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Pacific-Basin Finance Journal 11 (2003) 45–59
PACIFIC-BASIN FINANCE JOURNAL
www.elsevier.com/locate/econbase

How should liquidity be measured?

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Received 22 August 2001; accepted 24 January 2002

Abstract

Previous literature has adopted a broad range of measures to proxy for market liquidity, suggesting that there is no consensus about the most appropriate measure. The various measures used fall into two broad categories: trade-based measures and order-based measures. This paper reports that there is little correlation between the two. This suggests that the choice of measure may have a significant effect on research outcomes and therefore policy decisions. By examining changes in these two different measurement proxies before and after the commencement of the economic crisis on the Jakarta Stock Exchange (JSX), this paper provides evidence that order-based measures of liquidity provide a better proxy for liquidity. We also employ a new measure of liquidity, which captures the bid–ask spread, the order depth and the probability of order execution. The paper provides evidence of the value of this type of measure in assessing the impact of changes made to market structure.

JEL classification: G10; G14
Keywords: Liquidity; Jakarta Stock Exchange; Asian economic crisis

1. Introduction

A frequently quoted objective of stock exchanges around the world is to provide a liquid market, where liquidity is unambiguously defined as the ability to convert shares into cash (and the converse) at the lowest transaction costs. While easy to define, liquidity has proved far more difficult to measure. Previous literature offers a wide variety of measures for liquidity. These measures may be divided into two broad categories: trade-

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PII: S0927-538X(02)00093-8

and order-based measures. While there is some correlation between proxies within these categories, there is little correlation between the categories.

The lack of correlation between the measures suggests that the choice of measure will affect conclusions regarding the impact of changes in market structure on liquidity. This leads to the question of which is the more appropriate category, and more specifically, what is the best measure to use. While there is no definitive answer to these questions, one way of addressing them is to determine how the various measures reflect known events such as the liquidity crises experienced in Asia in the late 1990s.

This paper uses the Asian economic crisis of 1997 and 1998 in the context of the Jakarta Stock Exchange (JSX) to evaluate different measures of liquidity. Following the crisis, liquidity was expected to decline as investors withdrew from the market due to the increased risks. Although it is possible that liquidity may have increased over the short term (i.e. in the weeks following the commencement of the crisis) as investors closed out their positions, the medium-term period following the crisis, examined in this paper, is expected to show a decline in liquidity. Changes in the different liquidity measures are examined in the context of these expectations to determine which ones reflect this expectation.

2. Theoretical considerations

2.1. What is liquidity?

A perfectly liquid market is one where any amount of a given security can be instantaneously converted to cash and back to securities at no cost. In a less than perfect world, a liquid market is one where the transaction costs associated with this conversion are minimised (Harris, 1990).

Transaction costs include both explicit and implicit costs. The explicit costs include brokerage commissions and government taxes. These costs are usually easy to quantify but remain outside the direct control of the exchange and therefore are not considered. The paper focuses on the implicit costs of trading, such as bid–ask spreads, market impact costs and opportunity costs arise due to inefficient and/or inadequate technology, regulation, information dissemination, participation and instrumentation. For example, if the minimum tick size regulation leads to a tick size which is too large, the cost of trading is increased, acting as a deterrent to investing, leading to reduced liquidity. Further, if short selling is banned or derivative instruments are not available, the opportunities for trading in the underlying securities are restricted reducing their attractiveness and therefore their liquidity. Implicit in the examples identified above is that an exchange has the capacity to affect trading costs and therefore liquidity by altering the structure of its marketplace through improved regulations, technology and instrumentation.

2.2. Alternative liquidity measures

While relatively easy to define, liquidity has proved to be difficult to measure. The previous literature offers a wide variety of measurement proxies for liquidity. Aitken and Winn (1997) report that there are some 68 extant measures used in the literature suggesting

that there is little agreement on the best measure to use. Aitken and Winn also report that there is little or no correlation between many of these metrics suggesting that inappropriate measures may result in exchanges reaching the wrong conclusions about changes in market structure.

Liquidity measures may be divided into two broad categories: trade-based measures and order-based measures.

2.2.1. Trade-based measures

Trade-based measures commonly used in previous literature include trading value, trading volume, the number of trades (frequency) and the turnover ratio[1]. These measures are attractive, as they are simple to calculate using readily available data and have widespread acceptance particularly among market professionals[2]. However, they are perhaps the most problematic measures as they are ex post rather than ex ante measures. In this sense, they indicate what people have traded in the past. This is not necessarily a good indication of what will be traded in the future. To provide a more concrete example, a monthly turnover ratio may be driven by trading on particular days when major information was released. This is particularly the case for smaller stocks. These measures fail to indicate the ability of investors to transact immediately and the cost associated with this, which is the essence of liquidity.

2.2.2. Order-based measures

The advent of automated trading systems has brought with it access to more detailed data allowing for new order book liquidity measures to be calculated. These measures more accurately capture the ability to and cost associated with trading immediately.

The bid–ask spread represents the cost that an investor must incur in order to trade immediately. That is, to purchase (sell) a stock, investors must cross the spread and hit the existing ask (bid) orders in the schedule. For small investors, this is an effective and accurate method of calculating the liquidity of a stock. By calculating this cost as a percentage of the stock price (relative spread), liquidity may be compared across stocks with different prices. However, minimum tick rules, which constrain the numerator of such a ratio, limit its relative use for stocks in the same tick category but with significantly different prices.

For larger investors, the relative spread may underestimate the true cost of trading and hence overestimate liquidity. A more complete measure of liquidity must also consider the market impact and opportunity costs of trading. This requires an analysis of the volume of orders available at each price step. For example, if an investor wants to purchase 100,000 units of stock and there is only 10,000 units available at the best ask, then the investor must increase his price until there is adequate volume in the order book to absorb the

[1] The turnover ratio is the value of shares traded divided by market capitalisation. This measure is often used to make comparisons of liquidity across markets. Ideally, market capitalisation should be adjusted for the number of shares which are freely traded. This is particularly important in the case of the JSX where the company founders often hold large fractions of the stocks, which are not freely traded. However, this adjustment is not possible due to data limitations.

[2] The turnover ratio is the measure used by the International Federation of Stock Exchanges (FIBV) to compare liquidity across exchanges.

complete order. That is, the investor incurs market impact costs. The market is therefore less liquid than the bid–ask spread would suggest. Ideally, the depth measure should be adjusted for the number of shares on issue.

Although order-driven markets allow depth to be calculated, a number of issues must first be resolved:

1. Should all orders in the order book be included? That is, can it be assumed that all orders in the order book will remain in the order book even as the price begins to move?
2. Should the orders in the order book be weighted to give greater importance to those closer to the best bid and ask?
3. Is it possible to estimate new orders that may enter the market as the price moves (i.e. latent liquidity)?

This paper addresses these questions by examining the distribution of orders within the order book and the probability of execution.

3. Institutional detail

The JSX operates using the Jakarta Automated Trading System (JATS). JATS is an open electronic order book which trades continuously between 9:30 to 12:00 and 13:30 to 16:00 on Monday to Thursday and between 9:30 to 11:30 and 14:00 to 16:00 on Friday[3]. The JSX has two categories of trading boards: the Regular Board and the Negotiated Boards.

Regular Board orders must be in round lots of 500 units. These orders are matched continuously according to price and time priority. Orders may be amended or withdrawn prior to execution, but only limit orders may be entered. During the period examined, the minimum price variation (tick) is 25 rupiah for all stocks[4]. There is also a maximum price movement of 200 rupiah on any one trade. Short selling is prohibited.

For the period of the study, there were five negotiated markets available to investors. These were the Crossing Board, the Foreign Board, the Block Sales Board, the Odd Lot Board and the Cash Board. Negotiated Board trades arise from negotiations between brokers and do not compete with the Regular Board trades and are not automatically matched by the trading system.

Trades take place on the Crossing Board when the same broker represents both the buying and selling client or is buying or selling for himself. Trades between foreigners must take place on the Foreign Board when the foreign ownership limit of 49% has been reached[5]. All trades in excess of 200,000 units must be executed on the Block Sales Board. These boards resemble the upstairs market on the New York Stock Exchange.

[3] The longer trading break on Fridays allows the mainly Muslim population to comply with religious commitments to prayer.

[4] The JSX reduced the minimum price tick to 5 rupiah on 3 July 2000. This change provides an opportunity to examine the impact of the minimum tick size on liquidity and may be the subject of future research. The JSX has further plans to amend the tick size again to create different tick sizes depending upon stock price.

[5] This foreign ownership restriction was removed for all stocks except banks in September 1997.

Trades, which are less than the minimum parcel of 500 units, must be executed on the Odd Lot Board. Where parties have failed to settle their trades on $T+4$, they are required to close out their position in the Cash Market.

Typically all orders expire at the end of each Exchange Day, although it is also possible to enter orders which are only valid for one Exchange Session. This means that there are no orders in JATS each morning at the opening of trading. During the lunchtime close, the order book remains unchanged as orders may not be amended or withdrawn until the market reopens for the afternoon trading session.

4. Data and research method

The data used in this study is taken from the JATS database maintained by the Securities Industry Research Centre of Asia-Pacific (SIRCA). The JATS database provides details of all orders and trades placed on the JSX. These records provide details of the price, volume, date, time and broker for every order and trade.

This paper considers the period 1 June 1996 to 28 August 1998. All stocks that were listed prior to 1 June 1996 and were not de-listed prior to 28 August 1998 are included. This provides 221 stocks for analysis. The sample is reduced to 178 stocks due to difficulty in obtaining details about changes in issued capital during the period examined.

In order to compare the liquidity before and after the commencement of the crisis, it is necessary to determine the starting date. For the purposes of this paper, 14 August 1997 is used as it was the day the rupiah was floated. An examination of changes in the exchange rate (as shown in Fig. 1) reveals that after this time, the value of the currency began to

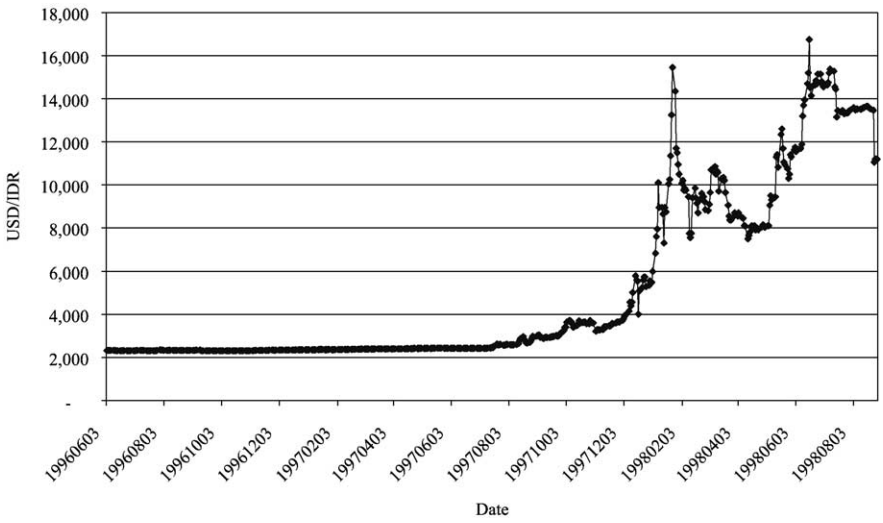

Fig. 1. USD/IDR exchange rate. This figure shows the daily US dollar/Indonesian rupiah exchange rate throughout the sample period.

decline quickly. The sample is divided into two periods, pre and post 14 August 1997. The period prior to 14 August is referred to as the pre-crisis period and the period after is referred to as the post-crisis period.

The sample is partitioned into shorter time horizons in order to ensure that the results are not driven by the time period considered. One- and six-month periods before and after 14 August 1997 are examined and produce results that are generally consistent with the whole sample. Differences in behaviour across the periods are noted in Section 5.

4.1. Descriptive statistics

The stocks in the sample are partitioned into quartiles based on trading value. Quartile 1 is the most liquid group of stocks and quartile 4 is the most illiquid. The average and standard deviation of the daily volumes, daily values, daily trade frequency and volume weighted average prices for each of these quartiles are calculated. These statistics are shown in Table 1.

Table 1 shows that the volume, value and frequency decrease monotonically as turnover decreases. There is no systematic variation in the average prices across the quartiles.

4.2. Operationalisation of the variables

4.2.1. Trade-based measures

Trading activity is measured using four different variables. These are the number of shares traded (volume), the number of shares traded divided by the number of shares on issue (relative volume), the number trades (frequency) and the value of shares traded (value).

4.2.2. Order-based measures

Two order-based measures are calculated: relative spreads and order depth. Consistent with McInish and Wood (1992), time-weighted relative spreads are calculated by dividing the difference between the best bid and ask by the midpoint price and weighting it by the

Table 1
Descriptive statistics

	Average daily volume		Average daily value ($000s)		Average daily trade frequency		Average closing price	
	Mean	Standard deviation	Mean	Standard deviation	Mean	Standard deviation	Mean	Standard deviation
All	560,128	3,034,080	858,340	4,509,960	31	116	2109.92	2819.83
Quartile 1	1,765,320	5,710,780	2,878,580	8,555,950	86	197	2538.38	2772.31
Quartile 2	395,339	1,458,610	459,186	1,642,340	29	97	1686.52	1579.00
Quartile 3	82,457	473,972	102,372	523,023	9	41	1965.45	3591.39
Quartile 4	7440	75,273	8670	79,876	1	9	2245.69	3829.52

The table shows details of the mean and standard deviation of the average daily value, volume, trade frequency and closing price. These statistics are provided for the whole sample and the samples partitioned into quartiles based on trading value.

Table 2
Pearson's correlation coefficients for liquidity proxies

	Volume	Value	Count	Relative volume	Relative bid ask spread	Order depth	Relative order depth
Volume	1.0000						
Value	0.8658	1.0000					
Count	0.8689	0.8218	1.0000				
Relative volume	0.4788	0.4223	0.5162	1.0000			
Relative bid ask spread	− 0.0845	− 0.0948	− 0.1115	− 0.0528	1.0000		
Order depth	0.3435	0.2568	0.2954	0.1369	− 0.1743	1.0000	
Relative order depth	0.1480	0.1134	0.1554	0.3292	− 0.0842	0.3839	1.0000

The table shows the Pearson's correlation coefficients for the trading activity and order book based measures of liquidity. These metrics are calculated every 30 minutes.

time it existed. Where the bid–ask spread is undefined[6] the interval is excluded from the estimate. This is likely to underestimate the true spread, particularly for the illiquid stocks.

Order depth is not often measured in the literature. This is due to the fact that order book data is not frequently available. Therefore, there is little guide to the most appropriate choice of depth measure. As discussed in Section 2.2.2 a number of issues need to be addressed when selecting a depth measure. First, should the whole order book be included? Second, should orders closer to the best prices be weighted more heavily?

Due to the fact that orders are cleared from the order book each night on the JSX, the possibility of stale orders is reduced. For this reason, we begin by measuring the total volume of all orders in the order book divided by the total number of shares on issue (relative depth). Dividing by the number of shares on issue makes this a relative measure facilitating comparisons across different sized stocks.[7]

Each of these statistics is calculated every 30 minutes throughout the period and averaged during the pre- and the post-periods.

5. Results

5.1. Correlation of liquidity measures

Table 2 shows that the three trade-based measures commonly used in the literature volume, value and frequency are highly correlated with correlation coefficients greater than 0.80. The fourth trading activity measure, relative volume, is only poorly correlated with the other three. There appears to be little or no correlation within the order-based measures. There also appears to be little correlation across the two types of liquidity measures.

The lack of correlation suggests that the choice of measure is likely to have a significant impact on the assessment of market liquidity.

[6] The spread is undefined when there is no bid and/or ask orders in the order book.
[7] This measure would also be useful for comparing depth across markets.

Table 3
Trading volume before and during the crisis

	Number of observations		Mean				
	Pre	Post	Pre	Post	Difference	% Difference	*t*-statistic
All	689,572	671,060	32,768	49,411	16,643	50.79	23.88
Quartile 1	170,456	165,880	93,446	169,589	76,143	81.48	28.13
Quartile 2	170,456	165,880	30,637	25,463	− 5174	− 16.89	− 7.91
Quartile 3	170,456	165,880	7778	4365	− 3413	− 43.88	− 16.99
Quartile 4	178,204	173,420	671	453	− 219	− 32.56	− 5.08

The table exhibits the average trading volume over 30-minute intervals for all stocks before and after the commencement of the economic crisis. The results are shown for the sample as a whole and partitioned into quartiles on the basis of turnover throughout the period. The *t*-statistics relate to the absolute differences.

5.2. Trade-based measures

The results are generally consistent for the four trade-based measures and therefore only the volume results are presented and inconsistencies noted. Table 3 shows the change in volume before and after the crisis. It indicates that across the whole sample, the average trading volume increased by approximately 51%[8]. This suggests that the crisis was good for the JSX, however, this is incongruent with the generally accepted view that the market was facing a liquidity crisis.

The results partitioned by quartiles show that the top quartile stocks drove the increase in trading activity which increased by approximately 81%. The other quartiles exhibited significant declines in trading activity[9]. These results suggest a "flight to quality," where investors moved out of small stocks and into larger stocks.

However, an examination of the extent of buying and selling pressure in these stocks suggests that this may not be the case (Table 4). The percentage of buyer-initiated trading fell across all quartiles of stocks. However, the magnitude of the decline increases as stock liquidity decreases. Quartile 1 exhibits a 1.96% decline compared to a 4.67% decline in quartile 4. This suggests that while there may not have been a flight to quality, investors were more aggressive in exiting the less liquid stocks.

5.3. Order-based measures

5.3.1. Relative bid–ask spreads

The average relative bid–ask spread before and after the crisis is examined. Table 5 exhibits the results for the sample as a whole and partitioned into quartiles by trading value.

The results for the sample as a whole show that there was a 101% increase in average relative spreads. These results also show that relative spreads on the JSX were high even prior to the crisis. The average spread of 6.3% is significantly higher than the relative spread of 0.719% estimated by Ricker (1998) on the NYSE for all stocks above US$2

[8] The relative volume results indicated that this change was not statistically significant.
[9] The relative volume results indicated that there was no significant change for quartile 4.

Table 4
Buyer- and seller-initiated trade percentages

	Buyer-initiated percentage (%)				Seller-initiated percentage (%)			
	Pre	Post	Difference	*t*-statistic	Pre	Post	Difference	*t*-statistic
All	50.43	47.42	− 3.00	− 17.06	49.57	52.58	3.01	17.09
Quartile 1	49.89	47.92	− 1.96	− 8.40	50.11	52.08	1.97	8.41
Quartile 2	50.70	46.94	− 3.75	− 11.48	49.30	53.06	3.76	11.49
Quartile 3	51.05	46.50	− 4.55	− 9.22	48.94	53.50	4.56	9.24
Quartile 4	52.52	47.85	− 4.67	− 4.15	47.48	52.15	4.67	4.15

The table shows the percentage of trading which is buyer- and seller-initiated before and after the crisis. A trade is buyer (seller)-initiated when a buyer (seller) crosses the spread to execute a trade. The table also shows the results for the sample as a whole and for the sample divided into quartiles based on trading value.

during the period 24 June to 30 September 1997. These results indicate that the JSX is a relatively illiquid market.

Table 5 illustrates that relative spreads increase as turnover declines. Prior to the crisis, the average relative spread was 2.15% for the top quartile of stocks compared to 16.4% for the bottom quartile. This is consistent with the literature analysing other markets which indicates an inverse relationship between trading activity and bid–ask spreads (Cohen et al., 1986).

Table 5 also indicates that the high turnover stocks experienced a greater increase in relative spreads than the low turnover stocks. Relative spreads for the top quartile stocks increased by an average of 236%. This suggests that the crisis affected the liquidity of the high turnover stocks more than the low turnover stocks. However, it is important to note that the number of observations declines as turnover declines. This indicates that there is an increasing number of undefined observations in the low turnover stocks[10]. This is particularly noticeable in quartile 4. This suggests that after the crisis, it became very difficult to trade these stocks, as there were no orders on at least one side of the order book. Therefore, the true decline in the liquidity of these stocks is grossly underestimated by the change in the bid–ask spread.

5.3.2. Order depth

Table 6 presents the average relative depth before and after the crisis. These results show that, on average, prior to the crisis, the order book contained 0.68% and 0.98% of the total shares on issue, on the bid and ask side of the order book, respectively. Surprisingly, following the crisis, the sample as a whole showed a large increase in relative depth of 216% on the bid side and 89% on the ask side. This suggests that there was an increase in the demand for JSX stocks following the commencement of the crisis.

Similar to the trading activity results, an analysis of the results by quartile shows that the top stocks drive the increase in order depth. The top quartile stocks exhibit an increase in depth of 494% on the bid side and 259% on the ask side of the order book. Quartile 3 was the only group not to exhibit an increase in depth[11].

[10] The undefined observations are excluded from the sample.

[11] It is noteworthy that the analysis of the order book 1 month before and after 14 August 1997 reveals an across the board decrease in order volume.

Table 5
Relative bid–ask spreads before and after the crisis

	Number of observations		Mean				
	Pre	Post	Pre (%)	Post (%)	Difference (%)	% Difference	*t*-statistic
All	514,793	268,779	6.32	12.72	6.40	101.35	189.30
Quartile 1	153,858	93,345	2.15	7.24	5.09	236.25	163.55
Quartile 2	151,718	85,233	4.23	10.69	6.46	152.91	140.43
Quartile 3	130,757	66,182	7.58	17.70	10.12	133.44	142.01
Quartile 4	78,460	24,019	16.40	27.44	11.04	67.30	60.34

The table exhibits the relative bid–ask spread of all stocks before and after the commencement of the economic crisis. The results are shown for the sample as a whole and partitioned into quartiles on the basis of trading value throughout the period. The values are calculated every 30 minutes and averaged across the pre- and post-periods. The *t*-statistics relate to the absolute differences.

5.4. Sensitivity analysis

The results outlined in Sections 5.2 and 5.3 show that different proxies for liquidity produce different results. The volume results suggest an overall increase in liquidity following the crisis driven by the top quartile stocks. The spread results indicate a reduction in liquidity with the size of this fall declining with stock liquidity. Finally, the order depth results show an increase in liquidity except in quartiles 3 and 4.

Reference back to the definition of liquidity helps to adjudicate which measure is more appropriate and to guide the development of a better measure of liquidity. As discussed in Section 2.2, a liquidity measure should capture the cost of immediately converting shares to cash and the converse.

Table 6
Order volumes as a percentage of shares on issue

	Number of observations		Mean				
	Pre	Post	Pre (%)	Post (%)	Difference (%)	% Difference	*t*-statistic
Ask volume							
All	623,348	337,183	0.98	1.85	0.87	88.77	36.81
Quartile 1	167,518	95,885	1.16	4.17	3.01	259.45	37.67
Quartile 2	167,064	94,305	1.20	1.64	0.44	36.63	23.22
Quartile 3	159,849	87,202	1.12	0.44	− 0.68	− 60.74	− 66.73
Quartile 4	128,917	59,791	0.30	0.54	0.24	79.35	24.23
Bid volume							
All	549,677	279,704	0.68	2.16	1.48	216.34	47.61
Quartile 1	164,132	93,509	0.75	4.48	3.73	494.33	41.48
Quartile 2	156,785	85,609	0.95	1.40	0.44	46.19	22.52
Quartile 3	135,463	68,967	0.55	0.54	− 0.01	− 2.48	− 1.18
Quartile 4	93,297	31,619	0.29	0.90	0.61	206.32	26.29

The table shows the average volume of orders on the bid and ask side of the order book divided by the number of shares on issue before and after the commencement of the crisis sampled every 30 minutes. The *t*-statistics relate to the absolute differences.

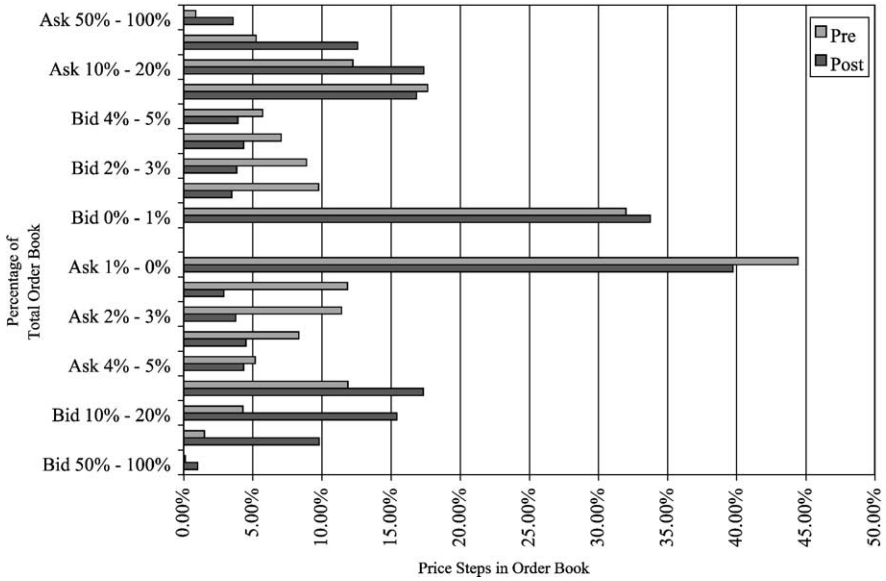

Fig. 2. Distribution of orders in the order book. This figure shows the percentage of orders at seven different price ranges in the order book. The categories are within 1% of the best bid or ask price, between 1% and 2%, between 2% and 3%, between 3% and 4%, between 4% and 5%, between 5% and 10%, between 10% and 20%, between 20% and 50% and between 50% and 100% of the best bid or ask. The bid and ask side are examined separately. This distribution of orders is calculated every 30 minutes and averaged during the pre- and post-periods.

While it is clear that a liquidity measure should consider both the spread and depth of the order book, it is not clear what level of order book depth should be included in such a measure and how these orders should be weighted. For this reason, the distribution of orders in the order book is considered. In addition, the probability of execution is calculated for orders at different price levels.

5.4.1. Distribution of orders in the order book

Fig. 2 shows the distribution of orders across the order book. This indicates that prior to the crisis, approximately 81% (63%) of bids (asks) orders were placed less than 5% below (above) the best bid (ask). After the crisis, this figure declined to 55% and 49%, respectively[12].

Fig. 2 shows that with the exception of asks within 1% of the best ask, there is a shift of orders away from the best bid and ask. This indicates that orders being placed more than 10% from the best bid and ask drive the increase in relative depth discussed above. This is particularly obvious on the bid side of the order book where the percentage of orders more than 10% away from the best bid increased from 6% to 26%.

[12] An examination of the distribution of orders within the order book across the different quartiles shows that orders are more tightly distributed in the lower quartile stocks. For quartile 4, approximately 55% and 65% of orders are placed less than 1% from the best bid and ask, respectively, compared to only 20% and 35% for quartile 1.

Table 7
Execution rates

Price band	Price range (%)	Bid execution rate (%)	Ask execution rate (%)
1	0–1	86.65	82.09
2	1–2	54.91	44.73
3	2–3	48.31	35.09
4	3–4	33.77	25.52
5	4–5	24.74	17.67
6	5–10	14.80	10.61
7	10–20	3.81	3.91
8	20–50	1.02	0.93
9	50–100	0.51	0.04

The table displays the probability of order execution in nine different price bands. There is no significant difference in the execution rates between the pre- and the post-period and therefore only the post-period results are reported. The price bands are within 1% of the best bid or ask price, between 1% and 2%, between 2% and 3%, between 3% and 4%, between 4% and 5%, between 5% and 10%, between 10% and 20%, between 20% and 50% and between 50% and 100% of the best bid or ask. The bid and ask side are examined separately.

Consistent with the bid–ask spread measure, this suggests that there was an increase in the level of uncertainty in the market after the commencement of the crisis causing investors to place orders further away from the market.

5.4.2. Execution rates

Table 7 shows the probability of execution for orders placed in each of the nine price bands examined in Fig. 2. The probability of execution is calculated by summing the number of orders executed in each price band as a percentage of the total orders placed in each band. Partial execution is included in this calculation.

Table 7 illustrates that the probability of execution declines as orders are placed further away from the midpoint price. Bid (ask) orders have an 87% (82%) chance of execution if they are placed within 1% of the midpoint price compared to only 0.51% (0.04%) for orders more than 50% away from the midpoint price. There is no significant change in the execution rates across the pre- and post-periods. For this reason, only the post-period execution rates are reported and used in later calculations.

5.4.3. New liquidity measure

The analysis of the order book and execution rates is used to develop a new liquidity measure, which weights the orders in the order book by the probability that they will be executed[13]. The following formula is used to calculate this measure:

$$\text{Weighted ask value} = \sum(\text{Ask order value}_b * \text{Ask order weight}_b), \quad (1)$$

$$\text{Weighted bid value} = \sum(\text{Bid order value}_b * \text{Bid order weight}_b), \quad (2)$$

where b is the price band in which the orders are placed.

[13] By incorporating the execution rate in the measure, it captures new orders being entered into the market in response to price changes and hence the notion of latent liquidity.

Table 8
Weighted order book metrics before and after the crisis

	Number of observations		Mean				
	Pre (000s)	Post (000s)	Pre ($000s)	Post ($000s)	Difference ($000s)	% Difference	*t*-statistic
Weighted bid value							
All	530	269	408,568	291,459	− 117,108	− 28.66	− 123.45
Quartile 1	164	93	919,753	750,483	− 169,270	− 18.40	− 109.20
Quartile 2	156	85	349,959	62,587	− 287,372	− 82.12	− 156.20
Quartile 3	132	66	74,975	17,469	− 57,505	− 76.70	− 115.32
Quartile 4	79	24	18,002	6843	− 11,159	− 61.99	− 5.60
Weighted ask value							
All	530	269	397,714	255,255	− 142,459	− 35.82	− 165.34
Quartile 1	164	93	922,877	652,287	− 270,590	− 29.32	− 162.99
Quartile 2	156	85	301,265	57,173	− 244,092	− 81.02	− 123.43
Quartile 3	132	66	86,017	19,186	− 66,831	− 77.69	− 127.37
Quartile 4	79	24	15,798	6904	− 8893	− 56.30	− 54.93
Weighted order value							
All	530	269	403,105	272,757	− 130,347	− 32.34	− 112.34
Quartile 1	164	93	921,314	699,665	− 221,649	− 24.06	− 163.31
Quartile 2	156	85	324,701	59,819	− 264,882	− 81.58	− 192.87
Quartile 3	132	66	80,306	18,308	− 61,999	− 77.20	− 129.36
Quartile 4	79	24	16,864	6874	− 9990	− 59.24	− 96.39

The table shows the average weighted order book metrics before and after the commencement of the economic crisis sampled every 30 minutes. These measures are calculated using the value of orders in the order book in each price band multiplied by the probability of order execution in that band. The *t*-statistics relate to the absolute differences.

A combination measure reflecting both the bid and ask depth is calculated as follows[14]:

$$\text{Weighted order value} = \sqrt{\text{Weighted ask value} * \text{Weighted bid value}}\,. \tag{3}$$

Table 8 provides a summary of the results for the new liquidity measure. This shows that liquidity declined for the sample as a whole by approximately 32%. The decline in liquidity was smallest for the top quartile of stocks which exhibited a 24% fall in liquidity. The decline in liquidity was greater on the ask side of the order book. For the sample as a whole, the weighted ask value fell by 36% compared to 27% on the bid size.

6. Conclusions and future research

This paper analyses market liquidity using two types of measures: trade-based measures and order-based measures. These measures are assessed by examining changes

[14] An arithmetic average of the weighted bid and ask orders is also calculated. This measure produced consistent results and therefore is not reported.

on the JSX before and after the commencement of the economic crisis. The two types of measures provide inconsistent evidence of the impact of the crisis on market liquidity. This suggests that the choice of a liquidity proxy may drive the results of research examining the economic impact of changes in market design. While there is no definitive way of choosing between measures, we have constructed a novel design in which we use a known liquidity crisis to compare and contrast the results from using alternative proxies.

The trade-based measures appear to grossly underestimate and in some cases misrepresent the impact of the crisis on market liquidity. The trading volume results suggest that across the market as a whole, there was an increase in liquidity of 50% after the crisis. This increase was greatest for the top quartiles of stocks where volume increased by 81%. These results are broadly inconsistent with expectations of a liquidity crisis.

Because trade-based measures are ex post in the sense they indicate what liquidity was available in the past, it could be argued that they do not give an accurate indication of the ability of investors to convert their securities to cash immediately, particularly for smaller stocks. In this sense, the order-based measures are more indicative of what is presently available. The relative spread measure, which incorporates part of this cost, indicates that consistent with expectations, there was a decline in liquidity across the market of 101%. These results tend to suggest that the decrease in spreads was greatest in the more liquid stocks; however, it should be noted that the true increase in spreads is underestimated, particularly in the low quartile stocks, due to fact that observations are ignored if the spread is undefined.

However, the spreads only indicate the cost of trading when an order can be satisfied by the volume at the best bid or ask and therefore only provide an indication of liquidity for small investors. In order to understand the change in liquidity for larger investors, the order book must also be examined. This analysis shows that although the volume of orders increased, this increase was driven by orders being placed at prices more than 10% above (below) the best ask (bid). The volume of orders close to the best prices actually declined significantly.

Our new liquidity measure based on the value of orders in the order book weighted by the probability of execution suggests that there was a 30% decrease in liquidity across all stocks. This decrease in liquidity was lowest in the most liquid quartile of stocks. This result is consistent with expectations.

The inconsistencies in the trade-based and order-based measures highlight the importance of identifying particular measures of liquidity in order to assess the impact of changes in market regulation and technology. The simple policy implication of this paper is that, where possible, the success of market reforms should be assessed using a measure which captures both spreads and depth and the probability of order execution.

While our new liquidity measure provides a better estimation of liquidity than the traditional measures such as volume and spreads, there is still opportunity for further improvement. Further research should consider how the time taken to execute a trade affects the measure of liquidity.[15]

[15] The authors thank Ghon Rhee for this suggestion.

Acknowledgements

This paper is an adaptation of a chapter of Carole Comerton-Forde's PhD dissertation entitled *The Microstructure of the Jakarta Stock Exchange*. The authors wish to thank Ghon Rhee, an anonymous referee and the participants at the APFA 2001 Conference for helpful comments and suggestions. The authors also acknowledge and thank the Jakarta Stock Exchange and the Securities Industry Research Centre of Asia-Pacific (SIRCA) for providing the data.

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