An Empirical Analysis of the Shanghai and Shenzen Limit Order Books

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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;

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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 3 billion RMB(bn).

Since their founding, both markets have seen impressive growth. During December 2007, Shanghai Stock Exchange's domestic market capitalization ranked the 7th worldwide and the total market capitalization including Shanghai and Shenzhen was $9,306$ RMB (bn).

After peaking in 2007, the market has fallen by more than half. By the end of August 2008, the market capitalization decreased to $4,315$ RMB(bn). Shanghai Stock Exchange Composite Index, SSEC, which once reached $6,092$ in October 2007, retreated to 2,397 at the end of August 2008. The combined loss in market value was more than $17,000$ RMB (bn).

Table 1

RMB(bn)	Dec. 1991	June 2007	Dec. 2007	Aug. 2008
Market capitalization:	about 3	$5,557$	$9,306$	$4,315$
Shanghai		$3,680$	$6,453$	$3,871$
Shenzhen		$1,878$	$2,853$	$1,443$
Total Market Value:	$17-18$	$16,633$	$32,714$	$15,544$
Shanghai		$12,899$	$26,984$	$12,703$
Shenzhen		$3,734$	$5,730$	$2,8401$

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 3 types of shares in the market, A shares that are denominated in Renminbi (RMB), 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 are 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, and 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. Following is the summary of our data set.

Table 3

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

Table 4

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

Table 5

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

A shares' median price in our data set is 12.26RMB, while the median prices of B shares and H shares are 0.998USD (about 6.78RMB) and 6.65HKD (about 5.86RMB), 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 1,367RMB (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 Has-

brouck'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 as following:

Table 6

	Median	**5%**	**95%**
Impact in % (all)	0.1367%	0.0098%	0.4192%
Impact in % (A shares)	0.1374%	0.0094%	0.4099%
Impact in % (B shares)	0.0993%	0.0155%	0.3752%
Impact in % (H shares)	0.1594%	0.0609%	0.5828%

Based on Hasbrouck's model, the median market impact 200 periods ahead is 0.1322% on price. This means, on average, a buy trade increases the quote midpoint of the stock by 0.1322% after 200 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,

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

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

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

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 as follows:

Table 7

	Median	**5%**	**95%**
Impact in %	0.1021%	0.0086%	0.4343%
Impact in % (A shares)	0.1000%	0.0085%	0.4299%
Impact in % (B shares)	0.0887%	0.0201%	0.4723%
Impact in % (H shares)	0.1531%	0.0254%	0.6131%

In the extended model, the median market impact 200 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 0.1%. 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:

Table 8

A shares	Constant	Ticks	Turnover	Market Cap	$\overline{R}^2$
Coef:	8.40×10^{-4}	-2.33×10^{-8}	0.025	4.37×10^{-15}	0.1506
(t-stat)	(4.73)	(−4.62)	(14.95)	(2.02)	

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.

Table 9

All shares	Constant	Ticks	Turnover	$\overline{R}^2$
Coef:	0.001	-2.56×10^{-8}	0.024	0.1443
(t-stat)	(6.70)	(−5.65)	(15.09)	

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, large trades cause the spread to widen, resulting in a larger price impact. In this section, we separate the effects of small trades and block trades and attain some interesting findings here.

We define trades with quantity less than 500 shares as small trades and those with quantity more than $25,000$ shares as block trades. Using Hasbrouck's model, we get the following results:

Table 10

$b_{r,1}\ \times 10^{-4}$	**Median**	**5%**	**95%**
Small Order	-1.81	-3.34	-0.751
Avg. Order	3.68	2.08	7.36
Block Order	12.00	4.48	28.30

Table 11

Impact in %	**Median**	**5%**	**95%**
Small Order	-0.077%	-0.390%	0.265%
Avg. Order	0.102%	-0.186%	0.490%
Block Order	0.252%	-0.080%	1.072%

The median market impact of small trades is negative, -0.077%, and the coefficient of the first lag $b_{r,1}x_{t-1}$ is also negative -1.81×10^{-4}. Meanwhile, the median market impact of average trades and block trades are both positive, 0.102% and 0.252% respectively, and so are the coefficients. We also find out that the median market impact of block trades is larger than that of average trades.

This conclusion is robust in our empirical models with other limit order book information:

Table 12

$b_{r,1}\ \times 10^{-4}$	**Median**	**5%**	**95%**
Small Order	-1.72	-3.34	-5.54
Avg. Order	3.68	2.06	7.46
Block Order	12.30	4.46	29.40

Table 13

Impact in %	**Median**	**5%**	**95%**
Small Order	-0.064%	-0.392%	0.289%
Avg. Order	0.113%	-0.186%	0.496%
Block Order	0.266%	-0.058%	0.976%

The median market impact of small trades is negative, -0.064%, and the coefficient of the first lag $b_{r,1}x_{t-1}$ is -1.72×10^{-4}. The median market impact of block trades is 0.266%, larger than that

of average trades 0.113%.

We believe the negative market impact of small trades is due to the negative coefficient of the first lag x_{t-1} in small trades' VAR. To investigate this, we also check the relationship between daily order imbalance of small trades and contemporaneous daily return. In Table 14, we found out volume-weighted daily order imbalances of small trades and contemporaneous daily returns are negatively related with each other in small trades while positively related in common trades and block trades.

Table 14

	Day's Return	Next day's Return
Small Order (<500)		
Volume Weighted OIB	−2.300	−0.887
	(−34.68)	(−13.69)
Common Order (500 - 25000)		
Volume Weighted OIB	0.047	−0.014
	(13.37)	(−4.03)
Block Order (>25000)		
Volume Weighted OIB	0.037	0.017
	(12.37)	(5.82)

According to Hasbrouck's analysis, the market impact of a trade is a function of how informed the trader is. Since most block trades are institutional, it is reasonable to assume that the large trades are more informed and will have greater market impact. The negative market impact of small trades indicates that market may regard those small trades as uninformed and lead market makers to trade against them.

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 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 a negative market impact.

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, average and block trades. We find that large trades have a proportionally larger market impact than averages trades and that small trades actually have a negative impact.

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.

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Table 2
Comparison of Microstructures

Microstructure Characteristics	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	9:30AM-11:30AM &13PM-15PM	9:30AM-16PM	9:30AM-16PM	9AM-11AM & 12:30PM-15PM	10AM-12:30PM & 12:30PM-14:30pm & 14:30PM-16PM
Pre-trading Period or Opening Session	9:15-9:25AM	4AM-9:30AM	7AM-9:30AM	No	9:30AM-10AM
After hours trading	No	16PM-20PM	16PM-20PM	No	16PM-16:10PM
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