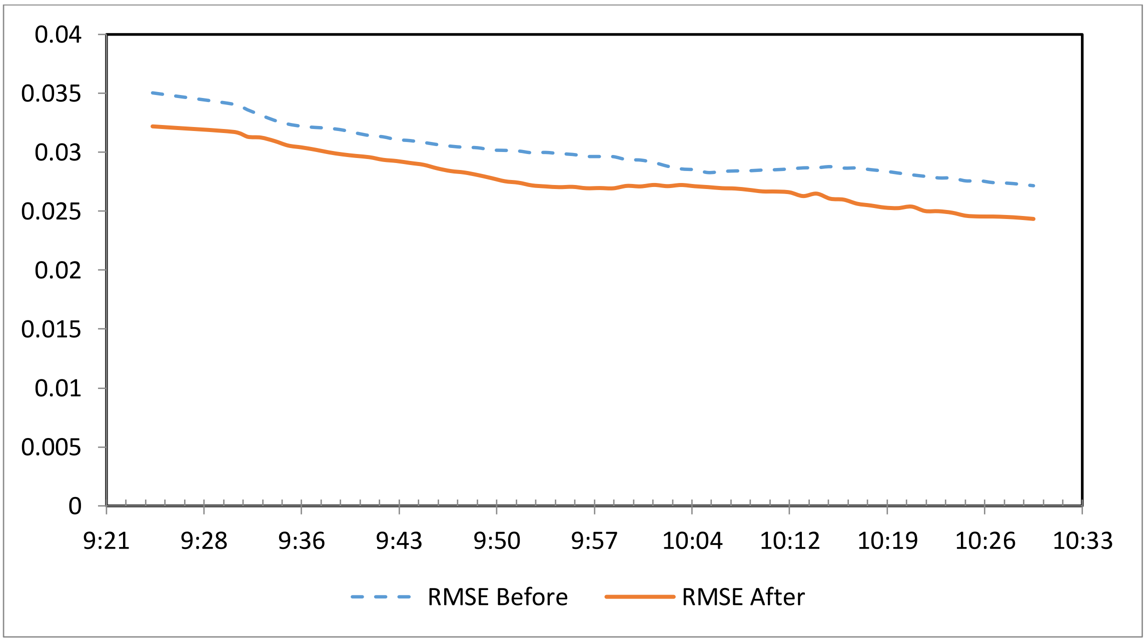
Mean value of the β estimates are plotted for the total sample and then for each quintile. 5% confidence intervals are calculated using the time series standard errors of the mean coefficient estimates.

Figure 3.3 RMSE of unbiasedness regressions.

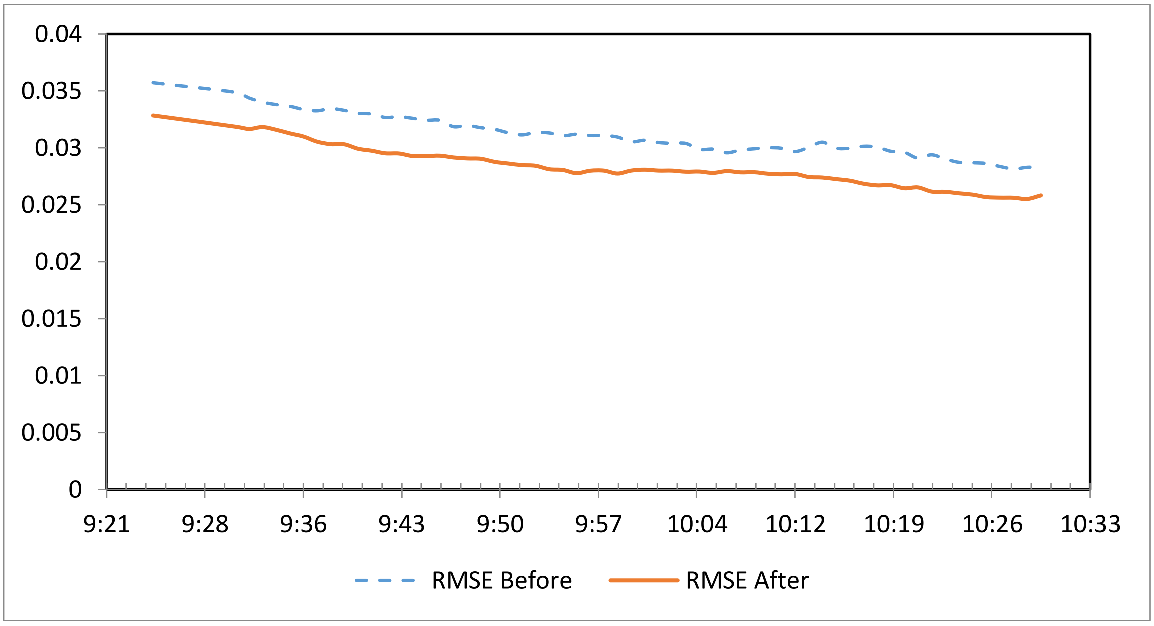
Graph 1 Overall



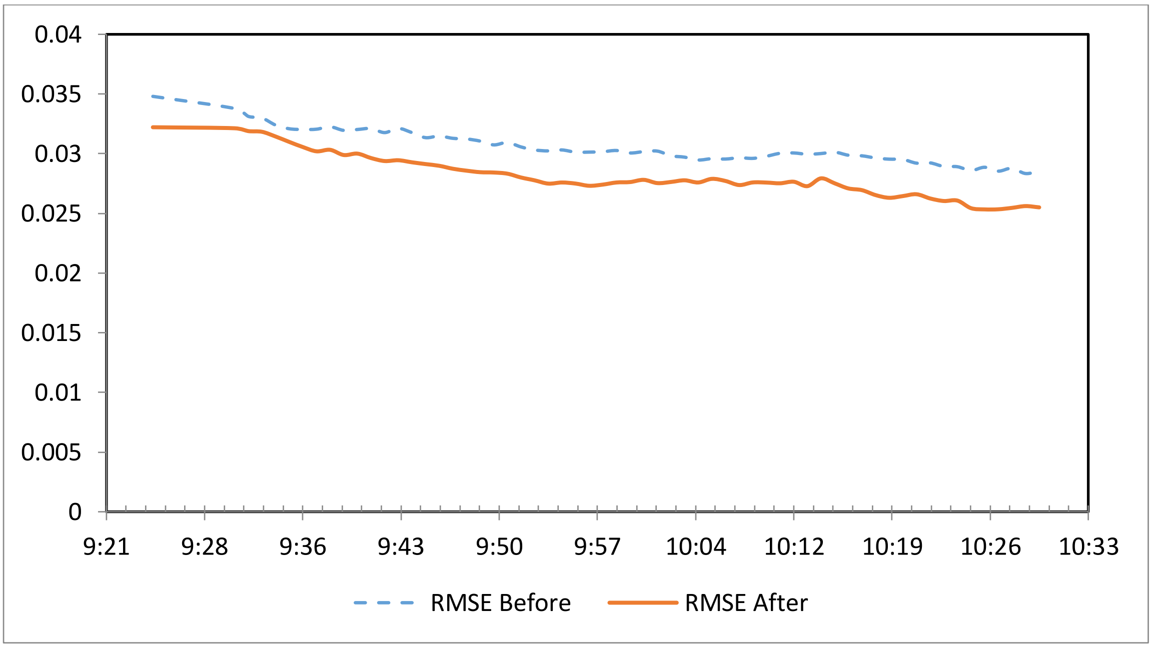
Graph 2 Quintile 1 (highest)



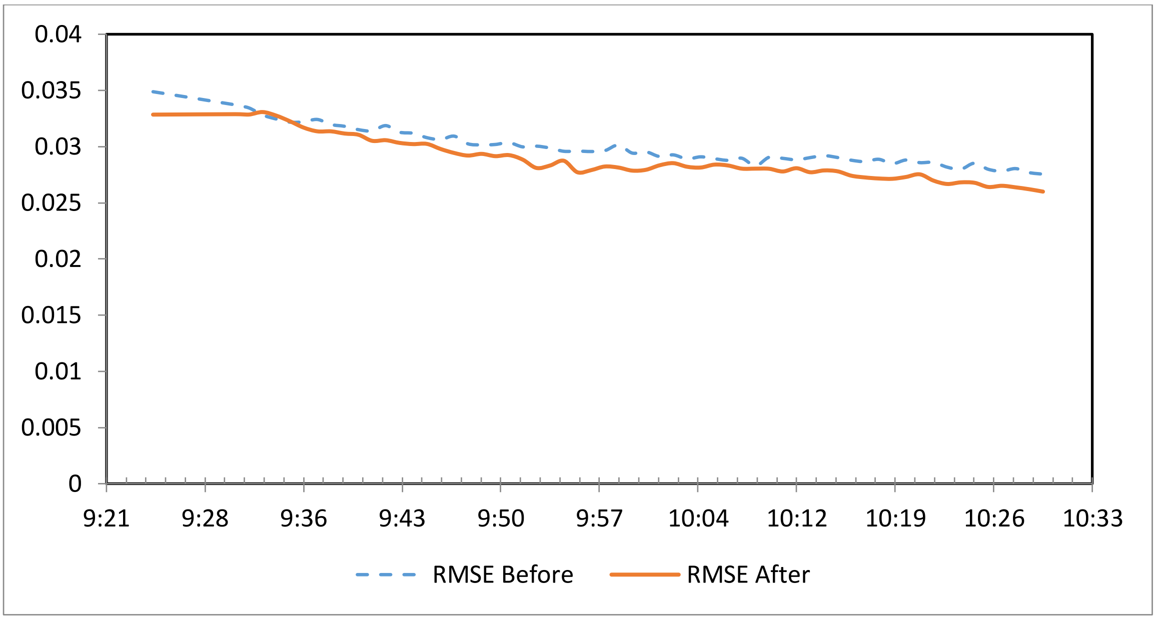
Graph 3 Quintile 2



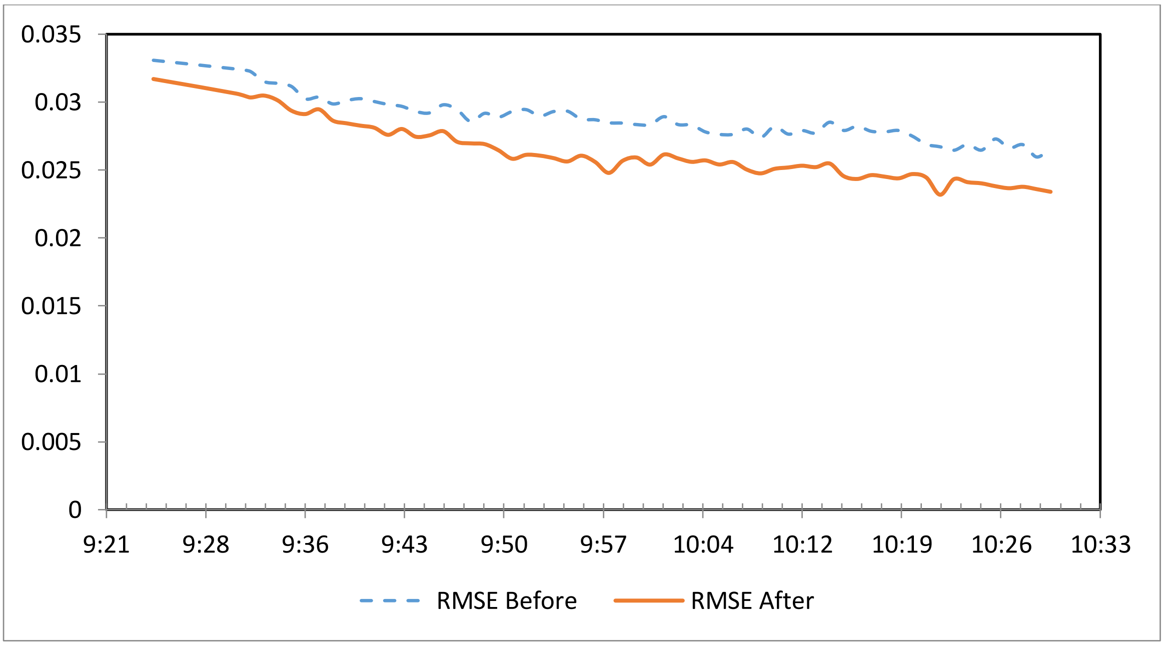
Graph 4 Quintile 3



Graph 5 Quintile 4



Graph 6 Quintile 5



Unbiasedness regressions are performed for each 1 minute period from 0925 to 1030 for 780 A-share stocks listed on the SSE. For each stock and each one minute time period, I regress the daily close-to-close return (ret_{cc}) on the return from the previous close to the end of that time period i (ret_{ci}):

$$ret_{cc} = \alpha + \beta \text{ x } ret_{ci} + \varepsilon_i$$

The five week pre-event sample period runs from 29 May 2006 to 30 June 2006, and the post-event sample period is from 01 July 2006 to 04 August 2006. Sample stocks are further sorted into quintiles based on their average trade volume during the study period. Quintile 1 represents the most liquid stocks, and quintile 5 contains the most illiquid.

Root mean standard errors (RMSE) are plotted for the total sample and then for each quintile.