A Review of Market Quality on SGX Securities Market:

The Relationship between Stock Price and Liquidity

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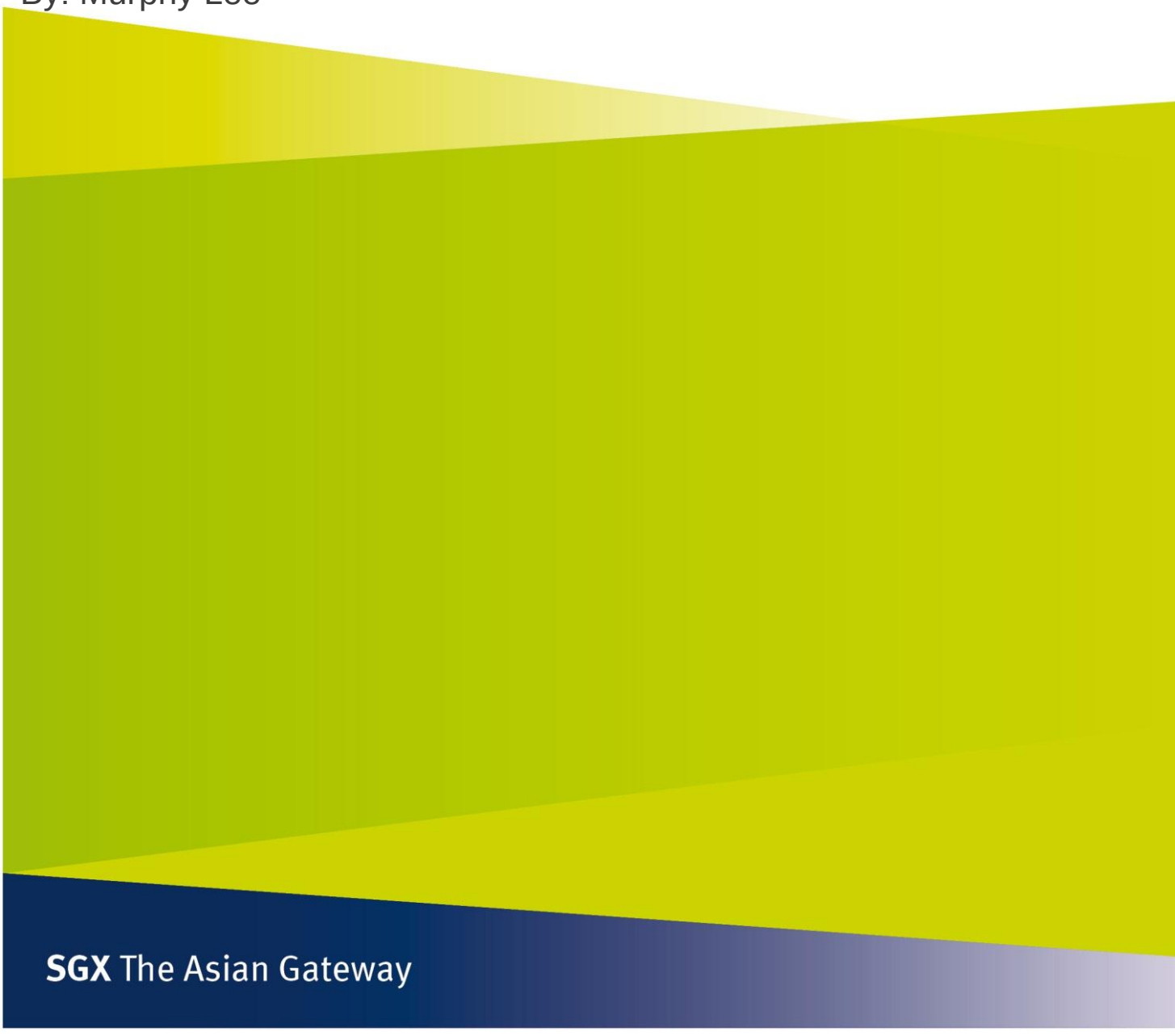
By: Murphy Lee



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Executive Summary

This paper aims to provide a review of the market quality of the SGX securities market in 2013, with a focus on stocks trading at various stock price levels. Numerous research studies explain and show that stock price is an important function of liquidity, a major component of market quality. Hence, this paper aims to present empirical evidence surrounding liquidity on SGX securities market. More importantly, it investigates if a higher level of market quality was observed at certain stock price levels. Specifically, two well-known liquidity measures are adopted to gauge market quality, namely (1) bid-ask spreads (bps) and (2) quoted best depth value. These liquidity measures are selected as they primarily capture the implicit trading costs faced by investors. A lower implicit trading cost ensures that investors will achieve a better quality of execution, which points to a higher quality market.

Both theoretical and empirical literatures indicate that higher stock prices tend to correlate with better liquidity or market quality. Empirically, this paper finds that this relationship is also consistent with the evidence found on SGX. This paper finds that stocks priced at or above $0.25 are quoted with narrower bid-ask spread (bps) and higher quoted best depth value. Further analysis into stock price levels shows that stocks trading at $0.25 or greater display higher levels of liquidity or market quality. For robustness, three secondary liquidity measures, namely (1) spread (ticks), (2) the proportion of time when the spread is at 2 ticks or less and (3) the proportion of time when the order book is one-sided are also examined. Similar conclusions are reached in terms of the presented results.

Overall, all empirical results surrounding stock price levels suggest that investors experienced higher liquidity when trading in stocks at $0.25 or greater as compared to stocks trading below $0.25 in 2013. It should also be noted that both theoretical and empirical evidence indicate that liquidity is positively related to market capitalization and company fundamentals. Hence, this highlights that these two factors also play important roles in evaluating overall market quality.

Based on the current market structure and the presented empirical evidence, stocks trading at $0.25 and greater would likely enhance the liquidity of the securities market. Furthermore, this would likely reduce the liquidity risk for the overall market that lower priced stocks are observed to exhibit.

1. Introduction

For a market to be of good quality, it has to be one in which stock prices always fully reflect available information. Amihud and Mendelson (1986) suggest that this price discovery process is greatly affected by the level of liquidity in the market. Stoll (2000) describes the lack of liquidity as a form of friction imposed on the market. Damodaran (2011) explains that liquidity refers to the ability of the market to facilitate the trading of high volumes at low cost. In general, liquidity is an important element that enables the smooth functioning of a stock market. Hence, a market with higher liquidity is commonly viewed to be of better quality.

An extensive amount of research has been conducted in understanding the cross-sectional variation of liquidity in the stock market. The market microstructure literature suggests that stock price is found to be a key determinant of liquidity. Drawing from theories of capital asset pricing, Amihud and Mendelson (2006) summarize that since investors are averse to the costs of illiquidity, they expect to be compensated for bearing these costs by achieving a higher expected return for taking on a higher level of risk. Hence, Amihud and Mendelson (2006) suggest that stock prices should depend on two characteristics – liquidity and risk. In general, both theoretical and empirical results show that liquidity is priced into the market. Specifically, illiquid stocks are expected to have a lower price or higher expected yield for any given level of risk. Motivated by the findings in the literature, this paper aims to review the relationship between the quality of the Singapore securities market and stock price by examining the liquidity of the market. Furthermore, this paper investigates if a higher level of market quality is observed at certain stock price levels.

Following prior research studies, this paper examines two main liquidity measures to gauge market quality – (1) quoted bid-ask spreads (bps) and (2) quoted best depth value. Within the market microstructure literature, the bid-ask spread is the most commonly used measure of liquidity and it captures the ex-ante transaction costs (O'Hara, 1995). Chan and Hwang (2001) further explain that lower bid-ask spreads lead to lower trading costs for investors. Hence, lower bid-ask spreads indicate better market quality. While the bid-ask spread embodies the cost of having to trade with immediacy, market depth or best depth will account for price impact costs and opportunity costs of trading from large order sizes (Aitken and Comerton-Forde, 2003). Following Lee and Radhakrishna (2000) and Barber et al (2008), this paper defines large order sizes as $50,000 or greater. Hence, stocks with a best depth value of $50,000 or greater are considered to have good market quality.

This paper is organized as follows. Section 2 presents a detailed literature review surrounding stock price and various liquidity measures. Section 3 describes the data and methodology used in this study. Section 4 presents and analyses the results on the relationship between stock price and liquidity. Section 5 discusses other key determinants of liquidity through a review of the existing literature. Lastly, Section 6 concludes with a summary of the key findings.

2. Literature Review

This section first presents a discussion on the relationship between stock price and liquidity. Next, it provides a review of the theoretical discussions as well as presents both theoretical and empirical evidence surrounding the relationship between stock price and the bid-ask spread. Lastly, it presents the theoretical discussions and empirical evidence documented by prior studies regarding the relationship between stock price and market depth.

2.1 The Relationship between Stock Price and Liquidity

Early market microstructure literature hypothesizes that liquidity should have an impact on stock prices, which is a major component of market quality. Amihud and Mendelson (2006) suggest that liquidity is an important factor in capital asset pricing. They explain that investors want to be compensated for bearing the costs of illiquidity and therefore, investors are only willingly to pay a lesser amount for illiquidity stocks.

Damodaran (2011) further explains that three different approaches are proposed to explain the effect of liquidity on stock prices. First, stock price is reduced by the present value of expected future transaction costs. Second, higher rates of return are required to reflect illiquidity. Third, the loss of liquidity will cause the stock holder to lose his option to sell the stock when it has a high price. Hence, stock price should be one of the major determinants of liquidity. More specifically, Amihud and Mendelson (2006) and Damodaran (2011) suggest that more illiquid stocks have lower stock prices, for any given level of risk.

According to Chan and Hwang (2001), empirical studies generally focus on bid-ask spreads and market depth as the main proxies of liquidity. Hsieh et al (2008) generalize that a market with increasing liquidity is one where the bid-ask spread is decreasing while the market depth is increasing.

2.1.1 Theoretical Discussions on the Relationship between Stock Price and Bid-Ask Spreads

According to Stoll (1989), bid-ask spreads differ significantly across stocks based on their stock characteristics. One such characteristic put forward is stock prices. Theoretical discussions present two arguments on the relationship between stock price and absolute bid-ask spreads.[1] Early postulations provided by Demsetz (1968) suggest that there is a proportional relationship between dollar bid-ask spreads and stock prices. He explains that this relationship should be observed because arbitrage opportunities will exist if the dollar spreads are unequal for low priced and high priced stocks, ceteris paribus. In contrast, Benston and Hagerman (1974) argue that arbitrage opportunities will exist in any case since brokerage costs are disproportionate. As a result, they suggest that it will be more expensive to trade with low priced stocks. Hence, Benston and Hagerman (1974) posit that the dollar bid-ask spreads should be positively related to stock prices rather than proportionally related as proposed by Demsetz (1968).

Apart from calculating the bid-ask spreads in terms of a dollar value, a large number of market microstructure studies also examine the percentage bid-ask spread.[2] [3] Stoll (1978) explains that due to minimum price variation rules, percentage spread may be "artificially" larger for lower-priced stocks. Further support is provided by Harris (1994) where he states that stock price is a major determinant of percentage spread. He explains that stock price determines the percentage spread for low priced stocks because stock price level determines the minimum tick size. For higher priced stocks, stock price will also affect the percentage spread since stock prices are found to vary more than the absolute bid-ask spread. Additionally, Stoll (1978) proposes that order processing costs cause the stock price and the percentage spread to be related. He states that order processing costs are distributed over a greater trade value for higher priced stocks. If percentage spread is part of the costs of order processing, lower processing costs should result in lower percentage spreads. In sum, these theoretical studies suggest that a negative relationship between stock price and percentage spread should be observed.

[1] Absolute bid-ask spread is defined as the calculated spread measured in dollar terms. A detailed discussion on the absolute bid-ask spread can be found under the section 3.2.1.
[2] Some of these studies include Christie and Huang (1994), Harris (1994) and Aitken and Frino (1996).
[3] See Section 3.2 for a detailed discussion on percentage spread.

2.1.2 Theoretical and Empirical Evidence on the Relationship between Stock Price and Bid-Ask Spreads

As discussed above, early theoretical discussions have proposed various hypotheses surrounding the relationship between stock price and bid-ask spreads. Thereafter, a substantial amount of theoretical and empirical evidence has provided strong support for these hypotheses across various stock markets while estimating different measures of the bid-ask spread. Table 1 summarizes the theoretical and empirical evidence on the relationship between stock price and bid-ask spreads.[4]

Table 1

Literature Review on the Relationship between Stock Price and Bid-Ask Spreads

This table shows the literature review on the relationship between stock price and bid-ask spreads. For a comprehensive literature review in this area, see Appendix A.

Relationship	Theoretical Evidence	American markets	Asian markets
Stock Price and Quoted Bid Ask Spreads	Demsetz (1968): dollar bid-ask spreads are proportional to stock prices Benston and Hagerman (1974): dollar bid-ask spreads are positively related to stock prices Stoll (1978): percentage spreads may be larger for lower-priced stocks due to tick size constraints and fixed order processing costs Harris (1994): spreads for lower price stocks may be constrained by the minimum tick size, whilst spreads increase at a less-than-proportional rate for higher priced stocks Copeland and Galai (1983): dollar bid-ask spread is increasing in stock prices	Tinic and West (1972): dollar spread positively related to stock price Benston and Hagerman (1974) : dollar spread positively related to stock price McInish and Wood (1992): relative spread negatively related to stock price Chordia et al (2000): stock price positively related to dollar spread and negatively related to percentage spread Harris (1994): stock price positively related to dollar spread and negatively related to percentage spread Porter and Weaver and (1997): relative spread negatively related to stock price	Aitken and Frino (1996): relative spread negatively related to stock price Chung et al (2011): relative spread negatively related to stock price Hsieh et al (2008): relative spread negatively related to stock price

[4] See Appendix A for a comprehensive discussion on the literature review regarding the relationship between stock price and bid-ask spreads.

In conclusion, both theoretical and empirical studies find strong evidence that stock price is one of the fundamental determinants of bid-ask spreads. Specifically, two major results are concluded – (1) the dollar bid-ask spread is positively related to stock prices and (2) the percentage bid-ask spread is negatively related to stock prices. More importantly, the majority of the documented evidence is similar. Furthermore, these results are also observed to remain consistent across time and extend to various global stock markets.

2.1.3 Theoretical Discussions on the Relationship between Stock Price and Market Depth

According to Chan and Hwang (2001) and Hsieh et al (2008), market depth is also an important determinant of liquidity. Aitken and Comerton-Forde (2003) explain that while bid-ask spread is an effective and accurate method of calculating liquidity for investors who trade with small order sizes, market depth will account for price impact costs and opportunity costs of trading for investors who trade with large order sizes. Amihud and Mendelson (2006) define market depth as the order size at the best bid price and the best ask price, which is the largest quoted size that does not incur a price impact cost above the bid-ask spread. Hence, they state that stocks with greater market depth are considered to be more liquid.

Apart from stating that a relationship exists between stock prices and bid-ask spreads, Harris (1994) also suggests that market depth is affected by stock price levels. Overall, he posits that stock prices and market depth should share a positive relationship. He explains that this relationship is observed based on two factors – (1) the minimum price variations stipulated by the stock exchange and (2) trading with quote matchers. For factor (1), Harris (1994) suggests that as the minimum tick size is generally stipulated to be larger for higher priced stocks, a larger tick size makes supplying liquidity more profitable. For factor (2), Harris (1994) explains that as high priced stocks are able to achieve more profits than low priced stocks due to their minimum tick size, liquidity providers will quote large market depth to prevent quote matchers from front-running their orders. Both explanations arrive at the conclusion that market depth increases as stock price increases.

2.1.4 Theoretical and Empirical Evidence on the Relationship between Stock Price and Market Depth

It can be noted that few empirical studies investigate the relationship between stock prices and market depth. Table 2 presents a summary of the theoretical and empirical evidence on the relationship between stock price and market depth.[5]

Table 2

Literature Review on the Relationship between Stock Price and Market Depth

This table shows the literature review on the relationship between stock price and market depth. For a comprehensive literature review in this area, see Appendix B.

Relationship	Theoretical Evidence	American markets	European markets	Asian markets
Stock Price and Market Depth	Harris (1994): stock price and market depth should share a positive relationship, since higher-priced shares tend to have a larger tick size, making liquidity supply a more profitable activity, and to prevent front running from quote-matchers	Chordia et al (2000): market depth increases with stock prices Seppi (1997): total market depth decreases with the minimum tick size, indicating that higher-priced stocks tend to display higher depth, since they have large tick sizes	Seppi (1997): total market depth decreases with the minimum tick size, indicating that higher-priced stocks tend to display higher depth, since they have large tick sizes	Chan (2000): market depth is positively related to stock prices when examining the price impact costs

Although a limited number of studies document the relationship between stock price and market depth, both theoretical and empirical studies agree that the relationship between stock price and market depth is positive. Similar to the evidence reported for bid-ask spreads, empirical evidence on market depth is also reported on various stock markets and at different time periods.

[5] See Appendix B for a comprehensive discussion on the relationship between stock price and market depth.

2.2 Market Structure on SGX Relative to Other Global Markets

While this paper has extensively reviewed the literature regarding the relationship between stock price and liquidity across various global stock markets, it should be noted that the documented evidence may be different in the Singapore stock market. This can be attributed to the varying market structures of other exchanges. One major market microstructure difference in the Singapore stock market as compared to the American and European stock markets is that a varying minimum tick size is stipulated at various price ranges on SGX. Furthermore, the minimum quantity for the majority of stocks traded on SGX is 1,000 shares. This is significantly different to other global markets where the minimum trading quantity is usually one share.[6] These two market microstructure features, coupled with a different trading community, would affect the quoting and trading behaviour of the investors. Hence, the documented evidence surrounding the relationship between stock price and each liquidity measure might potentially vary from results found for SGX.

[6] Global stock markets with a minimum trading quantity of one share are ASX, Euronext Paris, London Stock Exchange (LSE), NASDAQ and NYSE among others.

3. Data and Methodology

This section first presents the data used for this analysis. Next, it discusses in great detail the empirical proxies of market quality that will be examined in this paper. Lastly, it presents the methodology adopted for this analysis.

3.1 Data

This paper uses two sets of intraday tick-by-tick data for all Mainboard and Catalist stocks listed on SGX, sourced from Thomson Reuters Tick History. The first data-set contains complete records describing all individual trade observations transacted on SGX. Each trade observation reflects the price, volume, date and time (stamped to the nearest microsecond). The second data-set contains all order submissions from the first to the twentieth levels on both sides of the order book. This is recorded at every point in a trading day when an order change command is sent to the order book.[7] Each market depth observation reflects the price at the best bid and best ask levels to the twentieth bid and ask levels as well as their respective order size. Both data-sets cover a sample period from the 2nd January 2013 to the 31st December 2013. It is also important to note that only trades and orders submitted in the continuous trading session are examined.[8]

To check for data errors, this paper also sets four omission criteria for the trade and market depth data. Trades and orders are excluded if (1) the bid or ask price is less than or equal to zero, (2) the bid or ask size is less than or equal to zero, (3) the bid-ask spread is less than or equal to zero and (4) either the trade price or volume is less than or equal to zero. It can be noted that no data errors are found. Hence, no data points are excluded as a result of this process. Second, odd-lot orders and trades are also excluded as it is well documented that brokers charge a premium on top of the equilibrium price of a stock to account for inventory holding costs. Hence, these orders and trades do not occur at the true value of the stock. Third, 'married' trades are excluded as they can be reported in any time slot within 10 minutes of the trade execution, causing an inaccuracy in the time stamp of the trade occurring. More importantly, it can be noted that both odd-lot trades and 'married' trades are not executed on the ready market, where normal trading takes place. Lastly, stocks that did

[7] An order change command on SGX reflects either an order submission or order cancellation or order amendment or order execution.
[8] The continuous trading session on SGX runs from 09:00 to 17:00.

not record any trades or orders in the sample period are excluded from the analysis. As a result, the analysis consists of a sample size of 736 stocks with approximately 63.5 million data points across the sample period.

3.2 Empirical Proxies for Market Quality

Harris (1994) posits that various liquidity measures documented in the market microstructure literature are important variables to consider in determining the impact on market quality. In support of Harris's postulation, Christie and Huang (1994) explain that higher liquidity is strongly favoured by both individual and institutional investors. This is because a liquid market can promptly absorb their large orders without significant price impact costs. Furthermore, listed companies seek more liquid markets since lower trading costs permit them to obtain lower required rates of return.[9]

As summarized in Section 2, Harris (1994) and Porter and Weaver (1997) state that bid-ask spreads and market depth should be highly considered as the main liquidity measures to evaluate market quality. Further support is provided by Chan and Hwang (2001) where they highlight that the majority of market microstructure studies adopts bid-ask spreads and market depth as the main empirical proxies for liquidity and market quality.

3.2.1 Bid-Ask Spreads (bps)

A traditional and most commonly used measure of liquidity is the quoted bid-ask spread. O'Hara (1995) explains that this measure captures the ex-ante transaction costs. Chan and Hwang (2001) further explain that a lower bid-ask spread results in a lower transaction cost for investors. Hence, a lower bid-ask spread indicates better market quality, ceteris paribus. More importantly, Stoll (1978) and Harris (1994) suggest that the quoted bid-ask spread is only measured accurately if a uniform tick size is implemented across all stocks. However, SGX stipulates varying minimum tick sizes for different stock price segments. Table 3 shows the minimum price variations according to their respective stock prices.

[9] Empirical evidence documenting this relationship is provided by Amihud and Mendelson (1986) and Reinganum (1990).

Table 3

Minimum Bid Schedule on SGX

This table shows the minimum bid schedule implemented on SGX. This schedule is stipulated for stocks trading in SGD, USD or AUD only.

Stock Price	Minimum Tick Size
$0.001 to $0.1999	$0.001
$0.20 to $1.995	$0.005
>= $2	$0.01

As stated and adopted by most empirical evidence, Aitken and Frino (1996) suggest that the percentage bid-ask spread should be adopted when there are different minimum tick size stipulated at various stock price ranges. Apart from accounting for the minimum bid schedule on SGX, the percentage bid-ask spread will also facilitate cross-sectional comparison of the bid-ask spreads across stock price levels.

Specifically, Christie and Huang (1994) define the percentage bid-ask spread (commonly known as spreads (bps) by market participants) as follows.

$$Spread\ (bps)_{i,t} = \left[\frac{\left(Ask\ Price_{i,t} - Bid\ Price_{\ i,t}\right)}{Mid\ Quote_{i,t}}\right] * 10{,}000 \quad (1)$$

Where $Ask\ Price_{i,t}$ represents the best ask price for stock *i* at time *t* and $Bid\ Price_{i,t}$ represents the best bid price for stock *i* at time *t*. $Mid\ Quote_{i,t}$ represents the mid quote or the average of the best bid and ask prices for stock *i* at time *t*.

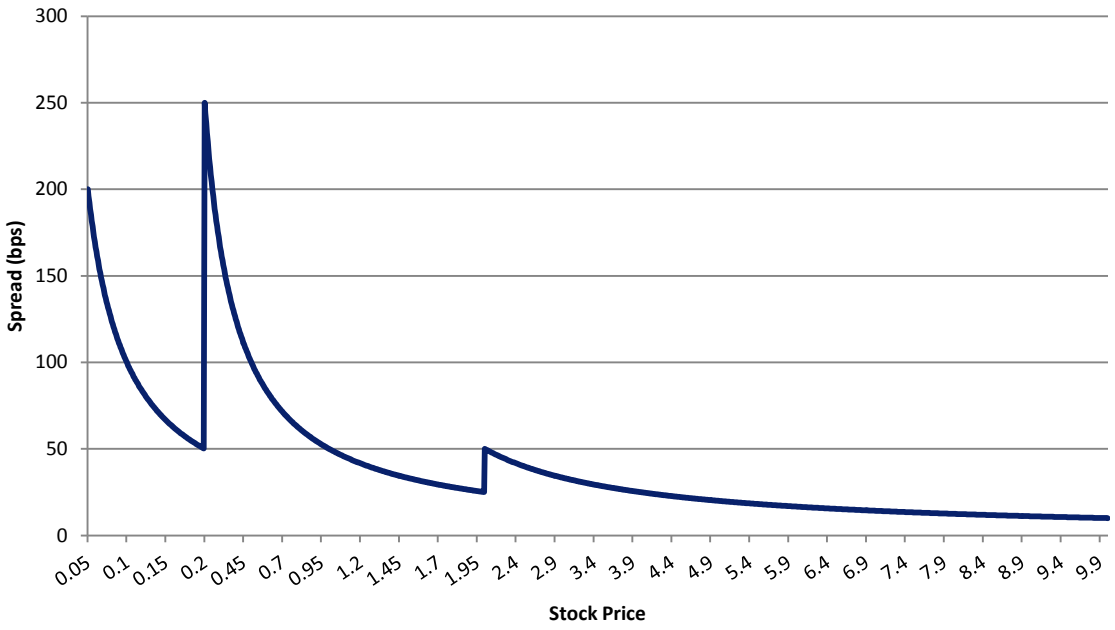
In general, theoretical discussions and empirical evidence provided by Benston and Hagerman (1974) and Aitken and Frino (1996) indicate that stock prices and spread (bps) share a negative relationship. Graphically, Harris (1994) posits that the relationship should look like a reverse "J". Similarly, this relationship is also expected for this analysis. However, due to the minimum tick size structure on SGX, a proportional decrease in this relationship is not found. Diagram 1 shows the distribution of minimum spread (bps) across all stock prices from $0.05 to $10. Although a reverse "J" pattern can be observed generally in Diagram 1, a small but sharp increase can also be observed when the stock price is at $0.20 and $2. Due to the stipulated minimum tick size, spread (bps) faces a significant increase at the $0.20

and $2 price levels. In summary, the general relationship between stock price and spread (bps) is expected to be negative, with a sharp increase in spread (bps) expected at the $0.20 and $2 stock price levels.

Diagram 1

Distribution of Minimum Spread (bps)

This diagram shows the distribution of the minimum bid-ask spreads, measured in basis points, from $0.05 to $10. Spread (bps) is calculated through dividing the stipulated minimum tick size by each stock price in various price steps.



3.2.2 Market Depth

According to Aitken and Comerton-Forde (2003), bid-ask spread embodies the cost of having to transact with immediacy. They explain that this is an effective and accurate method of calculating liquidity for investors who trade with small order sizes. In contrast, they also point out that the bid-ask spread measure overestimates liquidity for investors who trade with large order sizes. Hence, Aitken and Comerton-Forde (2003) suggest that examining the depth of the market will account for price impact costs and opportunity costs of trading from large order sizes. Aitken and Comerton-Forde (2003) explain that even if the bid-ask spread is at its minimum tick size but depth value at the best bid price or best ask price is significantly low, an investor must increase (decrease) his buying (selling) price until

there is sufficient volume in the order book to execute his entire order. As a result, the investor will incur price impact costs. This stock is therefore less liquid than the bid-ask spread would suggest. Consequently, examining market depth together with bid-ask spreads will provide a more comprehensive assessment of liquidity.

Chan and Hwang (2001) define market depth as the number of shares waiting to be executed at different bid and ask prices in the order book. They suggest that market depth should be examined at the best bid and ask prices because this is where depth matters the most. Hence, this paper measures the best depth value as a proxy for market depth. Specifically, best depth value is formulated as follows.[10]

$$Best\ Depth\ Value_{i,t} = Bid\ Price_{i,t} * Bid\ Size_{i,t} + Ask\ Price_{i,t} * Ask\ Size_{i,t} \quad (2)$$

Where $Bid\ Size_{i,t}$ and $Ask\ Size_{i,t}$ are the volumes at the best bid and ask prices for stock *i* at time t, respectively. To evaluate the appropriate best depth value to gauge market quality, this paper relies on an empirical benchmark provided by the market microstructure literature to determine an applicable best depth value. Regardless of the stock market, large trades are often defined as $50,000 or greater. Lee and Radhakrishna (2000) and Barber et al (2008) adopt this benchmark to identify large trades for the American stock markets while Jackson (2003) uses this for the Australian stock markets. Furthermore, the largest (at the 99th percentile) average daily trade size across all sample stocks on SGX is calculated to be at $31,577 in 2013. This suggests that benchmarking a large order as $50,000 on SGX is reasonable. Following this well-adopted benchmark for large trades, this paper suggests that stocks with a high level of market quality should be able to absorb the shock of an incoming $50,000 order without moving the bid or ask price. Hence, this paper suggests that stocks with a best depth value of $50,000 or greater is synonymous with good market quality.

[10] Following Degryse et al (2014), an alternative measure of market depth is also examined. Appendix C reports these alternate results as a robustness test. It is observed that these results are consistent with the presented results.

3.3 Methodology

First, all liquidity measures are calculated on an intraday level and are either averaged or aggregated to a per-stock per-day basis. Second, these resulting figures are averaged for each stock individually to derive the average daily measure. To obtain the overall market statistics, both average and median results are presented. Furthermore, this paper will present the various liquidity measures according to their respective stock price groups. Both average and median are also presented for all stock price groups. It is important to note that the results might be heavily skewed. If skewness is not taken into account, the interpretation of the results can be spurious. This paper uses two criteria to identify a non-normal distribution – (1) Kurtosis and (2) Skewness. If a distribution is found to be normal, the kurtosis measure will be found to be at the value of three while the skewness measure will be found to be at the value of zero. In the event where the distribution is found to be non-normal, the median figures will be used to discuss the results.

The main analysis of this paper is to investigate the market quality at various stock price levels. Hence, this paper will segment the overall market into different stock price groups. As this paper is more focused on liquidity at lower price levels, a finer segmentation is adopted for stocks trading under $0.50.[11] More specifically, a $0.05 price increment is used to form 10 stock price groups for stocks trading under $0.50. To ensure that the remaining stocks are segmented somewhat equally as compared to the smallest stock group for stocks trading under $0.50, this paper divides the remaining stocks into 9 groups while keeping each increment to rounded numbers for ease of viewing. In general, all stocks are divided into 19 stock price groups.

More importantly, this paper uses the annual volume-weighted average price (VWAP) to calculate the benchmark price for each stock. Ting (2006) explains that VWAP provides a less noisy estimate for the unobservable efficient price as compared to the closing price. Furthermore, VWAP is highly favoured by various market participants as their benchmark to measure their transaction performance. To ensure that the formulated VWAP is an efficient benchmark, this paper calculates the variance of the VWAP from the daily closing price of each stock. Results show that 78% of stocks have a price deviation of less than 20%

[11] 507 sample stocks (67%) are found to trade with a stock price at less than $0.50 during 2013. Hence, this paper chose to divide the data at finer increments for stocks trading from $0.005 to less than $0.50.

between the daily closing price and VWAP throughout 2013.[12] Hence, VWAP can be viewed as an efficient benchmark to form various stock price groups without significantly impacting on the overall results.

Table 4 shows the descriptive statistics of each stock price group. It is found that more than half of the sample stocks listed on SGX are priced under $0.30. As expected, higher priced stocks record a higher proportion of total traded value and total market capitalization. More specifically, stocks trading at $0.50 or greater accounted for 81% and 92% of the total traded value and total market capitalization in 2013, respectively. It can also be observed that stocks trading at $1 or greater were trading everyday throughout 2013.

[12] See Appendix D for detailed results on the relationship between stock price and its price deviation of each stock.

Table 4

Descriptive Statistics across Stock Price Groups

This table shows the descriptive statistics of the 736 stocks when grouped according to their various price ranges. All values are calculated for the period from 2nd January 2013 to 31st December 2013. For each stock price group, it provides the number of stocks found in each group, the proportion of the total traded value, the proportion of the total year-end market capitalization and the proportion of days traded. Total traded value is calculated through a summation of the traded value across stocks. Total market capitalization is calculated through a summation of the year-end market capitalization of each stock. It should be noted that this paper uses the median number of days instead of the average because this distribution is found to be non-normal.

Stock Price Groups	Number of Stocks	Proportion of Total Traded Value	Proportion of Total Market Capitalization	Proportion of Days Traded
< $0.05	80	2.3%	0.4%	83%
$0.05 to < $0.10	108	3.7%	1.7%	58%
$0.10 to < $0.15	84	2.7%	1.1%	59%
$0.15 to < $0.20	49	1.0%	0.4%	53%
$0.20 to < $0.25	44	0.4%	0.7%	61%
$0.25 to < $0.30	42	1.1%	0.7%	84%
$0.30 to < $0.35	28	2.6%	0.7%	88%
$0.35 to < $0.40	25	0.8%	0.6%	78%
$0.40 to < $0.45	23	2.0%	0.9%	80%
$0.45 to < $0.50	24	2.9%	0.8%	98%
$0.50 to < $0.60	28	6.9%	3.5%	97%
$0.60 to < $0.70	25	2.4%	1.3%	93%
$0.70 to < $0.85	26	4.0%	2.5%	99%
$0.85 to < $1.00	23	3.2%	2.0%	98%
$1.00 to < $1.20	20	7.1%	3.9%	100%
$1.20 to < $1.50	26	5.9%	7.7%	100%
$1.50 to < $2	23	6.1%	5.5%	100%
$2 to < $4	29	19.5%	19.5%	100%
>= $4	29	25.6%	46.1%	100%

4. Results

This section first presents the relationship between stock price and each liquidity measures for the overall market. This is followed by an in-depth analysis of each liquidity measures when segmented into their respective stock price groups. Next, it will briefly discuss the results of three secondary liquidity measures. Lastly, this section will present overall conclusions drawn from the results of each liquidity measure.

4.1 Relationship between Stock Price and Liquidity Measures for the Overall Stock Market

As discussed above, the majority of the theoretical and empirical literature show similar results when examining the relationship between stock price and various liquidity measures (bid-ask spreads and market depth). Table 5 shows the correlation estimates when examining stock price and the two proposed liquidity measures for the overall stock market.[13] First, results show that the expected negative correlation is found between stock prices and spread (bps). Furthermore, this relationship is found to be statistically significant. These results are consistent with the results presented in both theoretical and empirical literature. Hence, it can be concluded that spread (bps) decreases with an increase in stock price. In general, these results are expected and consistent with empirical evidence where it is documented that higher priced stocks are found to have lower percentage spreads. Hence, this suggests that investors experienced lower trading costs when trading in higher priced stocks.

[13] To derive the correlation coefficient for the overall market, this paper calculates the average daily measure for each stock. Subsequently, a Pearson Correlation Test is conducted to check for correlation between each liquidity measure with respect to the stock price.

Table 5

Correlation Matrix on Various Liquidity Measures with Respect to Stock Price

This table shows the calculated correlation coefficient of the two liquidity measures – Spread (bps) and Best Depth Value, with respect to stock price. Spread (bps) is calculated as described in Equation (1) while best depth value is calculated as described in Equation (2). The coefficients and their corresponding p-value are derived from the Pearson correlation calculations. The calculated correlation coefficient measures the strength and direction of the linear relationship between two variables, ranging from -1 to +1. -1 represents a perfectly negative correlation while +1 represents a perfectly positively correlation. The p-value tests the null hypothesis that the probability of the correlation coefficient is observed to be at zero. The anticipated direction of the correlation, as derived from empirical evidence, is also shown.

Liquidity Measures	Anticipated Correlation	Calculated Correlation Coefficient	*p*-value
Spread (bps)	Negative	-0.1633	<.0001**
Best Depth Value	Positive	0.0896	0.0150*

** and * indicate significance at the 1% and 5% level respectively.

Table 5 also reports the correlation between stock prices and best depth values. Consistent with empirical evidence, it is found that stock prices share a positive relationship with best depth values. This relationship is also found to be statistically significant. Specifically, stocks with a higher price are found to have higher best depth values. Hence, this suggests that higher priced stocks are more likely to absorb the shock of a large order execution without moving the best bid and ask prices. This will result in a lower cost of trading for investors.

Generally, these results provide further support to the existing literature on the relationship between stock price and various liquidity measures for the Singapore market. Results show that a negative relationship is found between stock price and percentage spread while a positive relationship is observed between stock price and market depth. As pointed out by Aitken and Comerton-Forde (2003), examining bid-ask spreads provide an accurate assessment of liquidity for investors who trade with small order sizes while examining market depth accounts for investors who trade with large order sizes. In summary, all results suggest that higher priced stocks are found to have higher liquidity or better market quality.

4.2 Relationship between Various Liquidity Measures in their Stock Price Groups

Thus far, results highlight the relationship between stock price and various liquidity measures for the overall stock market. This paper will now examine these relationships by their stock price groups. More importantly, this paper aims to determine if a higher level of market quality, proxied by bid-ask spreads and market depth, can be observed at certain price levels.

Table 6 reports the overall statistics for the two liquidity measures according to their stock price groups. All formulations are first reported in their averages and medians. As highlighted in Section 3.3, skewness and kurtosis measures are used to evaluate if the distribution is non-normal. A skewness measure of 2.44 and kurtosis measure of 7.63 are found for spread (bps) while a skewness measure of 16.30 and kurtosis measure of 332.70 are found for best depth value.[14] This indicates that both liquidity measures are not normally distributed. Hence, the median figures are used to evaluate liquidity across stock price groups.

More importantly, a positive skewness measure and a high kurtosis measure suggest that a positive skew is observed for both liquidity measures. This indicates that there are more observations of smaller values for spread (bps) and best depth value as compared to larger values of spread (bps) and best depth value. However, these initial results do not provide a clear indication of the distribution for both liquidity measures when grouped by different stock price ranges. Hence, the following sections aim to provide evidence on the distribution of the liquidity measures when divided into various stock price groups.

[14] For a normal distribution, the skewness and kurtosis measures are at zero and three respectively.

Table 6

Overall Statistics of Various Liquidity Measures for the Overall Market

This table shows the calculated statistics for spread (bps) and best depth value when grouped by their various stock price ranges as well as for the overall market. Both the mean and median values are presented. Spread (bps) is calculated as described in Equation (1) while best depth value (SGD) is calculated as described in Equation (2).

Stock Price Group	No of Stocks	Spread (bps)		Best Depth Value (SGD)	
		Mean	Median	Mean	Median
< $0.05	80	1,423	825	340,458	57,137
$0.05 to < $0.10	108	1,153	928	62,909	14,413
$0.10 to < $0.15	84	854	739	77,803	16,833
$0.15 to < $0.20	49	977	665	61,058	16,013
$0.20 to < $0.25	44	883	601	114,056	31,756
$0.25 to < $0.30	42	621	332	178,652	53,842
$0.30 to < $0.35	28	371	190	292,034	101,855
$0.35 to < $0.40	25	515	282	125,270	63,679
$0.40 to < $0.45	23	566	260	199,837	87,294
$0.45 to < $0.50	24	290	137	287,256	132,391
$0.50 to < $0.60	28	235	130	958,018	135,990
$0.60 to < $0.70	25	272	127	332,196	101,316
$0.70 to < $0.85	26	154	93	439,958	112,416
$0.85 to < $1.00	23	171	69	586,920	154,564
$1.00 to < $1.20	20	149	54	955,388	375,633
$1.20 to < $1.50	26	81	50	414,717	149,145
$1.50 to < $2	23	69	46	291,664	151,647
$2 to < $4	29	109	46	719,466	111,413
>= $4	29	67	25	1,581,398	292,925
Overall Market	736	678	313	329,172	49,527

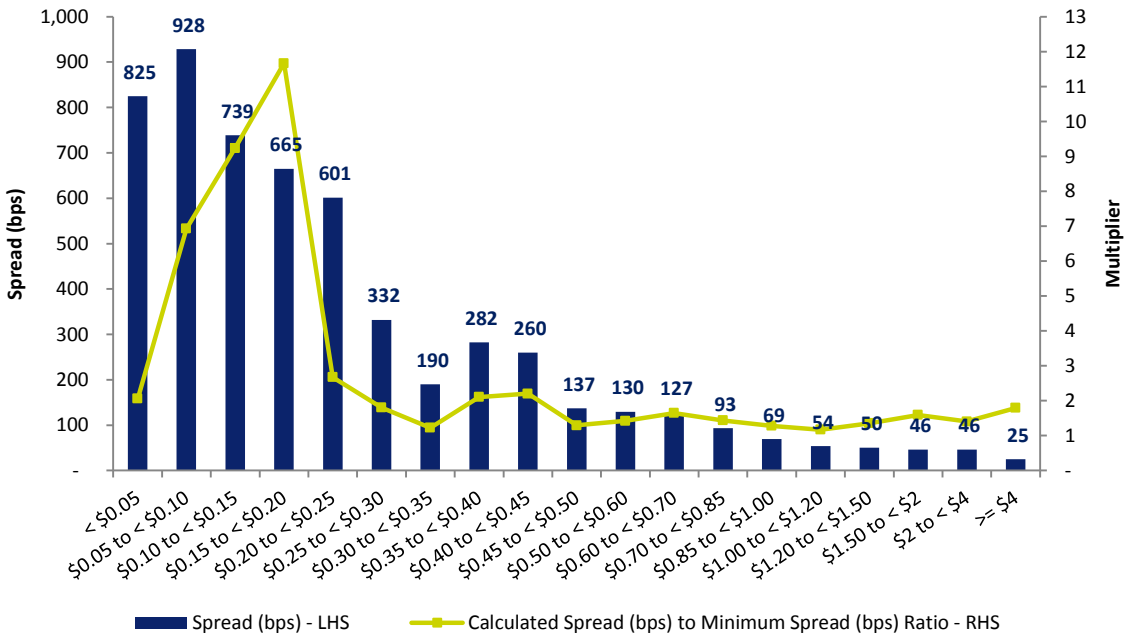
4.2.1 Spread (bps) According to their Stock Price Groups

As stated by Aitken and Frino (1996), spread (bps) provides a reliable measure to facilitate cross-sectional comparison of the bid-ask spreads. Diagram 2 shows the distribution of the median spread (bps) across all stock price groups. Consistent with Harris (1994), a reverse "J" pattern can be observed between stock price groups and spread (bps). More importantly, Diagram 2 also shows that the median spreads (bps) for stocks trading from $0.05 to less than $0.25 are found to be 3 to 12 times the median minimum spread (bps). In contrast, the multiplier for stocks trading at $0.25 or greater is found to be at 2 times or less. Overall, these results suggest that investors who traded stocks at $0.25 or greater faced lower trading costs as compared to trading stocks below $0.25.

Diagram 2

Distribution of the Median Spread (bps) across Stock Price Groups

This diagram shows the distribution of the median spread (bps) across the various stock price groups. Stock price groups are formed by the VWAP of each stock. Spread (bps) is calculated as described in Equation (1). The multiplier is ratio between the calculated median spread (bps) and the minimum median spread (bps). The median figures are used for the analysis as a non-normal distribution for spread (bps) is found.



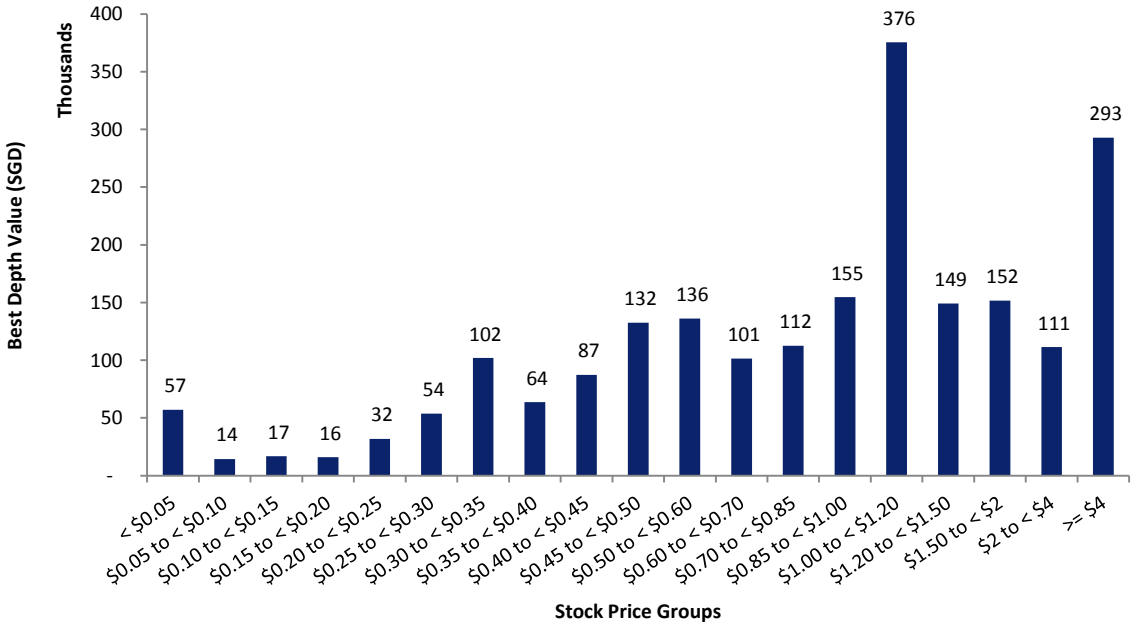
4.2.2 Best Depth Value According to their Stock Price Groups

Consistent with empirical evidence, Diagram 3 shows that best depth value is found to be an increasing function of stock price.[15] As stated by Aitken and Comerton-Forde (2003), liquid stocks are able to absorb the impact of a large trade without moving the best bid and ask prices. A highly-adopted benchmark for large trades is provided by Lee and Radhakrishna (2000) and Barber et al (2008) where they define large trades as an order size of $50,000 or greater. Results from Diagram 3 show that stocks trading at $0.25 or greater and at less than $0.05 display a best depth value in excess of $50,000. This implies that these stocks were able to execute a large order without price impact costs. Hence, this suggests that investors who traded these stocks experienced lower trading costs.

Diagram 3

Distribution of the Median Best Depth Value across Stock Price Groups

This diagram shows the distribution of the median best depth value across the various stock price groups. Stock price groups are formed by the VWAP of each stock. Best depth value is calculated as described in Equation (2) and is reported in SGD. The median figures are used for the analysis as a non-normal distribution for the best depth value is found.



[15] This result is also robust when an alternate measure of best depth value is calculated. See Appendix C for a detailed analysis.

4.2.3 Secondary Liquidity Measures Examined by their Stock Price Groups

Apart from the two main liquidity measures documented in this paper, three secondary liquidity measures are also examined. These liquidity measures are – (1) Spread (Ticks), (2) Proportion of time when the bid-ask spread is at two ticks or less and (3) Proportion of time when a one-sided order book is observed. Although these measures reach similar conclusions, they are also observed to be statistically insignificant. In general, the results for these liquidity measures suggest that market quality improves greatly for stocks trading at $0.25 or greater. For further discussions, the detailed results are elaborated in Appendix E.

4.3 Overall Results

In summary, this paper finds that all results documenting the relationship between stock price and various liquidity measures are highly consistent with both theoretical and empirical literature. Specifically, the main results show that (1) stock price is negatively related to percentage spread and (2) stock price is positively related to best depth value. Hence, this suggests that stocks that were higher priced exhibited better market quality.

In summary, this paper conducted further analysis through segmenting stocks into their respective stock price groups. Interesting results are drawn from this analysis. It is found that stocks trading at $0.25 or greater exhibited high liquidity. It may be noted that while similar liquidity levels are also observed for stocks trading at less than $0.05, significantly lower liquidity measures are observed for stocks that were traded from $0.05 to less than $0.25. Hence, these empirical results suggest that investors experienced lower implicit trading costs when trading stocks at $0.25 or greater as compared to stocks trading below $0.25 in 2013.

5. Discussions on Other Benchmarks to Evaluate Market Liquidity

This section presents two factors that are documented in both theoretical and empirical literature, which serve as important benchmarks to evaluate liquidity. Apart from stock price, the market microstructure literature has identified market capitalization and company fundamentals as other major determinants of liquidity. This section will first discuss the relationship between market capitalization and market liquidity as well as the correlation between market capitalization and stock price. Second, it will review the literature surrounding the relationship between company fundamentals and market liquidity.

5.1 The Relationship between Market Capitalization and Liquidity

From his market microstructure model, Merton (1987) suggests that due to information asymmetry, a distinct relationship between liquidity and market capitalization should be observed. This postulation is supported by numerous empirical studies as they find that market capitalization is a statistically significant determinant of liquidity.

Ho and Michaely (1988) further point out that this relationship should be positively related. They explain that this is observed because of information costs. Companies with higher market capitalization can be viewed as having lower information costs than those with low market capitalization as larger companies are more likely to have a public relations department to produce regular updates for investors. Additionally, Ho and Michaely (1988) indicate that larger companies will receive more investment coverage from various financial analysts. Accordingly, reliable information is released to the public on a frequent and timely basis. These explanations are validated by Chan (2000) as he empirically finds that large market capitalization stocks suffer less from information asymmetry. Ho and Michaely (1988) also suggest that stocks with small market capitalization will have low information efficiency. This can potentially lead to increased manipulation opportunities from errant market participants, which lowers the overall quality of the market.

5.1.1 Theoretical and Empirical Evidence on the Relationship between Market Capitalization and Liquidity

Theoretical discussions suggest that market capitalization should be positively related to liquidity. Table 7 presents a summary of the theoretical and empirical evidence on the relationship between market capitalization and liquidity.[16]

Table 7

Literature Review on the Relationship between Market Capitalization and Liquidity

This table shows the literature review on the relationship between market capitalization and liquidity. For a comprehensive literature review in this area, see Appendix F.

Relationship	Theoretical Evidence	American markets	European markets	Asian markets
Market Capitalisation and Liquidity	Ho and Michaely (1988): companies with higher market capitalisation have lower information costs and thus higher liquidity and information efficiency, benefitting from their public relations departments and increased coverage by financial analysts	Harris (1994): percentage spreads have a negative relationship with market capitalization Stoll (2000): percentage spread is lower for companies with larger market capitalization Pastor and Stambaugh (2003): small market capitalization companies have lower liquidity Chordia et al (2004): small market capitalization companies have lower liquidity	Bogdan et al (2012): stocks of large capitalization companies are more liquid	Chan (2000): stocks with higher market capitalisation have lower information asymmetry and lower price impact costs Chan et al (2012): percentage spread is lower for companies with larger market capitalization Chung et al (2011): market depth increases with market capitalization

[16] See Appendix F for a comprehensive discussion on the relationship between market capitalization and liquidity.

In summary, empirical evidence documenting the relationship between market capitalization and liquidity reach similar conclusions. Specifically, all studies find that larger market capitalization stocks have higher levels of liquidity. They mainly attribute this positive relationship to information asymmetry which subsequently affects the tradability of a stock. It is also important to note that these results are robust across time and various stock markets.

5.2 The Relationship between Market Capitalization and Stock Price

Within the market microstructure literature, it is commonly understood that market capitalization and stock price should be correlated (Chan et al, 2012). Further support is provided by Chordia et al (2004) where they find that companies with larger market capitalization have higher stock prices. Hence, this indicates that there is a positive correlation between market capitalization and stock price.

Diagram 4

The Relationship between Stock Price and Market Capitalization

This diagram shows a scatter plot between the stock price, as measured by VWAP, and its corresponding market capitalization for SGX. Market capitalization is taken as the year-end market capitalization. Subsequently, the median figure is calculated for each stock and is compared against their respective VWAP. It can be noted that the x-axis (stock price) and the y-axis (market capitalization) are being logged for ease of interpreting the scatter plot.

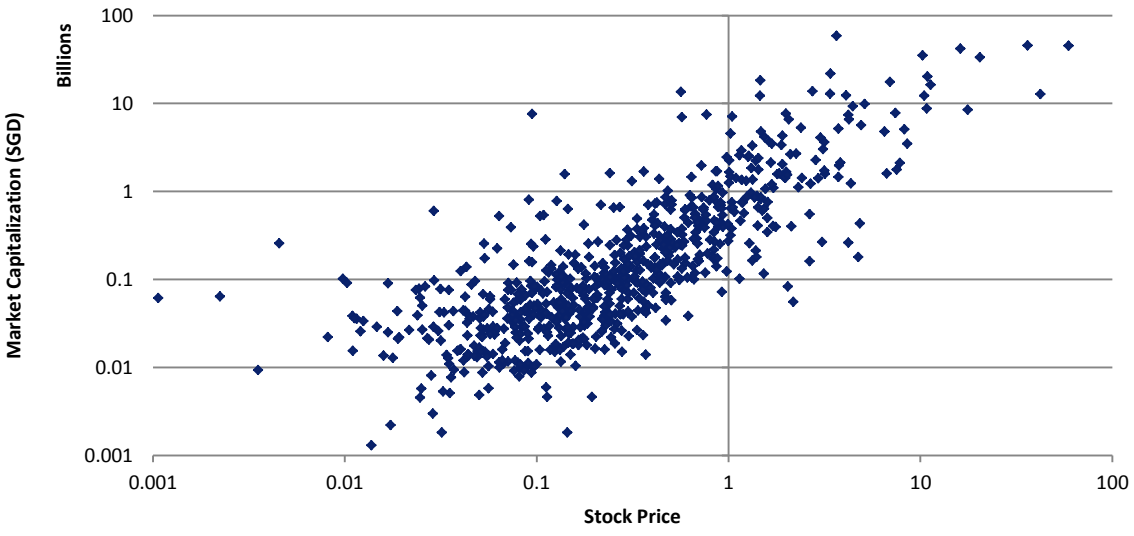


Table 8

Correlation Matrix on Market Capitalization with Respect to Stock Price

This table shows the calculated correlation coefficient between market capitalization and stock price for SGX. The coefficients and their corresponding p-value are derived from the Pearson correlation calculations. Market capitalization is taken as the year-end market capitalization while stock price is measured from VWAP. The correlation coefficient measures the strength and direction of the linear relationship between two variables, ranging from -1 to +1. -1 represents a perfectly negative correlation while +1 represents a perfectly positively correlation. The p-value tests the null hypothesis that the probability of the correlation coefficient is observed to be at zero. The anticipated direction of the correlation, as derived from empirical evidence, is also shown.

Measure	Anticipated Correlation	Calculated Correlation Coefficient	*p*-value
Market Capitalization	Positive	0.6971	<.0001**

** and * indicate significance at the 1% and 5% level respectively.

Diagram 4 shows the scatter plot between the stock price and market capitalization. From Diagram 4, a positive trend between stock price and market capitalization can be observed. Results from Table 8 confirm this observation as the correlation coefficient between stock price and market capitalization is found to be positive and statistically significant. Consistent with empirical evidence, stock price is found to be positively correlated to market capitalization for the overall SGX market.

5.3 The Relationship between Company Fundamentals and Liquidity

From the corporate finance literature, many empirical studies have hypothesized and found that on top of the business and financial risks of listed companies, company fundamentals are also a major determinant of liquidity. In general, researchers have noted that company fundamentals, such as company value, company performance and capital structure, are highly correlated with liquidity.[17]

[17] Empirical studies generally define company value as Tobin's Q. Tobin's Q is a commonly used measure to proxy for company valuation. Specifically, it is the ratio of market value of equity and book value of total debts divided by the book value of total assets. It is important to note that company value is a different measure as compared to market capitalization.

Amihud and Mendelson (2008) explain that listed companies seek to increase their stock's liquidity as it reduces the expected returns required by investors. A lower required return translates to a lower cost of capital for the listed company, which leads to a higher valuation for future cash flows that the company can generate. Hence, this increases the market value of the listed company and its tradability. Alternatively, Dow and Gorton (1997) and Subrahmanyam and Titman (1999) explain that a more liquid stock attracts informed traders who play important functions in that it gathers information from different market participants. As a result, liquid stocks will be more informative of company-specific information that is not known to company managers. Hence, they can use such information to improve company valuation by making better corporate decisions, resulting in an increase in the tradability of the stock.

Theoretical discussions also suggest that liquidity affects the governance role of block shareholders which consequently affects company valuation. Maug (1998) claims that block shareholders holding liquid stocks can easily threaten to sell their stocks (commonly known as "threat to exit"), which leads to effective corporate governance. Edmans and Manso (2011) and Edmans et al (2011) explain that the prospect of block shareholders selling company stocks makes managers follow their interests with those of major shareholders. When managers are coherent with shareholder's interest, this will result in an increase in the company valuation and thereby increasing liquidity.

In addition, Fang et al (2010) posit that the level of institutional participation in a stock might explain the positive relationship between company performance and liquidity. They suggest that institutional investors are commonly attracted to high performance companies as these companies have high market-to-book ratios. As a result, an increase in institutional investor participation increases market depth and augments liquidity. Hence, they conclude that companies with better company performance should be observed to have higher liquidity.

5.3.1 Theoretical and Empirical Evidence on the Relationship between Company Fundamentals and Liquidity

In general, empirical evidence is consistent with the theoretical predictions on the relationship between company value/company performance and liquidity. Table 9 summarizes the theoretical and empirical evidence on the relationship between company fundamentals and liquidity. [18]

In summary, both theoretical and empirical evidence highlights the importance of examining company fundamentals when evaluating market liquidity. Specifically, this paper identifies three measures of company fundamentals that affect liquidity. It is documented that company value is positively related to liquidity. A positive relationship is also found between company performance and liquidity as well as capital structure and liquidity. Overall, these results suggest that stocks with stronger fundamentals have higher liquidity.

[18] See Appendix G for a comprehensive discussion on the relationship between company fundamentals and liquidity.

Table 7

Literature Review on the Relationship between Company Fundamentals and Liquidity

This table shows the literature review on the relationship between company fundamentals and liquidity. For a comprehensive literature review in this area, see Appendix G.

Relationship	Theoretical Evidence	American markets	European markets	Asian markets
Company Fundamentals and Liquidity	Amihud and Mendelson (2008): liquidity reduces the expected return required by investors, and thus reduces the cost of capital Dow and Gorton (1997): liquidity makes the stock more informative of company-specific information Subrahmanyam and Titman (1999): liquidity makes the stock more informative of company-specific information Maug (1998): liquidity improves corporate governance, since block shareholders can exit their positions Edmans and Manso (2011): the threat of block-holder sales of liquid securities improves governance Edmans et al (2011): liquidity improves corporate governance Fang et al (2010): institutional shareholders have a preference for companies with high market-to-book ratios, increasing the liquidity of their shares	Fang et al (2010): company performance increases with liquidity Amihud and Mendelson (2008): company value increases with liquidity Frieder and Martell (2006): liquidity increases with the company's leverage Huang et al (2014): positive relationship between company value and stock liquidity	Loderer and Roth (2005): companies with a lower price-to-earnings ratio tend to have poorer liquidity Huang et al (2014): positive relationship between company value and stock liquidity	Huang et al (2014): positive relationship between company value and stock liquidity

6. Conclusions

This paper provides a review on market quality of the SGX securities market through using 2013 data. More importantly, it focuses on the market quality of stocks trading at various stock price levels. In order to evaluate market quality, this paper adopts two liquidity measures as proposed by the market microstructure literature. These two liquidity measures are the bid-ask spread measured in basis points (percentage spread) and the quoted best depth value. First, this paper provides empirical evidence surrounding the relationship between stock prices and the two liquidity measures. Next, it investigates if a higher level of market quality was observed at certain stock price levels.

The analysis finds that an expected negative relationship is found between stock price and spread (bps). This result suggests that investors who traded with higher priced stocks faced narrower bid-ask spreads and therefore experienced lower costs of trading. In addition, results show an expected positive relationship between stock price and market depth. This shows that investors who traded in higher priced stocks were able to execute large orders without incurring price impact costs. Hence, these investors experienced lower trading costs as compared to those trading in lower priced stocks.

When examining the various liquidity measures in their respective price groups, the analysis finds that stocks trading at $0.25 or greater exhibited high liquidity. It may be noted that similar conclusions are also found for stocks trading at less than $0.05. Specifically, these stocks were generally trading at narrower spreads while displaying sufficient depth at the best bid and ask prices to absorb the shock of a large executed order. In contrast, stocks that were traded from $0.05 to less than $0.25 displayed significantly lower liquidity as they did not meet the proposed benchmarks of desired market quality. Hence, investors who traded these stocks would have experienced higher implicit trading costs as compared to those in other stock price groups.

Additionally, this paper also briefly examines three secondary liquidity measures. These measures are (1) spread (ticks), (2) proportion of time when the bid-ask spread is at 2 ticks or less and (3) proportion of time when a one-sided order book is observed. In general, they are found to have the expected correlation relative to the stock price. However, their correlation coefficients are observed to be statistically insignificant. More importantly, the

results for these liquidity measures also suggest that market quality improves significantly for stocks trading at $0.25 or greater.

This paper also stresses that although stock price levels may serve as the main factor in market quality assessment, stock price alone does not sufficiently explain all aspects surrounding the evaluation of market quality. Prior research indicates that market capitalization and company fundamentals are also important determinants of liquidity. Overall, the empirical literature suggests that liquidity is positively related to market capitalization and company fundamentals.

Main results have shown that stock price is positively related to liquidity on SGX. These results are also consistent with the evidence shown in other global stock markets even though each market has a varying market structure in one form or another. These results are also consistent when stocks are segmented into their respective stock price groups. Moreover, results suggest that investors experienced lower implicit trading costs when trading stocks at $0.25 or greater as compared to stocks trading below $0.25 in 2013. A review of the literature surrounding market capitalization and company fundamentals has also suggested that these factors influence liquidity. In conclusion, results drawn from the empirical analysis and discussions have suggested that stocks which are either higher priced or have larger market capitalization or display stronger company fundamentals are more likely to exhibit higher levels of market quality.

7. Appendix

Appendix A: Literature Review on the Relationship between Stock Price and Bid-Ask Spreads

Copeland and Galai (1983) can be considered as the pioneers to provide theoretical evidence on the relationship between stock price and bid-ask spread. They aim to examine the behaviour of the bid-ask spread through a model where a market maker is transacting with liquidity investors and informed investors. Consistent with the reported theoretical discussions, the bid-ask spread, as measured in dollar terms, is found to be an increasing function of stock prices.

More support for this positive relationship between the dollar spread and stock price is provided by Tinic and West (1972) and Benston and Hagerman (1974). Examining the over-the-counter (OTC) market, both studies conclude that higher priced stocks have wider dollar spread. Additionally, Benston and Hagerman (1974) find that this positive relationship is less than proportional, with a 100% increase in stock prices leading to a 59% increase in the dollar spread, ceteris paribus. It is also important to note that among the explanatory variables of the dollar spread, Benston and Hagerman (1974) find that stock price is the most important determinant of bid-ask spreads when evaluating their *t*-ratios.[19]

While investigating the intraday patterns of the bid-ask spreads for stocks listed on the New York Stock Exchange (NYSE), McInish and Wood (1992) find that higher priced stocks are observed to have narrower percentage spreads. This result is also extended to the Australian Stock Exchange (ASX). Univariate results from Aitken and Frino (1996) show that percentage spreads are higher for stocks priced from $0.005 to $0.10 as compared to stocks priced between $0.10 and $10. Moreover, their multivariate results find a negative relationship between stock price and percentage spreads for both lower priced and higher priced stock groups. In general, overall results from Aitken and Frino (1996) indicate that percentage spreads are found to decline disproportionally with stock prices.

Chordia et al (2000) provide more empirical evidence on the relationship between stock price and the bid-ask spread, as measured in dollar spread and percentage spread, for NYSE stocks. Consistent with prior evidence, they also find that stock price is positively

[19] Other explanatory variables include the number of transactions, cost of carrying inventory, losses arising from trading with insiders and the number of competing dealers marking a market.

related to dollar spread while a negative relationship is shared between stock price and percentage spreads. They explain that the stock price and bid-ask spread relationship should be intuitive; stating that a $10 stock will clearly not have a similar bid-ask spread as compared to a $1,000 stock unless both have similar attributes. Similar to Benston and Hagerman (1974), Chordia et al (2000) also find that the stock price coefficient for dollar spread and percentage spread have the largest *t*-statistics. This result indicates that stock price is the major determinant of bid-ask spreads among other factors.

Numerous empirical studies have also documented the relationship between stock price and bid-ask spreads when examining the effects of varying minimum tick sizes. Harris (1994) provides initial empirical evidence for stocks listed on the American Stock Exchange (AMEX) and NYSE. He finds that dollar spread increases with stock price levels while the inverse relationship is found for percentage spread and stock price levels. Furthermore, these results hold when accounting for the minimum tick size stipulated on both stock exchanges (Harris, 1994). He attributes the cause of these results to the ability of liquidity providers to protect themselves against investors who implement quote-matching strategies. He further explains that for low priced stocks, it is easier for liquidity providers to protect themselves against quote-matchers because the minimum tick size represents a larger fraction of stock price for low priced stocks as compared to high priced stocks. As a result, high priced stocks should be observed to have narrower spreads as compared to low priced stocks after controlling for the effects of price discreteness.

Following Harris's (1994) analysis, Chung et al (2011) provide similar results when examining the varying tick size structure and market quality on the Korean Stock Exchange (KRX). Specifically, they find a negative relationship between stock price and the percentage spread. Similar results are also reported by Porter and Weaver and (1997) and Hsieh et al (2008) for the Toronto Stock Exchange (TSE) and the Taiwan Stock Exchange Corporation (TSEC) respectively. Both studies find that stock price and percentage spread is negatively related after implementing changes in the minimum tick size structure. More importantly, their results suggest that the negative relationship between stock price and percentage spread is also robust to market microstructure changes.

In conclusion, both theoretical and empirical studies find strong evidence that stock price is one of the fundamental determinants of bid-ask spreads. Specifically, two major results are concluded – (1) the dollar bid-ask spread is positively related to stock prices and (2) the percentage bid-ask spread is negatively related to stock prices. More importantly, the majority of the documented evidence is similar. Furthermore, these results are also observed to remain consistent across time and extend to various global stock markets.

Appendix B: Literature Review on the Relationship between Stock Price and Market Depth

To the best of the author's knowledge, few empirical studies investigate the relationship between stock prices and market depth. Early empirical evidence is provided by Seppi (1997) where he shows that total market depth decreases with the minimum tick size in the American and Paris stock markets. Harris (1994) indicates that the minimum tick size is generally stipulated to be larger for higher priced stocks. Hence, it can be concluded that the relationship between stock price and market depth should be positive.

In addition, Chan (2000) finds that market depth is positively related to stock prices when examining the price impact costs on the Stock Exchange of Hong Kong (HKSE). In support of Seppi (1997) and Chan (2000), Chordia et al (2000) also find that market depth increases with stock price for stocks listed on the NYSE. This positive relationship between market depth and stock price is also found to be robust to market microstructure changes. When examining a reduction in tick size on TSEC, Hsieh et al (2008) find that stock price is positively related to market depth.

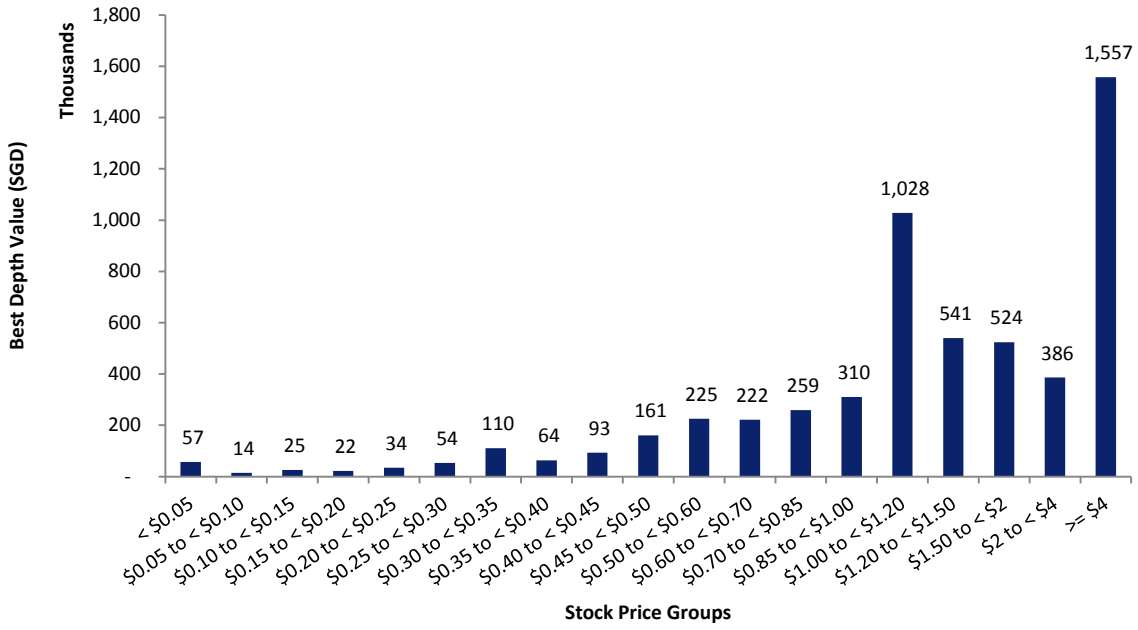
Although a limited number of studies document the relationship between stock price and market depth, both theoretical and empirical studies agree that the relationship between stock price and market depth is positive. Similar to evidence reported for bid-ask spreads, empirical evidence on market depth is also reported on various stock markets and at different time periods.

Appendix C: Robustness Test for Best Depth Value

Diagram C-1

Distribution of Alternate Best Depth Value Measure across Stock Price Groups

This diagram shows the distribution of the alternate best depth value across the various stock price groups. Stock price groups are formed by the VWAP of each stock. This measure aggregates the total bids and asks values within 1% of the mid-point quoted price or the best or the total value at the best bid and ask prices where the minimum tick size exceeds 1%. It can be noted that this measure is reported in SGD.



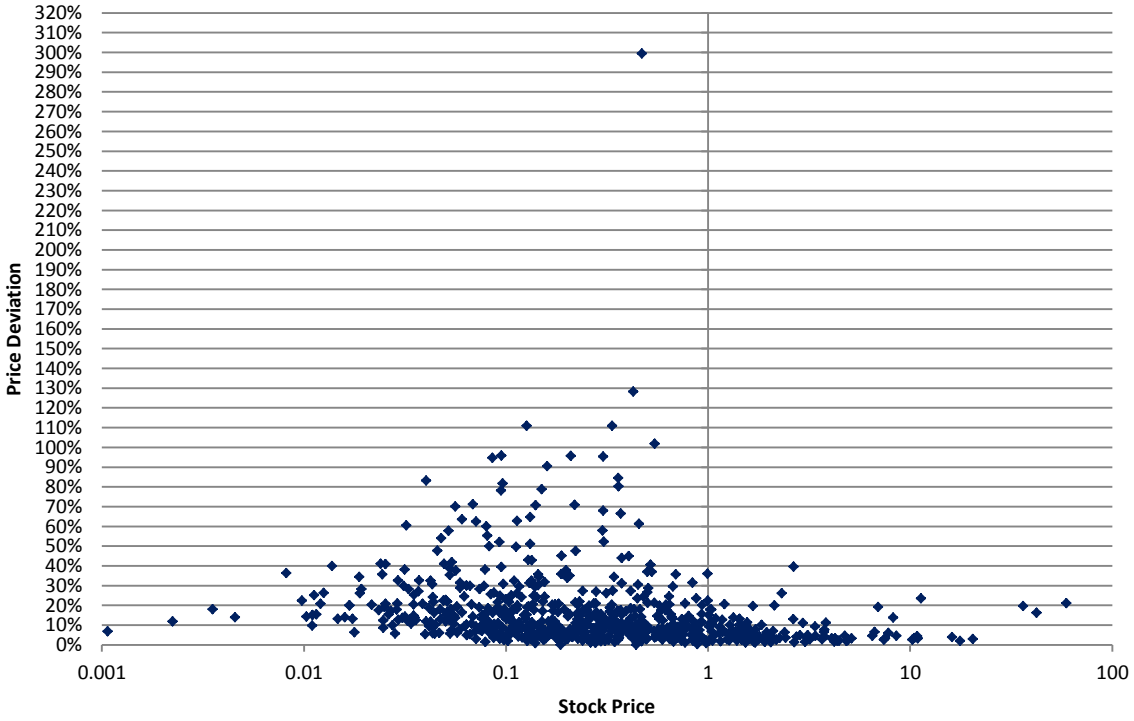
Following Degryse et al (2014), this paper also measures the best depth value by incorporating the depth value beyond the best price levels. Specifically, this measure aggregates the total bids and asks values within a fixed internal (1%) of the mid-point quoted price. In general, the result observed from the diagram above is consistent with Diagram 3. More specifically, the result shows that depth value is an increasing function of stock price. Additionally, this relationship is found to be increasing disproportionately. These results are also in line with the correlation coefficient on Table 5.

Appendix D: Robustness Test for VWAP as an Efficient Benchmark

Diagram D-1

The Relationship between Stock Price and its Price Deviations

This diagram shows a scatter plot between the stock price, as measured by VWAP, and its price deviations from the daily closing price. The price deviation is calculated by taking the absolute difference from the VWAP and the closing price of each stock on a daily basis. Subsequently, the median figure is calculated for each stock and is compared against their respective VWAP. It can be noted that the x-axis (stock price) is being logged for ease of interpreting the scatter plot.



As a robustness test to ensure that VWAP is an efficient price benchmark across the sample period, this diagram plots the relationship between stock price and its price deviations from the daily closing price for each individual stock. Results show that 51%, 78% and 88% of stocks are found to have a median price deviation of less than 10%, 20% and 30% respectively. Hence, majority of stocks are found to have minimal price deviations. This suggests that VWAP can be considered as an efficient benchmark to segment the stocks into various stock price groups.

Appendix E: Analysis Surrounding the Secondary Liquidity Measures

Three secondary liquidity measures are also examined with respect to stock prices. These secondary liquidity measures are (1) spread (ticks), (2) proportion of time when the bid-ask spread is at 2 ticks or less and (3) proportion of time when a one-sided order book is observed. Similar to the main analysis, this paper first determines the relationship between stock prices and these liquidity measures. Next, it will discuss the results on whether a higher level of liquidity is observed after a certain stock price level.

E.1 Calculation Methods Surrounding the Secondary Liquidity Measures

This paper will first explain the formulation process behind these three liquidity variables. As a minimum bid schedule is implemented on SGX, this rule limits the minimum bid-ask spread that can be quoted and therefore, the quoted spread can never be less than the mandated minimum tick size. To account for the different stipulated minimum tick size at various stock price ranges, the spread (ticks) is calculated as follows.

$$Spread\ (Ticks)_{i,t} = \left(Ask\ Price_{i,t} - Bid\ Price_{i,t}\right) \Big/ Minimum\ Tick\ Size_{i,t} \quad \text{(E-1)}$$

Where $Minimum\ Tick\ Size_{i,t}$ represents the stipulated minimum price increment for stock *i* at time *t*. For stocks to display good market quality, their spread (ticks) is expected to be at 2 ticks or less.[20] Extending from this measure, this paper also examines the proportion of time in a trading day when the spread (ticks) is at 2 ticks or less. This measure aims to show that stocks are frequently trading at narrower spreads and therefore investors are constantly experiencing lower trading costs. This paper posits that stocks with good market quality should have a spread (ticks) at 2 ticks or less for at least 50% of a trading day. Specifically, the proportion of time in a trading day when spread (ticks) is at 2 ticks or less is computed as follows.

[20] Ideally, the spread (ticks) should be expected at 1. However, such expectations can be viewed as unreasonable because incoming large orders can cause the bid-ask spread to widen significantly for a short period of time before liquidity is replenished.

$$PTime\ Spread\ (Ticks) \leq 2_{i,d} = \frac{\sum Time\ when\ Spread\ (Ticks)\ \leq 2_{i,d}}{Total\ Trading\ Hours_{i,d}}$$

(E-2)

Where $Time\ when\ Spread\ (Ticks) \leq 2_{i,d}$ represents the time in a trading day when spread (ticks) is at 2 ticks or less for stock *i* at day *d*. $Total\ Trading\ Hours_{i,d}$ represents the total trading hours for the stock *i* at day *d*, which is recorded at 08:00:00 for every observation.

Thus far, the formulations for the above two secondary liquidity measures require both bid and ask prices. A one-sided order book also poses severe liquidity issues for investors. When an order book is one-sided, an investor can go into an open position but will face difficulties closing out his open position. As a result, this increases his risk of transacting and leads to higher trading costs. Hence, this paper adopts a liquidity measure which captures the proportion of time when the order book is one-sided. This paper hypothesizes that stocks with good market quality should not have one-sided order books. Specifically, this new measure is defined as follows.

$$PTime\ One\ Sided_{i,d} = \frac{Time\ When\ Order\ Book\ is\ One\ Sided_{i,d}}{Total\ Trading\ Hours_{i,d}}$$

(E-3)

Where $Time\ when\ Order\ Book\ is\ One\ Sided_{i,d}$ represents the total time in a trading day when bid orders or ask orders are not present for stock *i* at day *d*. $Total\ Trading\ Hours_{i,d}$ represents the total trading hours for the stock *i* at day *d*, which is recorded at 08:00:00 for every observation.

E.2 Results on the Relationship between Stock Price and the Three Secondary Liquidity Measures

Table E-1 shows the correlation estimates when examining the relationship between stock price and the three secondary liquidity measures.[21] First, results show that there is a

[21] To derive the correlation estimates for the overall market, this paper calculates the average daily measure for each stock. Subsequently, a Pearson Correlation Test is conducted to check for correlation between each liquidity measure with respect to the stock price.

negative and weak correlation between stock price and spreads (ticks). Hence, this result suggests that as stock price increases, spread (ticks) decreases but at a disproportionate rate. However, this relationship is found to be statistically insignificant at the 5% level.

Next, results indicate that stock price is positively correlated with the proportion of time when the quoted spread is at 2 ticks or less. In general, these results suggest that higher priced stocks are found to quote with narrower spreads. However, the relationship is found to be statistically insignificant at the 5% level.

Table E-1

Correlation Matrix on Various Secondary Liquidity Measures with Respect to Stock Price

This table shows the calculated correlation coefficient of the three secondary liquidity measures with respect to stock price. Spread (Ticks) is measured as described in Equation (E-1) while the proportion of time quoted spread is at 2 ticks or less is calculated as described in Equation (E-2). The proportion of time when the order book is one-sided is calculated as described in Equation (E-3). The coefficients and their corresponding p-value are derived from the Pearson correlation calculations. The correlation coefficient measures the strength and direction of the linear relationship between two variables, ranging from -1 to +1. -1 represents a perfectly negative correlation while +1 represents a perfectly positively correlation. The p-value tests the null hypothesis that the probability of the correlation coefficient is observed to be at zero.

Liquidity Measures	Calculated Correlation Coefficient	*p*-value
Spread (Ticks)	-0.0087	0.8132
Proportion of Time Quoted Spread ≤ 2 Ticks	0.0177	0.6320
Proportion of Time Order Book is One-Sided	-0.0668	0.0701

** and * indicate significance at the 1% and 5% level respectively.

Lastly, results also show that there is a negatively weak relationship between stock price and the proportion of time when the order book is observed to be one-sided. This suggests that higher priced stocks should have a lower occurrence of a one-sided order book. Once again, this relationship is found to be statistically insignificant at the 5% level. In general, all three results suggest that there is a low probability of a relationship between stock price and the three respective liquidity measures.

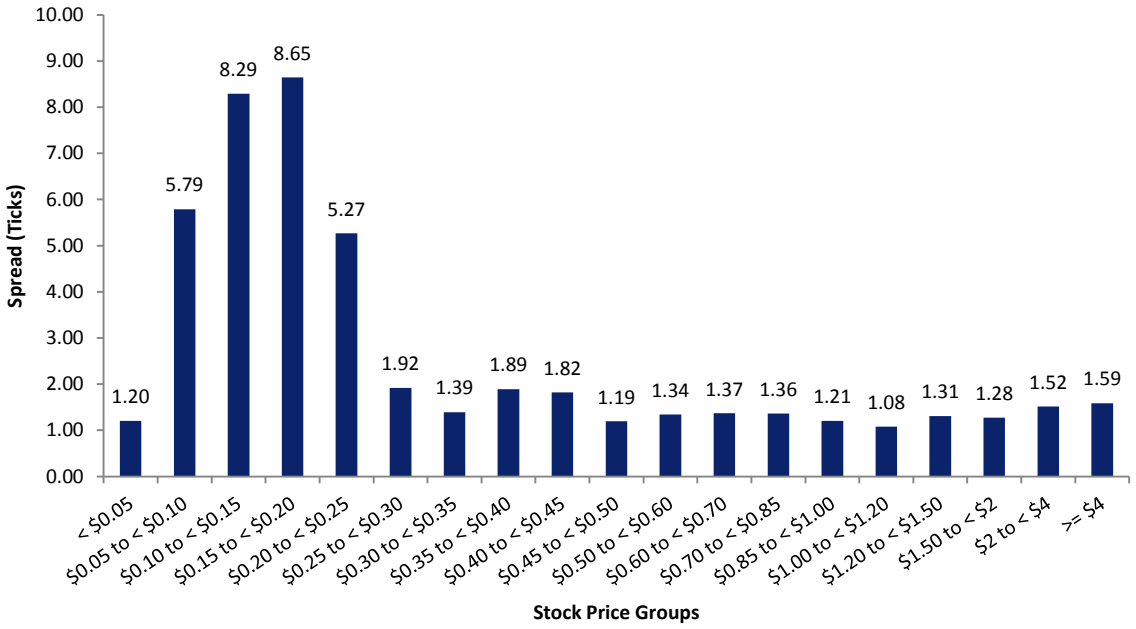
E.3 Spread (Ticks) According to their Stock Price Groups

In section E.1, it is suggested that spread (ticks) is expected to be at 2 ticks or less for stocks to display good market quality. Diagram E-1 illustrates the distribution of the median spread (ticks) according to their stock price groups. It can be seen that stocks trading at less than $0.05 and at $0.25 or greater exhibit desirable bid-ask spreads. Furthermore, Chordia el at (2004) state that the minimum tick size constraint will be less binding as stock price increases. That is, spread (ticks) should be wider for higher priced stocks as compared to lower priced stocks. In contrast, results from Diagram E-1 show that stocks priced at less than $0.05 and at $0.25 or greater were trading close to minimum tick. Hence, this result accentuates the quality of these stocks.

Diagram E-1

Distribution of the Median Spread (Ticks) across Stock Price Groups

This diagram shows the distribution of the median spread (ticks) across the various stock price groups. Stock price groups are formed by the VWAP of each stock. Spread (bps) is calculated as described in Equation (E-1). The median figures are used for the analysis as a non-normal distribution for spread (ticks) is found.

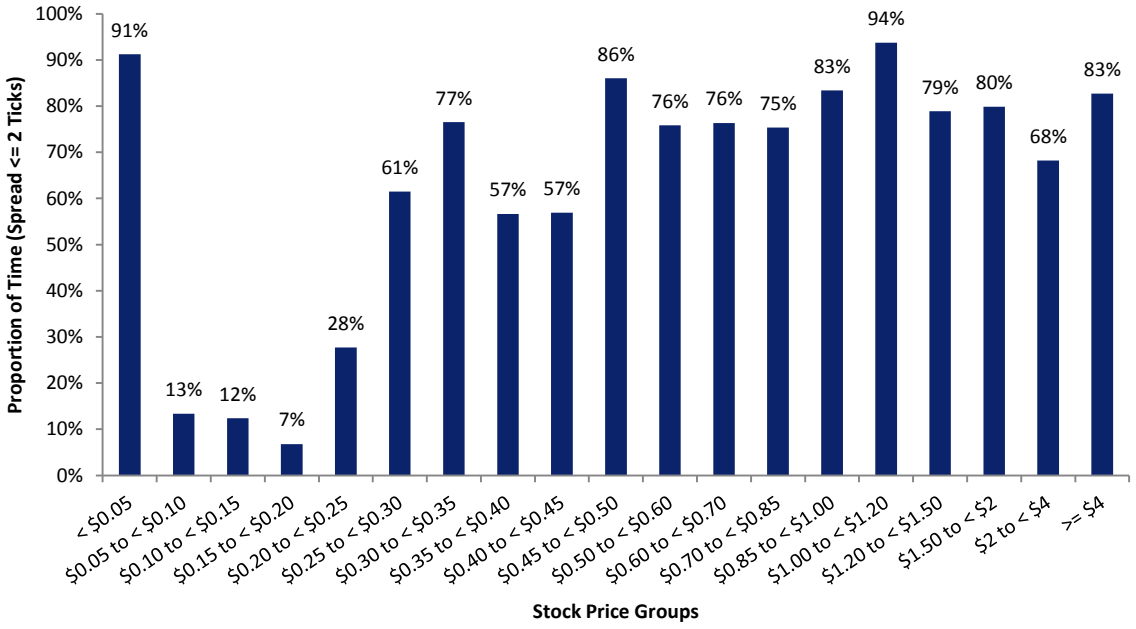


E.4 Proportion of Time Spread is at 2 Ticks or Less According to their Stock Price Groups

Following the postulation that stocks with good market quality should have a spread (ticks) at 2 ticks or less for at least 50% of a trading day, Diagram E-2 shows that stocks trading at less than $0.05 and at $0.25 or greater meet this criterion. This implies that these stocks were quoting close to their minimum tick spread for at least half of the trading day. Examining the results from Diagram E-2 together with Diagram E-1, the results also suggest that stocks that were traded from $0.05 to less than $0.20 had poor liquidity as they were constantly trading at wider bid-ask spreads throughout a trading day.

Diagram E-2
Distribution of the Median Proportion of Time Spread ≤ 2 Ticks across Stock Price Groups

This diagram shows the distribution of the median proportion of time when spread is at two ticks or less across the various stock price groups. Stock price groups are formed by the VWAP of each stock. The median proportion of time when spread is at two ticks or less is calculated as described in Equation (E-2). The median figures are used for the analysis as a non-normal distribution for the proportion of time when the spread is at two ticks or less is found.

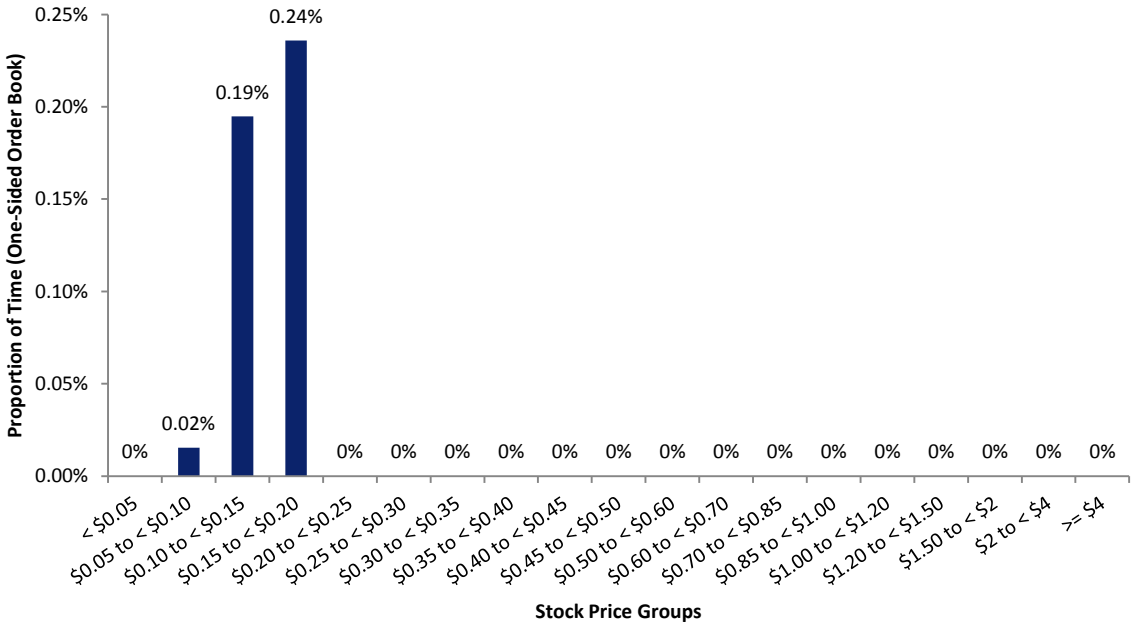


E.5 Proportion of Time When the Order Book is One-Sided According to their Stock Price Groups

Diagram E-3 presents the distribution of the median proportion of time when the order book is observed to be one-sided. Results indicate that stocks trading from $0.05 to less than $0.20 display one-sided order books. Hence, this poses severe liquidity issues for investors. Specifically, investors will face difficulties in closing out their open positions where they are forced to offer a large price premium (discount) to buy (sell) their stocks. In addition, this lack of liquidity will also deter potential investors from trading these stocks. In sum, stocks that were traded from $0.05 to $0.20 displayed further increased trading costs as they exhibited one-sided order books.

Diagram E-3
Distribution of the Median Proportion of Time Order Book is One-Sided across Stock Price Groups

This diagram shows the distribution of the median proportion of time when the order book is observed to be one-sided across the various stock price groups. Stock price groups are formed by the VWAP of each stock. The median proportion of time when the order book is observed to be one-sided is calculated as described in Equation (E-3). The median figures are used for the analysis as a non-normal distribution for the proportion of time when the order book is observed to be one-sided is found.



Appendix F: Literature Review on the Relationship between Market Capitalization and Liquidity

Early empirical evidence is provided by Harris (1994) for stock trading in AMEX and NYSE. He finds that percentage spread shares a negative relationship with market capitalization. In accordance with Merton (1987) and Ho and Michaely (1988), Harris (1994) suggests that this relationship is found due to the degree of public information available for a stock. He explains that if a stock has a large market capitalization, information asymmetry and adverse selection costs will be lower. As a result, percentage spread will be smaller.

Additional evidence is documented by Stoll (2000) and Chan et al (2012) where they find that percentage spread is lower for companies with larger market capitalization for the US markets and HKSE respectively. Chan et al (2012) explain that investors trading in large market capitalization stocks have a significantly high probability of finding counterparties to trade. Subsequently, this lowers the inventory and order processing costs faced by liquidity providers. Hence, they are more probable to quote with narrower bid-ask spreads for stocks with large market capitalization.

These findings are also extended to markets with low liquidity. Results from Bogdan et al (2012) show large market capitalization companies are more liquid than those with lower market capitalization in the Croatian Stock Market. Consistent findings are also reported by Pastor and Stambaugh (2003) and Chordia et al (2004) where they observe that small market capitalization companies have lower liquidity in various US stock markets. Furthermore, they find that the liquidity of these companies is less resilient to stock price volatility. This suggests that the market depth of small market capitalization companies can be severely impacted when stock prices vary significantly, resulting in an increase in trading costs. Chung et al (2011) provide support to this result through finding a positive relationship between market capitalization and market depth in KRX.

Apart from examining bid-ask spreads and market depth, empirical studies have also provided evidence on the relationship between market capitalization and price impact costs. Damodaran (2011) defines price impact costs as the impact on prices which results from a large order being executed. As a result, this price change is attributed to the lack of liquidity in the stock market. Empirically, Breen et al (2000) and Chan (2000) document that market

capitalization is inversely related to price impact costs. Hence, these results suggest that investors who trade in larger market capitalization stocks experience lower trading costs.

In summary, empirical evidence documenting the relationship between market capitalization and liquidity reach similar conclusions. Specifically, all studies find that larger market capitalization stocks have higher levels of liquidity. They mainly attribute this negative relationship to information asymmetry which subsequently affects the tradability of a stock. It is also important to note that these results are robust across time and various stock markets.

Appendix G: Literature Review on the Relationship between Company Fundamentals and Liquidity

In general, empirical evidence is consistent with the theoretical predictions on the relationship between company value/company performance and liquidity. Examining the various US stock markets, Amihud and Mendelson (2008) and Fang et al (2010) find a positive relationship between stock liquidity and company value/company performance. This result is also found to be robust to other stock markets. Examining the Swiss stock market, Loderer and Roth (2005) find that poor liquidity, as shown by wide bid-ask spreads, is found for companies with a lower price-to-earnings ratio (low company performance). Additionally, Huang et al (2014) document a positive relationship between company value and stock liquidity across numerous global stock markets.

According to Frieder and Martell (2006), capital structure as measured by company leverage influences the liquidity of the listed company. Grossman and Hart (1982) and Frieder and Martell (2006) explain that high financial leverage undertaken by managers increases the company's risk of default, which ultimately leads to bankruptcy. Hence, this encourages managers to be consistent with shareholders' interests and make better business decisions. This decreased agency costs between managers and shareholders would reduce information asymmetry and therefore lead to an increase in liquidity of the stock. Empirically, Frieder and Martell (2006) show that there is a positive relationship between capital structure (high leverage) and liquidity (narrower bid-ask spreads) for stocks listed on NYSE.

In summary, both theoretical and empirical evidence highlight the importance of examining company fundamentals when evaluating market liquidity. Specifically, this paper identifies three measures of company fundamentals that affect liquidity. It is documented that company value is positively related to liquidity. A positive relationship is also found between company performance and liquidity as well as capital structure and liquidity. Overall, these results suggest that stocks with stronger fundamentals have higher liquidity.

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Singapore Exchange • London • Tokyo • Beijing • Hong Kong • Mumbai
2 Shenton Way, #02-02 SGX Centre, Singapore 068804
main: +65 6236 8888 fax: +65 6535 6994