Center for Quantitative Economics

An Empirical Analysis of the Shanghai and Shenzhen Limit Order Books

Huimin Chung[†], Jie Lu and Bruce Mizrach[‡]

1/2009

[†] Graduate Institute of Finance, National Chiao Tung University, Taiwan

[‡] Department of Economics, Rutgers University, USA

wissen.leben
WWU Münster

An Empirical Analysis of the Shanghai and Shenzhen Limit Order Books

Huimin Chung
Graduate Institute of Finance
National Chiao Tung University

Jie Lu
and
Bruce Mizrach*

Department of Economics
Rutgers University

September 2009

Abstract:

This paper investigates the market microstructure of the Shanghai and Shenzhen Stock Exchanges. The two major Chinese stock markets are pure order-driven trading mechanisms without market makers, and we analyze empirically both limit order books. We begin our empirical modeling using the vector autoregressive model of Hasbrouck and extend the model to incorporate other information in the limit order book. We also study the market impact on A shares, B shares and H shares, and analyze how the market impact of stocks varies cross sectionally with market capitalization, tick frequencies, and turnover. Furthermore, we distinguish the market impacts of small, average and block trades, and conclude that the market impacts of small trades are significantly lower than those of other trades.

Keywords: limit order book; Chinese stock market; microstructure; VAR model

JEL Codes: G14;

* Corresponding author: Bruce Mizrach, Department of Economics, Rutgers University, New Brunswick, NJ 08901, mizrach@econ.rutgers.edu. We would like to thank Enzo Weber and participants at the Chinese Financial Markets and the World Economy conference at the Bank of Finland for helpful comments.

1. Introduction

There are two stock exchanges in mainland China. The Shanghai Stock Exchange was founded on November 26, 1990 and trading began on December 19,1990. The Shenzhen Stock Exchange started stock trading on December 1, 1990. After the first year of trading, the market capitalization, including all shares in Shanghai Stock Exchange and Shenzhen Stock Exchange, was only about three billion Renminbi (RMB). Shanghai had only eight listings, and had a daily average turnover of only 18 million RMB.

Since these modest beginnings, both markets have seen impressive growth. By December 2007, Shanghai Stock Exchange's market capitalization ranked sixth worldwide and Shenzhen ranked 20th. Their combined market capitalization of $32,714$ billion RMB ($4,474$ billion USD) was the second largest globally after the United States. There are more than $1,600$ listings on the two markets, and combined daily average trading volume exceed 100 billion RMB.

After peaking in 2007-8, the markets have fallen by more than half. The Shanghai Stock Exchange Composite Index (SSEC), which once reached $6,092$ in October 2007, retreated to $1,821$ at the end of 2008. The Shenzhen Composite Index closed 2008 at 553.02, after peaking at $1,576.501$ on January 15, 2008. The combined loss in market value in 2008 was over $20,000$ RMB billion, a loss of almost 63%.

[Insert Table 1 Here]

The trading mechanism of the stock market in mainland China is similar to that of the Hong Kong or Tokyo Stock Exchanges. Both Shanghai and Shenzhen run a pure order-driven trading mechanism on electronic systems without official market makers. Trading is conducted from Monday to Friday, except holidays. For each trading day, there is a morning session and afternoon session. The morning session includes one pre-trading auction 9:15-9:25 AM and one continuous trading period 9:30-11:30 AM. The afternoon session includes only one continuous trading period 13:00-15:00. Only limit orders and market orders are allowed in both exchanges and orders are filled following price, time and size priority. The limit of price change for each trading day is $\pm 10\%$ of the previous closing price, beyond which, trading will be halted for the rest of the day. The quantity of stock purchased must be in round lots of 100 while there is no requirement on the quantity of sales.

There are three types of shares in the market, A shares that are denominated in Renminbi,

H shares that are denominated in Hong Kong Dollar (HKD) and B shares that are dominated by U.S. Dollar (USD). H shares are only traded in Shenzhen Stock Exchange while B shares are only traded in Shanghai Stock Exchange. A shares are traded in both exchanges. Domestic investors can trade all 3 types of shares while the foreign investors only have access to B shares and H shares. The minimum tick size for A shares, B shares and H shares are 0.01RMB, 0.001USD and 0.01HKD, respectively.

[Insert Table 2 Here]

There is a limited literature about the microstructure of the Chinese stock market, but only a few papers analyze intraday limit order book information. Xu (2000) discussed the trading mechanism of Chinese stock market but the paper's quantitative study focused on stocks's daily returns. As to limit order book, Shenoy and Zhang (2007) studied the relationship between daily order imbalance from limit order book and daily stock returns. Bailey, Cai, Cheung and Wang (2006) separated the order imbalance from individual, institutional and proprietary investors and investigated the various influences of different traders. As far as we know, this is the first paper to apply vector autoregressive model into analyzing the intraday quotes and limit order book in Chinese stock market.

This paper studies the market impact of limit order book information in Chinese stock markets. Section 2 introduces the data and basic statistics. Section 3 specifies the baseline Hasbrouck model and reports the market impact of quotes and trades on stock prices. In Section 4, we extend the model to incorporate other information on limit order book and assess the market impact of one buy order in our limit order book model. Section 5 studies the relationship between market impacts and microstructure characteristics. Section 6 pays particular attention to small and block order market impacts. Section 7 concludes.

2. Data

We have the limit order book information on $1,652$ Chinese stocks for the month of June 2007, including all A shares, B shares and H shares traded on Shanghai Stock Exchange and Shenzhen Stock Exchange during the sample period. In this limit order book, we have trade-driven data with 5 bids and 5 asks with quantities, with updates no faster than every second. The trades are not combined with each other even if they happened on the same price at the same time. We report

summary statistics on the three share classes in Table 3.

[Insert Table 3 Here]

A shares' median price in our data set is 12.26 RMB, while the median prices of B shares and H shares are 0.998 USD (about 6.78 RMB) and 6.65 HKD (about 5.86 RMB), respectively. As to market cap, the median market cap of A share is $1,964$ RMB (mn), higher than that of B shares, 201 USD (mn) or about $1,367$ RMB (mn), and that of H shares, 999 HKD (mn), or about 879 RMB (mn). A shares have much higher turnover 0.0537 than H shares and B shares, whose turnover rate are both around 0.0202. This is in accordance with the common understanding that A shares are traded much more actively than B shares and H shares.

3. Hasbrouck Model

Hasbrouck's vector autoregressive model (1991) is regarded as the standard model in analyzing intraday quotes and trades of a limit order book. According to Hasbrouck's theory, the ultimate price impact of a trade can meaningfully measure the trade's information effect.

We begin our empirical modeling of Chinese stock market's limit order book using of Hasbrouck's model. Let r_t be the percentage change in the midpoint of the bid-ask spread, $\log((p_t^b + p_t^a)/2) - \log((p_{t-1}^b + p_{t-1}^a)/2)$. Let x_t denote the sequence of signed trades, where trade initiation is determined by the distance from the the bid-ask midpoint. A transaction is considered to be a buy (sell) and is signed $+1$ (-1) if it is initiated by a buy(sell) order. The quote revision model is specified as

$$r_t = a_{r,0} + \sum_{i=1}^{M} a_{r,i} r_{t-i} + \sum_{i=0}^{M} b_{r,i} x_{t-i} + \varepsilon_{r,t}, \tag{1}$$

$$x_t = a_{x,0} + \sum_{i=1}^{M} a_{x,i} r_{t-i} + \sum_{i=1}^{M} b_{x,i} x_{t-i} + \varepsilon_{x,t}. \tag{2}$$

where M is the average length in ticks corresponding to roughly 3 minutes. Market impact, which indicates the trade's information effect, is determined by the arrival of a buy order to the market,

$$\partial r_{t+s} / \partial x_t. \tag{3}$$

We apply the model to our data set and limit our sample to stocks that trade at least $1,000,000$ shares in the trading month. The market impact of a trade is summarized across different share classes and market caps in Table 4.

[Insert Table 4 Here]

Based on Hasbrouck's model, the median market impact $5 \times M$ periods ahead is 0.1367% on price. This means, on average, a buy trade increases the quote midpoint of the stock by 0.1367% after $5 \times M$ periods.

A shares' median market impact is 0.1374%. Since A shares include much more stocks than B shares and H shares, we should consider A shares as a large sample whose market impact range $(0.0006\%, 3.24\%)$ contains B shares' $(0.006\%, 0.5\%)$ and H shares' $(0.036\%, 1.2\%)$. Thus, we cannot simply compare A shares with B shares or H shares.

B shares has lower median market impact 0.0993% than H shares' 0.1594%, indicating that the average trade's price impact in B shares is lower than that in H shares. The reason will be explained in Section 5.

4. An Empirical Model of the Limit Order Book

In this section, we extend the VAR model as in Mizrach (2008) to incorporate more details in the limit order book, beyond the inside quote and apply the model to our data set.

Let $p^b_{k,t}$ be the bid on the tier k of the quote montage at time t, and let $p^a_{k,t}$ be the corresponding quote on the tier k of the ask. The posted depths of each participant are denoted by $q^b_{k,t}$ and $q^a_{k,t}$. Now we incorporate the entire book of quotes and depths into an extended specification for the VAR,

$$\begin{aligned} r_t &= a_{r,0} + \textstyle\sum_{i=1}^{M} a_{r,i} r_{t-i} + \sum_{i=0}^{M} b_{r,i} x_{t-i} \\ &\quad + \textstyle\sum_{i=1}^{M} \sum_{k=1}^{5} \beta_{r,k} (q^b_{k,t-i} - q^a_{k,t-i}) + \varepsilon_{r,t}, \end{aligned} \tag{4}$$

$$\begin{aligned} x_t &= a_{x,0} + \textstyle\sum_{i=1}^{M} a_{x,i} r_{t-i} + \sum_{i=1}^{M} b_{x,i} x_{t-i} \\ &\quad + \textstyle\sum_{i=1}^{M} \sum_{k=1}^{5} \beta_{x,k} (q^b_{k,t-i} - q^a_{k,t-i}) + \varepsilon_{x,t}. \end{aligned} \tag{5}$$

$$\begin{aligned} q^b_{k,t} - q^a_{k,t} &= a_{i,0} + \textstyle\sum_{i=1}^{M} a_{n,i} r_{t-i} + \sum_{i=1}^{M} b_{n,i} x_{t-i} \\ &\quad + \textstyle\sum_{i=1}^{M} \sum_{k=1}^{5} \beta_{1,i} (q^b_{k,t-i} - q^a_{k,t-i}) + \varepsilon_{q,k,t}, k = 1, ..., 5. \end{aligned} \tag{6}$$

where M is the average length in ticks corresponding to roughly 3 minutes.

The 3 variable VAR is now given by (4), (5), (6). While there are about $7 \times M$ parameters in each equation, the large data sample makes the estimation feasible.

We then use this system to examine the effects over the next $5 \times M$ periods of a net one unit buy, $x_t = 1$. We still limit our sample to stocks that trade at least $1,000,000$ shares in the trading month. The estimates are summarized in Table 5.

[Insert Table 5 Here]

In the extended model, the median market impact $5 \times M$ periods ahead is 0.1021% on price, less than that of Hasbrouck's model, but the $5\% - 95\%$ range of market impact, $0.0086\% - 0.4343\%$, is larger than that of Hasbrouck model, $0.0098\% - 0.4192\%$. A shares' median market impact is 0.1000%. We still have B shares' median market impact 0.0887% lower than H shares' 0.1531%. We will try to put these results into perspective in the next section.

5. Cross Section Estimation of Market Impact

Hasbrouck (1991) stated that information asymmetries are larger for smaller companies. Mizrach (2008) empirically checked the cross-sectional market impacts on the Nasdaq and found them to be positively related with average price, tick frequency, number of market makers and negatively related with market capitalization.

As for the Chinese markets, we investigated cross-sectional market impacts first for the A shares and fit the following relationship:

[Insert Table 6 Here]

Average price has an insignificant influence in this case, and we omitted it from the final specification. For all A shares, the market impacts are positively related with turnover and market cap while negatively related with tick frequencies within the sample period. Those A share stocks, which have large market cap, high turnover and traded less often, attain higher market impact from transaction.

If we consider A shares, B shares and H shares altogether, market cap becomes insignificant. The market impacts are only positively related with turnover and negatively related with tick frequencies within the sample period. Those stocks with high turnover and traded less often attain higher market impact from transaction. The median number of ticks for B shares is $14,446$ and for H shares, $11,687$. Compared with B shares, H shares have the same turnover but lower tick frequency. Thus H shares' median market impact is larger than B shares, consistent with our

findings in Section 3 and 4.

6. Small Trades and Block Trades

In Hasbrouck's empirical tests, all trade sizes are constrained to have a similar price impact. In this section, we separate the effects of small trades and block trades and attain some interesting findings here.

6.1 Market impact

Ng and Wu (2007) analyzed Chinese individual and institutional investors' trading behaviors from brokerage accounts. According to their survey in 2000-2001 period, the average trading sizes of small individual accounts, middle individual accounts, wealthy individual accounts and institutional accounts are about 650, $2,150, 16,800$ and $111,800$ shares, respectively. Thus, we classify trades with size less than 650 shares as small trades and others as average trades. We report the two results for Hasbrouck's model in the left side of Table 7.

[Insert Table 7 Here]

The median market impact of small trades is 0.0234% , while the median market impact of average trades is larger, 0.1026%.

This conclusion is robust in our empirical models with other limit order book information which appears in the right side of Table 7. The median market impact of small and average trades are 0.0445% and 0.1151%, respectively.

6.2 Effect on returns

To investigate the small market impact of small trades, we also check the relationship between daily order imbalance of small trades and contemporaneous daily return. In Table 8, we show that volume-weighted daily order imbalances of small trades are negatively related with both the contemporaneous daily and next day's returns.

[Insert Table 8 Here]

According to Hasbrouck's analysis, the market impact of a trade is a function of how informed the trader is. Since most small trades are from individual investors, it is reasonable to assume that the small trades are less informed and have smaller market impact.

There is an established literatures on retail investors' poor trading performance. Hvidkjaer (2008) found that small trades are negatively related with a stocks' future performance. Stocks with intensive sell-initiated small trade volume outperform those with intensive buy-initiated small trade volume, from one month to two years later. And Barber, Lee, Liu and Odean (2008) also showed that, in Taiwan's stock market, individual traders' losses are equivalent to 2.2% of Taiwan's GDP. Our empirical findings actually show that small trades, which are mostly conducted by retail investors, may be a magnet for informed traders and result in smaller market impacts.

7. Conclusions and Extensions

In this paper, we investigate the microstructure of the Chinese stock markets and focus on limit order book information. We first compare the Shanghai and Shenzhen Stock Exchange's trading mechanism with other microstructures. We then apply Hasbrouck's vector autoregressive model, and then extend his specification to incorporate more limit order book information. We analyze how the market impact of stocks varies cross sectionally with market capitalization, tick frequencies, and turnover. Furthermore, we distinguish the market impacts in small and average trades. We find that small trades have a proportionally smaller market impact than averages trades.

There is additional work needed on the properties of the limit order book, such as liquidity, depth, and clustering. A direct comparison of price impacts in mainland China to Hong Kong and Tokyo, for stocks of similar size and liquidity, would also provide a useful quantitative perspective.

References

Bailey, Warren, Jun Cai, Yan Leung Cheung, and Fenghua Wang (2006). "Stock returns, order imbalance and commonality: evidence on individual, institutional, and proprietary investors in China," Working Paper 01-27.

Barber, Brad M., Yi-Tsung Lee,Yu-Jane Liu, and Terrance Odean (2008). "Just how much do individual investors lose by trading? " *Review of Financial Studies,* forthcoming.

Cai, Bill M., Charlie X. Cai, and Kevin Keasey (2006). "Which trades move prices in emerging markets?: Evidence from China's stock market" *Pacific-Basin Finance Journal* 14, 453-466.

Comerton-Forde, Carole and James Rydge (2004). "A review of stock market microstructure," SIRCA Research Paper 01-91.

Hasbrouck, Joel (1991). "Measuring the information content of stock trades " *Journal of Finance* 46, 179-207.

Hvidkjaer, Soeren (2008). "Small trades and the cross-section of stock returns," *Review of Financial Studies* 21, 1123-1151.

Mizrach, Bruce (2008). "The next tick on Nasdaq," *Quantitative Finance* 8, 19-40.

Ng, and Wu (2007). "The Trading Behavior of Institutions and individuals n Chinese equity markets, " *Journal of Banking and Finance* 31, 2695–2710.

Shenoy, Catherine, and Ying Jenny Zhang (2007). "Order imbalance and stock returns: Evidence from China," *Quarterly Review of Economics and Finance* 47, 637–650.

Xu, Cheng Kenneth (2000). "The microstructure of the Chinese stock market," *China Economic Review* 11, 79-97.

Table 1
Market Statistics for Shanghai and Shenzhen

	Dec. 2007	**Dec. 2008**
Market cap. (RMB bn):	32,714	12,136
Shanghai	26,984	9,725
Shenzhen	5,730	2,411
Daily avg. trading volume (RMB bn):	147.489	101.473
Shanghai	99.480	68.070
Shenzhen	48.009	33.403
Number of listings	1,530	1,604
Shanghai	860	864
Shenzhen	670	740

Source: World Federation of Exchanges (http://www.world-exchanges.org/statistics). Market capitalization and daily average trading volume are in billions of Renminbi (RMB bn).

Table 2
Comparison of Microstructures

Characteristic	Shanghai/Shenzhen	NYSE	NASDAQ	Tokyo	Hong Kong
Market Type	Order-driven	Hybrid	Hybrid	Order-driven	Order-driven
Floor Trading	No	Yes	No	No	No
Market makers	No	Yes	Yes	No	Yes
Open Hours	09:30-11:30 13:00-15:00	9:30-16:00	9:30-16:00	09:00-11:00 12:30-15:00	10:00-12:30 12:30-14:30 14:30-16:00
Pre-trading Period or Opening Session	09:15-09:25	04:00-09:30	07:00-09:30	No	9:30-10:00
After hours trading	No	16:00-20:00	16:00-20:00	No	16:00-16:10
Market Order	Yes	Yes	Yes	Yes	No
Limit Order	Yes	Yes	Yes	Yes	Yes
Stop Limit Order	No	Yes	Yes	No	No
Fill-or-kill Order	No	Yes	Yes	No	Yes
Call auction used? at market opening? at market closing?	Yes Yes No	Yes Yes No	No* No* No	Yes Yes Yes	Yes Yes No
Call Auction Design	Price/Time	Price/Time	N/A	Price/No time priority	Order type/Price/Time
Intraday trading mechanism	Continuous Auction	Continuous Auction	Continuous Auction	Continuous Auction	Continuous Auction
Priority	Price/Time/Size	Price/Time	Price/Time/Size or Price/Size/Time or Price/Time/Access Fee	Price/Time	Price/Time
Tick size	A shares: 0.01RMB B shares: 0.001USD H shares: 0.01HKD	0.01 USD	0.01 USD	JPY: $\leq$ 2k: 1 2k-3k: 5 3k-30k: 10 30k-50k: 50 50k-500k: 100 500k - 1M: 1k 1M - 20M: 10k 20M - 30M: 50k $>$ 30M: 100k	HKD: $\leq$0.25: 0.001 0.25-0.5: 0.005 0.5-2: 0.01 2-5: 0.025 5-30: 0.05 30-50: 0.1 50-100: 0.25 100-200: 0.5 200-1k: 1 1k-9995: 2.5

Table 3
Statistics on Share Classes

A shares (RMB)	**Median**	**5%**	**95%**
Price	12.26	6.75	40.49
Market Cap (mn)	1,964	525	15,656
Shares Outstanding (mn)	146	33	832
Turnover	0.0537	0.0138	0.0929

B shares (USD)	**Median**	**5%**	**95%**
Price	0.998	0.547	2.213
Market Cap (mn)	201	63	845
Shares Outstanding (mn)	176	59	519
Turnover	0.0202	0.0078	0.0348

H shares (HKD)	**Median**	**5%**	**95%**
Price	6.65	3.30	31.57
Market Cap (mn)	999	260	6,629
Shares Outstanding (mn)	133	57	736
Turnover	0.0202	0.0050	0.0442

Table 4
Hasbrouck Model Market Impact Estimates

	Median	**5%**	**95%**
A, B, H: Overall	0.1367%	0.0098%	0.4192%
A: Overall	0.1374%	0.0094%	0.4099%
A: Small Cap	0.1267%	0.0085%	0.3686%
A: Mid Cap	0.1559%	0.0125%	0.3903%
A: Large Cap	0.0993%	0.0079%	0.4489%
B: Overall	0.0993%	0.0155%	0.3752%
H: Overall	0.1594%	0.0609%	0.5828%

Small Cap, $< 1B$ RMB, 247 stocks; Middle Cap, $1B\tilde{}4B$ RMB, 757 stocks; Large Cap, $\geq 4B$ RMB, 345 stocks

Table 5
Order Book Model Market Impact Estimates

	Median	**5%**	**95%**
A, B, H: Overall	0.1021%	0.0086%	0.4343%
A: Overall	0.1000%	0.0085%	0.4299%
A: Small Cap	0.0986%	0.0093%	0.3612%
A: Mid Cap	0.1071%	0.0083%	0.4181%
A: Large Cap	0.0869%	0.0081%	0.4830%
B: Overall	0.0887%	0.0201%	0.4723%
H: Overall	0.1531%	0.0254%	0.6131%

Small Cap, $< 1B$ RMB, 247 stocks; Middle Cap, $1B \tilde{} 4B$ RMB, 757 stocks; Large Cap, $\geq 4B$ RMB, 345 stocks.

Table 6
Cross Sectional Market Impact Estimates

Dep. Var.	**Constant**	**Ticks**	**Turnover**	**Market Cap**	$\overline{R}^2$
A: Overall	8.40×10^{-4}	-2.33×10^{-8}	0.025	4.37×10^{-15}	0.1506
	(4.73)	(−4.62)	(14.95)	(2.02)	
A: Small Cap	0.0021	-1.9×10^{-7}	0.0354	1.16×10^{-12}	0.4725
	(3.36)	(−7.74)	(12.41)	(1.34)	
A: Mid Cap	8.60×10^{-4}	-7×10^{-8}	0.027	5.76×10^{-13}	0.0737
	(2.88)	(−6.54)	(6.92)	(5.44)	
A: Large Cap	8.96×10^{-4}	-1.7×10^{-8}	0.029	7.77×10^{-15}	0.2297
	(2.93)	(−2.12)	(9.79)	(1.24)	
A, B, H: Overall	0.001	-2.56×10^{-8}	0.024		0.1443
	(6.70)	(−5.65)	(15.09)		

Table 7
Market Impact by Trade Size

	Market impact					
	Hasbrouck Model			**Order Book Model**		
	Median	**5%**	**95%**	**Median**	**5%**	**95%**
Small	0.0234%	−0.2587%	0.3826%	0.0445.%	−0.2407%	0.3947%
Avg.	0.1026%	−0.1598%	0.4952%	0.1151%	−0.1499%	0.4801%

Table 8
Impact of Trade Size on Returns

Shares	r_t	r_{t+1}
<650		
Vol. Wtd. OIB	$-1.34E-6$	$-5.252E-7$
	(−83.39)	(−30.48)
>650		
Vol. Wtd. OIB	$1.401E-9$	$3.902E-10$
	(14.04)	(3.90)