The Effects of Reducing the Minimum Tick on Market Quality

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Abstract

This paper examines the effect of reducing the minimum tick size on the 100 largest stocks (by market capitalization) listed on the Singapore Exchange (SGX). Using intra-day trade and quote data from the 30th Jun 2006 to 30th Jun 2008, we examine the effects of reducing the minimum tick on market quality for different liquidity demanders across different tick size reductions. Whilst prior studies have analysed the effects of a tick reduction on various liquidity demanders, none have examined how the magnitude of a reduction affects these investors. The tiered reduction of the minimum tick in SGX on the 24th December, 2007, provides a unique opportunity and a natural control group to examine this issue. Overall, we find empirical evidences that the size of the decrease in bid-ask spreads and market depth of affected stocks are influenced by the magnitude of the tick size reductions. However, changes to trading activities are not directly affected by this factor. Instead, results suggest that stocks with a higher bid-ask premium after the event experience the largest increase in daily turnover.

1. Introduction

The minimum tick size is the smallest increment of price movement possible in trading a stock or futures contract. The effects of changing the minimum tick size draws considerable attention from academics, industry practitioners, operators of stock exchanges and regulators worldwide due to its potential impact on market quality. In particular, the bid-ask spread (implicit cost of trading), market depth (proxy for liquidity), market impact costs (function of both spreads and depth) and trading volume are indicators of market quality which are of most interest to them.

In a seminal paper, Harris (1994) hypothesises that a smaller tick size is likely to cause a significant reduction in the bid-ask spread which lowers the cost of trading for investors. He proposed two possible reasons for the reduction in spreads; (i) a constraint imposed by the relatively high tick size, and (ii) the ability of investors to place limit orders at prices which were previously unavailable. Hence the removal of the artificial ceiling which investors operate within previously allows them to quote at a more optimal level which subsequently results in tighter spreads for affected stocks.

Harris also proposes that quoted depth at the best prevailing level is likely to decrease as liquidity providers seek to maintain the same level of premium that they charge prior to the change. For example, investors and traders that previously placed limit orders at the best bid and ask price may now choose to place them further away from the best prices in order to ensure that they continue to capture a larger premium. They may choose to shift some or all of their order away from the best bid and ask price, therefore reducing the depth offered at these prices. In addition to potentially altering the level of liquidity provided, impatient traders may now choose to use market rather than limit orders as the cost of demanding liquidity is reduced. As a result, the reduction in the minimum tick size will lead to a reduction in the depth at the best bid and ask prices.

Subsequent researchers examining the effects of reducing the minimum tick generally find evidence consistent with the hypotheses proposed by Harris (1994) (see for example, Bacidore, 1997; Goldstein and Kavajecz, 2000; Jones and Lipson, 2001; Bessembinder, 2003; and Aitken and Comerton-Forde, 2005[1]). While these studies document that there is on average a substantial decline in both bid-ask spreads and quoted depth, the examination of how various classes of liquidity suppliers and demanders are affected by the magnitude of different tick size changes has not been *simultaneously* examined.

As Harris (1997) observes, the profitability of liquidity providers is closely related to the minimum bid-ask spread that can be quoted within the tick size allowance (e.g. the larger the minimum tick size, the higher the premium they can charge without losing their competitive edge). With a reduction of the minimum tick size, investors are now able to quote at prices which were previously unavailable (e.g. between the intervals of the original bid-ask spread), which leads to tighter spreads as competition between liquidity providers narrows the margin (see Hart, 1993; Peake, 1995; O'Connell, 1997; Ricker, 1998). With this increased competition, the profitability of liquidity providers is likely to decline and consequently decrease their willingness to supply quoted depth to the market (Grossman and Miller, 1988, and Harris, 1997).

[1] See Section 3 (Literature Review) for further literature on tick size reductions.

Goldstein and Kavajecz (2000) posit that there are numerous ways that liquidity providers can respond to a reduction in the minimum tick size. For example, they can choose to quote reduced depth at the best prevailing levels to stay competitive (but lose the premium that they charged previously), quote at the same price level prior to the change in the minimum tick (to maintain profit margin but risk lower execution), provide numerous quotes at reduced depth at the new intervals, or simply leave the market if it is no longer profitable for them. They propose that the aggregated effects of the expected decline in spreads and quoted depth can decrease or increase the overall transaction costs faced by different classes of liquidity demanders depending on the reaction of the liquidity providers. While it is hypothesized and commonly observed that quoted depth at the best levels will decline as limit orders are segregated across more price intervals, Goldstein and Kavajecz note that the cumulative depth[2] at a certain price can remain unaffected.

This study seeks to extend the literature by examining how various tick size reductions across different price bands over the same period affects the market quality of the affected stocks. Specifically, we examine how a reduction in the minimum tick size affects bid-ask spreads, the reallocation of quoted depth by liquidity providers, the expected price impact of executing different parcels of trades and the trading activities of affected stocks. While prior studies examine these factors, to the best knowledge of the authors, none thus far examine how the magnitude of the tick size reduction (which results in more price intervals) affects market participants. This topic is of particular

[2] Cumulative depth at a certain price is calculated by adding up all of the shares available at that price or better (see Goldstein and Kavajecz, 2000).

interest to financial regulators, operators of stocks exchanges and market participants as the magnitude of the tick size reduction and the increase in price intervals may potentially cause a migration of liquidity providers (and subsequently trading activities) from one–tier to another due to profitability considerations. For example, if a trading venue has a 2-tiered system and the minimum tick of a $10 stock shifts from $0.10 to $0.02, the premium that can be charged shrinks from 1% (for a round trip) to 0.2% (assuming the liquidity providers stay competitive at the best prevailing bid/ask quotes level), *ceteris paribus*. On the other hand, the revision of a stock price at $3 which experiences a decline in minimum tick from $0.02 to $0.01 in a different tier would experience a margin drop from only 0.67% to 0.33%. Hence, in percentage terms, it becomes more profitable for liquidity providers to transfer their limit orders to stocks that experience a lower reduction[3].

This potential migration of liquidity providers and trading activities across different tiers after the reduction of the minimum tick is of particular concern to financial regulators, stock exchanges and investors as the market quality of one band may improve significantly (liquidity and trading activities) at the expense of another tier. To examine this issue, the Singapore Exchange's (SGX) implementation of a tiered minimum tick reduction on 24 December, 2007, provides an ideal experimental setting for examining how the magnitude of a tick size reduction affects the reallocation of liquidity provision by market participants.

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[3] As trading activities are likely to congregate in stocks with more depth, a shift in liquidity provision is likely to cause a shift in trading activities. In addition, scalpers are likely to favour $3 stocks as the premium that can be captured from trading at the minimum tick is higher compared to $10 stocks.

Specifically, the SGX reduced the tick size for stocks above $10 from $0.10 to $0.02, for stocks between $5 and $9.95, from $0.05 to $0.01, for stocks between $3 and $4.98, from $0.02 to $0.01, while stocks below $3 were unaffected by the change[4]. From this tiered reduction, we are able to specifically examine how the magnitude of the reduction (e.g. from $0.10 to $0.02, compared to $0.05 to $0.01, etc) and the number of new price intervals available (e.g. 5 compared to 2) affects the provision of liquidity (and migration) across the different bands. Another motivation for examining the SGX's move to reduce the minimum tick is the provision of a *natural* control group that allows us to account for other extraneous factors that may have influenced liquidity around the event date As stocks below $3 are unaffected by the changes, they provide a *natural* control group to account for broad market movements.

Consistent with prior studies examining changes in minimum tick sizes, traditional proxies of market quality, including bid-ask spreads, quoted depth, trading volume and number of trades are included in this study pre- and post- the event. In addition, this paper adopts the methodology of Goldstein and Kavajecz (2000) to simulate the available market depth facing a trader across 5-minute intervals for the different price bands that experience various tick size reductions. This allows us to proxy for the estimated market impact costs of executing different sized parcels of shares.

To control for contract-specific factors which affect bid-ask spreads and quoted depth, a multivariate model similar to Harris (1994) is estimated to control for changes in trading volume and price volatility. Similar to Chordia, Roll and Subrahmanyam (2000), we

[4] See appendix for the schedule of minimum tick size changes.

recognize that market-wide factors can affect market quality and have utilized stocks below $3 as a natural control group as they are not affected by the change in minimum tick. As a further robustness test, this study also combines the models of Harris (1994) and Chordia, Roll and Subrahmanyam (2000) to develop a multivariate model that controls for both contract-specific volume and volatility and market-wide variation.

The remainder of this paper is structured as follows. Chapter 2 presents a brief outline of the institutional details of stocks trading in the Singapore Exchange. Chapter 3 presents a review of the previous literature on tick size reductions and price impact, in equities markets, and outlines several hypotheses tested in this thesis. Chapter 4 describes the data used and outlines the research design. Chapter 5 presents the results of the analysis, as well as several robustness tests. Chapter 6 concludes and provides suggestions for future research.

2. Institutional Details

The Singapore Exchange Limited (SGX) is the predominant stock exchange in Singapore and was formed on 1 December, 1999, following the merger of two established financial institutions (the Stock Exchange of Singapore and the Singapore International Monetary Exchange). On 23 November, 2000, SGX became the first exchange in Asia-Pacific to be listed via a public offer and a private placement and was the pioneer demutualised and integrated securities and derivatives exchange within the same region.

As at 30th June, 2008, the Singapore Exchange had 762 listed companies with a combined market capitalization of $658 billion. Of these firms, 39.1% are foreign companies and they make up about 35% of market capitalization. Securities trading accounts for 74.3% of SGX's operating revenue and the remaining 25.7% consists of derivatives clearing and stable revenues[5]. The market phases and trading hours for Singapore listed securities are provided in Table 2-1.

Table 2-1			
This table presents the market phases and trading hours of SGX listed securities			
Period	Time	Period	Time
Pre-Open	8.30am - 8.59am	Non-Cancel	1.59pm to 2.00pm
Non-Cancel	8.59am - 9.00am	Trading Hours (Afternoon Session)	2.00pm - 5.00pm
Trading Hours (Morning Session)	9.00am - 12.30pm	Pre-close	5.00pm - 5.05pm
Adjust Phase	12.30pm - 1.59pm	Non-Cancel	5.05pm - 5.06pm

The SGX operates a fully automated electronic limit book order since 2 October, 2006[6]. To improve market efficiency, SGX implemented a tiered minimum tick revision on 24 December, 2007. Prior to the reduction in minimum tick, stocks listed on the SGX operated on a 5-tiered tick system with the largest tick size $0.10 (for stocks priced $10

[5] Source SGX Annual Report 2008.
[6] The open outcry trading facility at SGX Centre was officially closed on Friday, 29th September, 2006 at the end of the business day. The first trading day where SGX is fully automated occurred on the following business day which is Monday, 2nd October, 2006.

or above) and the smallest $0.005 (for stocks below $1). This was changed to a 3 tiered-system, which reduced the tick size for stocks above $10 from $0.10 to $0.02 and those with a price range from $3 to $9.95 to a tick size of $0.01. The schedule of these changes to the minimum tick sizes are provided in Table 2-2.

<table>
<tr><th colspan="4">Table 2-2 : Schedule of Minimum Tick Changes</th></tr>
<tr><td colspan="4">This table presents the schedule of minimum tick size changes which occurred on 24 December, 2007. For the purpose of this study, we have denoted the period prior to 24 December, 2007 as the pre-period and the period after as post-period.</td></tr>
<tr><td colspan="2">Minimum tick Size (Pre-Period)</td><td colspan="2">Minimum tick Size (Post-Period)</td></tr>
<tr><td>Price Range</td><td>Bid Size ($)</td><td>Price Range</td><td>Bid Size ($)</td></tr>
<tr><td>Below $1</td><td>0.005</td><td>Below $1</td><td>0.005</td></tr>
<tr><td>$1 - $2.99</td><td>0.01</td><td rowspan="3">$1 - $9.99</td><td rowspan="3">0.01</td></tr>
<tr><td>$3 - $4.98</td><td>0.02</td></tr>
<tr><td>$5 - $9.95</td><td>0.05</td></tr>
<tr><td>$10 and above</td><td>0.1</td><td>$10 and above</td><td>0.02</td></tr>
</table>

3. Literature Review and Hypotheses Development

This section provides a review of literature regarding tick size reduction and price impact. Tick size reduction is examined both theoretically and empirically in the literature, with studies primarily focusing on equities markets. Price impact is an issue which has evolved throughout the literature as new methods are developed to gain a more thorough understanding of price impact in both equities and futures markets.

3.1. Tick Size Reduction

One of the earliest papers in this area by Harris (1994) suggests that a smaller tick size is likely to lead to significant reduction in the bid-ask spread which lowers the cost of trading for investors. In his paper, he proposes two possible reasons for the reduction in spreads; (i) a constraint imposed by the relatively high tick size, and (ii) the ability of investors to place limit orders at prices which were previously unavailable. Hence the removal of the artificial ceiling which investors operated within previously allows them to quote at a more optimal level which subsequently results in tighter spreads for affected stocks.

Harris also proposed that quoted depth at the best prevailing level is likely to decrease as liquidity providers seek to maintain the same level of premium that they charge prior to the change. For example, investors and traders that previously placed limit orders at the best bid and ask price may now choose to place them further away from the best prices to ensure that they continue to capture a larger premium. They may choose to shift some or all of their order away from the best bid and ask price, therefore reducing the depth offered at these prices. In addition to potentially altering the level of liquidity provided, impatient traders may now choose to use market rather than limit orders as the cost of demanding liquidity is reduced. As a result, the reduction in the minimum tick size will lead to a reduction in the depth at the best bid and ask prices.

These conflicting effects provide a challenging research question as to the overall impact of reducing the minimum tick on market quality. Pursuant to this, studies in this area globally test the hypothesis proposed by Harris (1994) and provide mixed empirical evidence on the trade-off. Goldstein and Kavajecz (2000) examine the June 1997 move by the New York Stock Exchange (NYSE) to reduce tick sizes from eighths to sixteenths, providing a thorough cross sectional study of how tick size reductions impact stock groups as well as market participants. They find that on average, stocks on the NYSE experience significant declines in both the bid-ask spread and quoted depth after the minimum tick size was reduced by 50%[7]. Specifically, they estimate the cost of demanding liquidity for various parcel sizes and find that the combined effect of reduced spreads and depth made small orders cheaper to execute, while large investors, particularly in low volume and low priced stocks, did not benefit. Overall, their results support the hypotheses of Harris (1994) that tick reductions are most beneficial for more actively traded stocks, while illiquid stocks experience a decline in market quality.

The same event was also examined by Jones and Lipson (2001) who observe similar findings of a decrease in quoted and effective spreads, and quoted depth. More importantly, the authors find that trading costs increase after the tick size is halved, indicating that quoted and effective bid-ask spreads are not an adequate measure of market quality. This is particularly true for institutional investors, as it is common practice for institutions to separate large orders into several smaller trades to minimise price impact. To address these issues, Jones and Lipson examine a large sample of proprietary trading by institutions. They find that while small traders may have benefited, large orders greater than 10,000 shares are more expensive to execute after the tick size is halved, with one way transactions costing an addition 3.4 basis points. Orders exceeding

[7] Bollen and Whaley (1998), Ricker (1998) also documented that NYSE stocks experienced declines in bid-ask spread spreads ranging from 13% to 26% and that quoted depth decreased between 38% to 45%.

100,000 shares cost a third more after the tick size reduction. Isolating the effect of the tick size reduction from individual firm characteristics and order types, the authors find that across all firms, average execution costs increase by 22.5 basis points.

Bessembinder (2003) extends the work of Goldstein and Kavajecz (2000) and Jones and Lipson (2001) by examining the adaptation of decimal trading by the NYSE and Nasdaq in 2001. By examining the change in an order driven and quote driven market, the author is also able to compare two market structures. Consistent with the studies analysing the 1997 (NYSE) tick reduction, he observes that quoted depth levels in both markets are substantially reduced. Bessembinder finds that, on average, quoted spreads decline both across markets and across market capitalisation groups, with large capitalisation stocks in both markets experiencing the largest reductions. Bessembinder also observes that the average effective spreads for Nasdaq stocks remain unchanged after decimalisation, while NYSE stocks experience a decline in effective bid-ask spreads. Overall, he concludes that market quality improves as the reduction in quoted depth is more than offset by the fall in effective bid-ask spreads and lower volatility.

Similar to Jones and Lipson (2001), Chakravarty, Panchapagesan and Wood (2005) examine trading costs after the move to decimal pricing on the NYSE. Using proprietary data, the authors compare institutional transactions costs before and after the reduction in the minimum tick. Using the implementation shortfall measure of Perold (1988), they find that trading costs for institutional traders decrease by 32 percent. In contrast to Jones and Lipson (2001), Chakravarty, Panchapagesan and Wood find that total trading costs decline by 22.6 basis points, with the greatest decrease in costs occurring in the largest size group. Consistent with previous literature, they find significant disparity between changes based on activity levels, with stocks trading at the minimum tick experiencing the greatest bid-ask spread reductions, while illiquid stocks experience an increase in bid-ask spreads. Large traders who aggressively seek liquidity experience cost increases of 10 basis points, while large traders that execute orders over several days experience cost reductions of around 32 basis points.

Bacidore (1997) addresses the decimalisation debate by analysing the move to decimal trading on the Toronto Stock Exchange (TSE) in April 1996. As the TSE had a tiered tick regime prior to the move to decimal trading, Bacidore examines differences in various levels of tick size changes. Results highlight that when ticks are reduced from an eighth to a cent, bid-ask spreads are reduced with no adverse effect on market quality, while for stocks which move from 5 cents to 1 cent, the reduction does not impact on market quality.

The findings of Bacidore (1997) are supported by Smith, Turnbull and White (2006) who analyse the 2001 move to decimal trading on the TSE, finding that the move to decimal trading leads to reduced spreads, with an overall reduction in quoted spreads of 12 percent. The reduction in quoted spreads is greatest for the most actively traded stocks. The authors note that, unlike in Goldstein and Kavajecz (2000), the Toronto Stock Exchange *does not* experience a change in quoted depth[8]. The reduction in bid-ask spreads leads to a reduction in trading costs for large traders, consistent with Chakravarty, Panchapagesan and Wood (2005).

[8] See also Porter and Weaver (1997).

Aitken and Comerton-Forde (2005) also examine the reduction in tick size in a tiered tick regime on the Australian Stock Exchange (ASX), an order-driven market. Unlike previous studies, this study has a control group of stocks which do not undergo a tick size reduction, thus providing an ideal control sample. Results indicate that the reduction in bid-ask spreads is greatest for lower capitalisation stocks. The largest stocks, with already small relative tick sizes, experience an increase in the average bid-ask spreads. The authors find that across all stocks, depth at the best bid and ask quote is significantly lower following the move to smaller minimum price increments. The control sample experiences no significant change in either bid-ask spreads or quoted depth. Using the Aitken and Comerton-Forde (2003) measure of liquidity, the authors find that there is a dramatic increase in liquidity in all event groups, with the increase in liquidity diminishing as stock price increases (i.e. the stocks with the largest reduction in the relative minimum tick size experience the largest increase in liquidity).

ap Gwilym, McManus and Thomas (2005) analyse the move to decimal trading for the UK Long Gilt Futures on the London International Financial Futures and Options Exchange (LIFFE). Prior to the move to decimal trading, this contract traded at a minimum tick of £1/32. In May 1998, the minimum price increment was reduced to £0.01. The authors postulate that the tick size reduction will lead to an increase in price clustering, a reduction in average trade size and a reduction in quoted spreads, while mean daily traded volume will be unchanged. The LIFFE provides both an open outcry and electronic market for UK Long Gilt futures contract, and as such, the authors analyse each market separately.

The results of the study indicate price clustering around orders that end in a “0”, primarily due to the commonality of the end digit in a decimal setting. Interestingly, the study finds that quoted spreads increase after decimalisation, despite claims that the market was constricted at the minimum tick prior to the move to decimal trading. Further, the mean trade size across both markets is reduced, while daily volume traded increases only in the floor setting. These results, however, do not provide conclusive evidence as to the effect of a tick size reduction in a futures market setting.

While the majority of these studies persistently document a decline in both bid-ask spreads and quoted depth, the examination of how various classes of liquidity demanders are affected by the magnitude of different tick size changes is not simultaneously examined. This topic is of particular interest to liquidity providers as various tick size reductions over the same period affects the profitability of supplying liquidity to the market and determine their allocation of quoted depth. The subsequent reallocation of these quotes will affect the cost of execution for different parcels of trades.

As Harris (1997) observes, the profitability of liquidity providers is closely related to the minimum bid-ask spread that can be quoted within the tick size allowance (e.g. the larger the minimum tick size, the higher the premium they can charge without losing the competitive edge). With a reduction of the minimum tick size, investors are now able to quote at prices which were previously unavailable (e.g. between the intervals of the original bid-ask spread), which leads to tighter spreads as competition between liquidity providers narrows the margin (see Hart, 1993; Peake, 1995; O’Connell, 1997; Ricker, 1998). With this increased competition, the profitability of liquidity providers is likely to decline and consequently decrease their willingness to supply quoted depth to the market (Grossman and Miller, 1988, and; Harris, 1997).

Goldstein and Kavajecz (2000) posit that there are numerous ways that liquidity providers can respond to a reduction in the minimum tick size. For example, they can choose to quote reduced depth at the best prevailing levels to stay competitive (but lose the premium that they charged previously), quote at the same price level prior to the change in the minimum tick (to maintain profit margin but risk lower execution), provide numerous quotes at reduced depth at the new intervals, or simply leave the market if it is no longer profitable for them. They propose that the aggregated effects of the expected decline in spreads and quoted depth can either decrease or increase the overall transaction costs faced by different classes of liquidity demanders depending on the reaction of the liquidity providers. While it is hypothesized and commonly observed that quoted depth at the best levels will decline as limit orders are segregated across more price intervals, Goldstein and Kavajecz note that the cumulative depth at a certain price can remain unaffected[9].

3.2. Market Impact costs

Price Impact, as defined by Domowitz, Glen and Madhavan (2001), is the difference between the price at which a trade is executed and the price prevailing in the market had the trade not occurred. Price impact is an implicit cost of trading and a primary concern

[9] Cumulative depth at a certain price is calculated by adding up all of the shares available at that price or better (see Goldstein and Kavajecz, 2000).

for all institutional investors. Previous literature indicates that bid-ask spreads and quoted depth may change when tick sizes are reduced. The literature on price impact around a tick reduction in equities markets is inconclusive.

Early studies into the price impact of trades, such as Kraus and Stoll (1972), Holthausen, Leftwich and Mayers (1987, 1990), Ball and Finn (1989) and Chan and Lakonishok (1993) focus on price changes surrounding large individual trades. However, Chan and Lakonishok (1995) show that large institutions execute large orders over several trades ("packages"), spanning periods that may last days or weeks. Consequently, Chan and Lakonishok (1995) use proprietary trading records of 37 large institutions to determine the price impact of trades and find relationships between trading costs and firm capitalisation, the size of packages and the firm engaged in trading. They find that the round trip cost of an institutional trade relative to the opening price of the first day of trade is 1.32 percent, and that execution costs are lower for larger firms. Finally, the authors also document an asymmetry in price impact, with buy orders experiencing significantly greater price impact compare to sell orders.

Aitken and Frino (1996) examine the price impact of institutional trading on the ASX. Their data set (from SEATS) contains broker identifiers and trade level data, allowing trade packages to be reconstructed. Using various benchmarks, as well as the VWAP of the package, the authors find that buy orders cost more than sell orders to execute. They also find that execution costs are higher for more complex trades and in less liquid stocks. The authors find a strong a relationship between trading costs and broker identity, supporting prior literature. Keim and Madhavan (1997) examine trading costs across manager styles, trade size and across markets. Similar to Chan and Lakonishok (1995), they find that buys incur greater price impact, and that investment style and trade size significantly affect trading costs.

Domowitz, Glen and Madhavan (2001) analyse equity trading across 42 countries to determine the impact of different levels of volatility and market liquidity on institutional trading costs. Results indicate that trading costs are higher in developing countries with relatively new securities markets. Importantly, the paper documents that investment managers are conscious of trading costs, and alter their trading strategies depending on the market.

Chiyachantana, Jain, Jiang and Wood (2004) also examine price impact across countries. While Domowitz, Glen and Madhavan (2001) focus on a single period, this paper examines price impact in bull and bear markets, finding that price impact for institutional buys is greater than sell orders in bull markets, while the price impact of institutional sells is greater than buys in bear markets. Consistent with prior literature, Chiyachantana, Jain, Jiang and Wood (2004) document that trading costs are negatively related to a firm's capitalisation and price level, while a positive relationship exists between trading costs, order complexity and volatility.

Analysing the trading costs of fund managers around tick size reductions, Bollen and Busse (2006) provide empirical evidence on the relationship between trading costs and manager style. The authors study institutional trading costs before and after the 1997 reduction from eighths to sixteenths, and the 2001 move to decimalisation, on US equity markets. They find that after each tick size reduction, trading costs for passive fund managers do not significantly differ while active fund managers experience a statistically significant increase in trading costs between 0.361 percent and 0.502 percent. Further, they find that trading cost increases are most pronounced for low capitalisation stocks.

There are limited studies on price impact in futures markets. Berkman, Brailsford and Frino (2005) and Kurov (2005) find that trades in futures markets contain information. Berkman, Brailsford and Frino (2005) examine single trades on the London International Financial Futures and Options Exchange. They conclude that both buy and sell orders have a small, but statistically significant, permanent price impact. Kurov (2005) examines average returns associated with trades on the Chicago Mercantile Exchange. Results indicate that after a single trade is executed, prices adjust to new permanent levels, suggesting that these trades are information motivated.

Frino and Oetomo (2005) examine the price impact of institutional trading on the SFE. Following Chan and Lakonishok (1995), they analyse trade packages, although noting the higher levels of liquidity in futures markets, the authors reduce the trading gap used to reconstruct packages from five days to one day. Price impact in futures markets largely mimics price impact in equity markets, with costs increasing with trade size. However, the magnitude of price impact in futures markets is significantly lower than in equity markets, with the largest trades in 3 Year Bond Futures contracts costing an average of 2.14 basis points to execute. Information effects of trades are not statistically different to zero, implying that price impact consists of only liquidity effects and that futures trading is not information motivated.

A recent study by Frino, Kruk and Lepone (2007) reconciles the differences in the methodology between Berkman, Brailsford and Frino (2005) and Frino and Oetomo (2005). Examining price impact around individual trades known to belong to trade packages, they find that trading in futures markets is information-motivated. However, when price impact for the entire trade package is calculated, they find no evidence of information, consistent with Frino and Oetomo (2005). They conclude that analysing individual trades in futures markets leads to biased results and that accurate price impact measurement requires the reconstruction of trade packages.

3.3 Hypothesis Development

The consensus from prior literature is that after a reduction in the minimum tick, the bid-ask spreads of affected stocks is likely to tighten (see Goldstein and Kavajecz, 2000; Bacidore, 1997 and; Ahn, Cao and Choe, 1996, 1998). Further, as shown in Goldstein and Kavajecz (2000), instruments trading predominantly at the minimum tick experience significant spread reductions after a tick size reduction. This leads to the first hypothesis;

H1: Bid-ask spreads will decrease after the reduction in minimum tick, ceteris paribus

Also, we expect that stocks with larger minimum tick reductions will have more price intervals which leads to tighter bid-ask spreads (Harris, 1994, 1997). Hence, the second hypothesis;

H2: Bid-ask spreads will decrease more for stocks with a larger minimum tick reduction, ceteris paribus

Considering the liquidity available in the limit order book and the findings of prior literature, including Aitken and Comerton-Forde (2005) and Jones and Lipson (2001), it is expected that quoted depth at the best bid and ask will fall. This leads to the following hypotheses;

H3: Quoted Depth will be reduced at the best bid and ask quotes after the reduction in minimum tick, ceteris paribus

Similar to H2, we expect that a larger reduction in the minimum tick will reduce the market depth more as more price intervals are available. Hence,

H4: Quoted Depth will reduce more for stocks with a larger minimum tick reduction, ceteris paribus

Bacidore (1997) finds that trading costs on the TSE are reduced after a reduction in the minimum tick. Similarly, Chakravarty, Panchapagesan and Wood (2005) find that after a reduction in the minimum price increment, trading costs for highly liquid securities decline. Goldstein and Kavajecz (2000) extended the literature by documenting that small orders experience lower transaction costs and larger trades experience greater transaction costs. This leads to the following hypotheses;

H5: Trading costs will be reduced for small orders after the reduction in minimum tick, ceteris paribus

H6: Trading costs will be increased for large orders after the reduction in minimum tick, ceteris paribus

The next section describes the data and methodologies used to test these hypotheses.

4. Data and Methodologies

4.1. Data

The analysis draws on intra-day trade and quote data provided by the Securities Industry Research Centre of Asia-Pacific (SIRCA). The data contain the contract code, date, price, time and volume traded for each trade executed between 30 June, 2006 and 30 June, 2008 for the Top 100 stocks (by market capitalization[10]) listed on the SGX. The dataset also contain order book data, with information on the prices and volumes of prevailing bid and ask quotes for the 10 best levels in the same period. For the purpose of this study, we classify the period from 30 June, 2006 to 24 December, 2007 as the *pre-reduction period* and the period from 26 December, 2007 to 30 June, 2008 as the *post-reduction period*. It is worthwhile to note that the *post-period* is likely to be influenced by the global credit crisis that has significantly reduced trading activity for equities markets worldwide.

As SGX implemented a tiered reduction in minimum tick sizes, we segregate the stocks affected by this event into 4 price bands (PB) based on their share prices (and tick reduction) to determine how the magnitude of the reduction affects market quality. Groups are denoted PB1 for stocks above \$10, PB2 for stocks between \$5 and \$9.95, PB3 for stocks between \$3 and \$4.98, and PB4 for stocks below \$3. Since stocks in PB4 are

[10] Based on market capitalization as of 30th June, 2008.

not affected by the minimum tick revision, this group is used as a *natural* control to account for broad market movements.

Given that share prices are likely to fluctuate over any given period, it is highly probable that stocks will move between bands during the sample period. To prevent any potential bias that can result from these movements, three sets of analyses are conducted.

In the first test, stocks are segregated into price bands based only on prices at any given point in time. For example, if Stock X has a price of $10.10 on 23 November, 2007 and $9.50 on 3 December, 2007 and $4.50 on the 5 February, 2008, it is classified as PB1, PB2 and PB3 respectively. Although this method is intuitive and allows an accurate allocation of PB based on prices, it has the drawback of ignoring the movements in a stock between the pre- and post-period which may bias results as different bands have different minimum tick sizes in the pre- and post-periods. This analysis is denoted as *All Observations* in the remainder of the paper.

An alternative to this methodology is to assign a PB to a stock based on the most frequent PB they fall into. For example, if Stock X is in PB1 for 154 days, in PB2 for 27 days and in PB3 for 10 days, Stock X is classified as PB1. All days that are not within this allocated PB are removed from the sample size. This methodology seeks to remove any bias associated with the fluctuation of affected equities between different price bands and improves on the main shortcoming of the first methodology. However the results from this analysis may not fully reflect the impact of reducing the minimum tick on market quality due to the omission of some observations. Moreover, if the stock price experiences a fundamental shift (either higher or lower), the stock's shift to another band may be *permanent* (indicate a new status, athough it is not the most frequent within the sample period). This analysis is denoted as *Most Frequent* in the remainder of the paper.

The third method of analysis seeks to address the two main shortcomings of the previous allocations. We first shorten the sample period to three months pre- and three months post- to reduce the probability of movements between bands while maintaining an adequate sample period for analysis. From this shortened sample period, we remove any stocks that fluctuate across two or more bands. This method seeks to remove any bias relating to movements between two or more PB and allows us to isolate the effects of reducing the minimum tick without exogenous factors. This reduces our sample size from 100 stocks to XX stocks. This analysis is denoted as *Restricted Period* in the remainder of the paper.

Table 4-1 provides descriptive statistics on the number of observations in each analysis (by price bands)[11]. Consistent with expectation, we noted that the number of observations in the second group (*most frequent*) is lower than the first (*all observations*)[12]. It is also noted that stocks in PB2 and PB3 experienced the most movement between bands, while PB1 has the least.

[11] 3 stocks were removed from the restricted period as they experienced price quotes that fluctuate within 2 or more bands. Table 4-1 consists of all observations for the remaining 97 firms.
[12] This reduction can be attributed to the removal of observations that does not reside in a stock's most frequent price bands.

Table 4-1: Number of Observations in each Analysis						
This Table presents the number of observations in each price band *pre-* and *post-* the reduction of the minimum tick. The *pre-period* is denoted as the period prior to the 24 December, 2007 and the *post-period*, after. *All Observations* include every trade for all stocks in the sample, *Most Frequent* contains only trades occurring in the most frequent price bands. The restricted period contains only observations from 23 September, 2007 to 23 March, 2008 for stocks that do not fluctuate within price bands. Groups are denoted PB1 for stocks above $10, PB2 for stocks between $5 and $9.95, PB3 for stocks between $3 and $4.98, and PB4 for stocks below $3. Stocks in PB4 which are not affected by the reduction in minimum tick are utilized as controls.						
	All Observations (30/06/06 - 30/06/08)		Most Frequent (30/06/06 - 30/06/08)		Restricted Period (23/09/07 - 23/03/08)	
	Pre-Period	*Post-Period*	*Pre-Period*	*Post-Period*	*Pre-Period*	*Post-Period*
Price Band 1 (PB1)	811,847	443,468	723,516	426,698	166,304	225,915
Price Band 2 (PB2)	884,005	635,687	575,840	549,434	199,773	330,885
Price Band 3 (PB3)	1,387,614	841,115	839,648	587,418	247,858	413,706
Price Band 4 (PB4, Control)	3,820,411	1,245,597	3,227,830	1,161,543	479,738	605,429
Total	6,903,877	3,165,867	5,366,834	2,725,093	1,093,673	1,575,935

4.2. Methodology

This study seeks to examine the change in market quality surrounding the change in the minimum tick size. For the purpose of this research, the primary measures used to proxy market quality are bid-ask spreads, quoted depth, trading activity (trading volume and number of trades) and simulated market impact costs. To control for potential market-wide events, stocks below $3 which are not affected by the reduction in minimum tick sizes are utilized as a *natural* control group. Various measures of the bid-ask spread are examined, including the time-weighted bid-ask spread measure from McInish and Wood (1992), and used in Bacidore (1997) and Aitken and Comerton-Forde (2005), among others.

The quoted spread, as per McInish and Wood (1992), is the difference between the prevailing ask and bid quotes, and is calculated for every single quote revision and then weighted for how long the quotes prevailing are "alive" in 1-, 5-, and 15-minute intervals. These time-weighted bid-ask spreads are averaged across the trading day and then averaged across each stock to determine the change in bid-ask spreads around the change in tick size.

To examine quoted depth, this study focuses on (i) the change in depth at the best quotes, and (ii) the change in the total visible order book depth. The quoted best depth is calculated as the sum of the volume available at the prevailing bid and ask quotes at the end of each interval, and averaged over the day and then across each stock, allowing a comparison of the depth at the prevailing quotes before and after the tiered tick reductions.

To examine changes in trading activity around the reduction in minimum tick, average daily traded volume and number of trades are compared before and after the reduction in tick size.

4.3. Market Quality Multivariate Testing

Harris (1994) argues that there are several factors that could impact on changes in bid-ask spreads, including the level of trading activity, volatility and volume. To control for these potential factors, a number of multivariate models are estimated. These models control for market-wide factors that could influence market quality. As univariate analysis compares stocks in the affected price bands (PB1, PB2 and PB3) to the natural control group (PB4), the regression models are estimated for all three price bands. These regression models allow for the effects of the tick size change to be isolated from other explanatory variables. The first models are derived from Harris (1994) and control for market-wide volume and volatility:

$$BAS_i = \alpha_0 + \alpha_1 Change + \alpha_2 \, Ln(DailyVolume_c) + \alpha_3 Volatility_c + \varepsilon \qquad (3)$$

$$Ln(BestDepth_i) = \alpha_0 + \alpha_1 Change + \alpha_2 \, Ln(DailyVolume_c) + \alpha_3 Volatility_c + \varepsilon \qquad (4)$$

For each equation, the dependent variable is (1) the time-weighted average bid-ask spread and (2) the average best depth of the affected stocks, where *i* equals PB1, PB2 and PB3. *BASi* is the average time-weighted bid-ask spread, $Ln(BestDepth_i)$ represents the natural logarithm of daily depth at the prevailing bid and ask quotes. *Change* is a dummy variable equal to one for the period post-change and zero otherwise, $Ln(DailyVolume_c)$ is the natural logarithm of the average daily volume of the *control group* and $Volatility_c$ is the daily volatility of the *control group*, calculated as the log difference between daily high and low prices. The two equations are estimated separately for the three analyses, (a) All Observations, (b) Most Frequent Band, and (c) Restricted Period.

Chordia, Roll and Subrahmanyam (2000) find that broad market factors can influence liquidity in financial markets. Applying their method to our study, changes in bid-ask spreads and quoted depth in the control group (PB4) can affect liquidity in the affected stocks (PB1, PB2 and PB3). Therefore, the following regressions are estimated:

$$BAS_i = \alpha_0 + \alpha_1 Change + \alpha_2 BAS_c + \varepsilon \qquad (5)$$

$$Ln(BestDepth_i) = \alpha_0 + \alpha_1 Change + \alpha_2 Ln(BestDepth_c) + \varepsilon \qquad (6)$$

where the dependent variables are as described for the first set of regressions. BAS_c *and* $Ln(BestDepth_c)$ are the average daily time-weighted bid-ask spread and average daily best prevailing depth for the control group, respectively. These two regressions are estimated separately for the three analyses, (a) All Observations, (b) Most Frequent Band, and (c) Restricted Period.

4.4. Price Impact Simulation

Similar to Goldstein and Kavajecz (2000), an important focus of this study is how liquidity providers are affected by the change in tick size, and what these changes imply about trading costs faced by market participants. The response of liquidity providers to a reduction in the minimum tick size, and its subsequent impact on spreads and depth, is uncertain. One possible response is that while liquidity providers supply less depth at the new, narrower quoted spread, they may continue to supply the same liquidity at the previous prices. While the depth at the quoted spread will be reduced, the cumulative depth at a certain price, defined as the sum of the depth for all limit orders up to and including that price, will remain unaffected. Alternatively, liquidity providers could shift their limit orders to prices further from the quotes or, if the costs to liquidity providers sufficiently increase, choose to leave the market altogether. As a result, the number of liquidity providers could decrease, causing not only the depth at the best quoted bid and ask prices to decline, but also the cumulative depth to decline[13]. Thus, while order sizes smaller than the quoted depth could benefit from the reduction in spreads, larger sized orders could become more expensive to execute.

As Lee et al. (1993) note, any study of liquidity provision must examine changes in both prices and depths. Moreover, Harris (1994) notes that to address properly whether or not liquidity is enhanced or hampered requires an investigation into how depth throughout the limit order book is altered. Thus, to study the combined effects of possible changes in bid-ask spreads, depth at the market, and cumulative depth, we adopt the method of Goldstein and Kavajecz (2000) and use order level data to reconstruct the limit order book before and after the change in tick size[14].

Market impact costs in this simulation are then taken as the value-weighted cost of executing different parcels of trades (in notional value) less the best quoted price divided by the best quoted price. If the order is a buy (sell), we simulate the fulfilling of orders against the cumulative ask (bid) depth (in notional value) to compute the value-weighted

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[13] Studies considering only the best quotes and depth are not able to evaluate whether liquidity provision has changed or remained constant. If spreads decrease, even measures that relate posted spreads to posted depth cannot determine if these newer spreads are caused by new limit orders submitted or a shift of existing limit orders. Using the cumulative depth measure, we are able to determine how this liquidity provision has changed.

[14] Other ways to examine price impact using proxies include; Berkman et al. (2005) use an intraday benchmark of mid-quotes five trades before and after large single transactions, Kurov (2005 uses intra-day analysis to examine price impact from trade -10 to trades +30 relative to the transactions for single trades, Frino and Oetomo (2005) use daily opening and closing prices as benchmarks in their analysis for packaged trades.

cost of executing a trade[15]. Snapshots for each 5-minute interval are calculated and averaged across the sample period. We generate limit order book estimates for the entire two year period from 30 June, 2006 to 30 June, 2008, into the periods specified in section 4.1. In addition, as the overall market was falling during the sample period, there could be asymmetries between the bid and ask sides of the market that are not associated with the minimum tick reduction. Consequently, in the following analysis, we average the bid and ask sides of the market to reduce any potential effect resulting from general price direction.

5 Results

5.1. Descriptive Statistics and Multivariate Results for Trading Activities

Table 5-1 provides descriptive statistics of changes to trading activity around the reduction in minimum tick. Proxies of trading activity include the daily turnover of stocks, the daily number of trades and the average value per trade. Descriptive statistics for the Full Sample Period (*All Observations*) are not provided as movements between price bands affects the sample of stocks within each band, and thus leads to a natural change in trading activity for that band. Similarly, descriptive statistics for the Full Sample Period (*Most Frequent Band*) are not provided as the methodology for this analysis requires the removal of trades when it does not fall within the most frequent band. The omission of these trades is likely to distort any analysis of trading activity.

[15] For example, the value-weighted costs of executing a buy order worth $100,000, against market depth of 5,000 at $7.00 ($35,000), 6,000 at $7.02 ($42,120) and 10,000 at $7.04 ($70,400) will be $ 7.0176 [($7 * 0.35) + ($7.02*0.4212) + ($7.04*0.2288)].

Results in Table 5-1 document that the mean (median) daily trading volume in PB1 falls by 7.98% (15.27%), PB2 increases by 29.75% (33.65%), PB3 increases by 40.39% (40.82%) and the control group PB4 increases by 2.11% (-2.53%). Results are observed to be statistically different from zero at the 1% level for PB2 and PB3, but not for PB1 and the control group (PB4). These results suggest that PB2 and PB3 have benefited most from the reduction in minimum tick sizes as trading activity increases significantly.

Table 5-1 also documents that the number of trades that are successfully matched increases significantly. Specifically, the mean (median) number of trades increases by 215% (279%), 315% (651%), 251% (336%) and 88% (93%) for PB1, PB2, PB3 and PB4, respectively. It is noteworthy that the increased trading frequency is most pronounced for the affected stocks. The average value per trade falls over the same period. Stocks in PB1 experience a mean (median) decline of 37.94% (36.82), PB2 decline by 23.53% (23.93%), PB3 decline by 26.51% (25.81%) and the control group PB4 declines by 24.43% (24.89%). Results are found to be statistically different from zero for all price bands.

These results are consistent with ap Gwilym, McManus and Thomas (2005) and suggests that stocks affected by the minimum tick reduction will experience an increase in trading activity. This is particularly true for stocks in PB2 and PB3 where daily turnover and daily number of trades increase significantly after the event. However for PB1, although the number of trades significantly increases (proportionality more than the control group), daily turnover is not significantly different. The increase in daily turnover for PB3 is greater than that for PB2. These results suggest that the magnitude of the reduction does not create a proportional increase in the trading activities of the affected stocks.

The results for stocks in PB1 are somewhat unintuitive (when compared to results for stocks in PB2 and PB3). A possible explanation is that market makers[16] and individual scalpers[17] (traders that profit by the quick buying and selling of shares at the minimum tick) will find that it is strategically more profitable to trade in PB3 compared to PB1 and PB2 after the reduction in minimum tick. For example, at the lower threshold for PB3, the premium that can be earned for trading at the best prevailing level is 0.33% ($0.01 / $3.00). Comparatively, for PB1 and PB2, the maximum profitability that can be charged at the best levels is 0.2% ($0.02 / $10.00 and $0.01 / $5.00). Prior to the change, the premium earned from trading in PB1 is 1% ($0.10 / $10.00), for PB2 is 1% ($0.05 / $5.00) and for PB3 is 0.67% ($0.02 / $3.00). This provides a natural strategic incentive for these participants to increase their trading activity in PB3 stocks[18]. Consistent with this hypothesis, we observe that stocks in PB3 experience the highest increase in daily turnover of 40.39% (compared to 29.75% for PB2, and no statistically significant change in PB1 and PB4).

The next section provide results on the bid-ask spreads.

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[16] SGX does not have any designated market maker, however large institutions do engage in market-making activities.

[17] Grossman and Miller (1988) argued that the minimum tick size supports a minimum level of profit to market makers and guarantees provision of liquidity. Much of the liquidity in electronic markets, however, is “outsider liquidity” provided by speculators, hedgers, or investors rebalancing their portfolios (e.g., Locke & Sarkar, 2001).

[18] The results presented in the example represent only the lower threshold. The upper bound premiums that can be charged after the reduction for PB1 (assuming that PB1 has an upper limit of $20.00) and PB2 (at $9.98) is approximately the same at 0.1%, for PB3 it is approximately 0.2%. It is noted that the difference in premium is still observed in the upper threshold. For the purpose of the example, the upper bounds were not used as there is no imposed ceiling on the upper limits of PB1 (i.e. stocks price can exceed $20.00).

Table 5-1 : Daily Turnover, Number of Trades and Average Trade Value							
Period	Price Band	Results for Selected Period (24/09/07 - 24/03/08)					
		Daily Turnover (Mean)	Daily Number of Trades (Mean)	Average Value (SGD) Per Trade (Mean)	Daily Turnover (Median)	Daily Number of Trades (Median)	Average Value (SGD) Per Trade (Median)
Pre	1	345,094,311	1,096	137,621	344,031,550	854	132,791
Post	1	317,568,689	3,454	85,408	291,512,975	3,239	83,901
Pre	2	194,034,638	1,194	61,311	182,572,961	611	60,625
Post	2	251,766,606	4,953	46,883	244,007,959	4,587	46,117
Pre	3	134,027,829	1,872	37,954	133,016,988	1,505	37,247
Post	3	188,167,943	6,563	27,894	187,318,122	6,559	27,633
Pre	4	167,839,486	5,152	22,194	161,500,527	4,752	21,767
Post	4	171,380,333	9,711	16,771	157,414,609	9,167	16,350

Note: Descriptive Statistics for the Full Sample Period (*All*) were not provided as the methodology for this analysis as the movements of any stock within two or more price bands will automatically create a change in the trading activities of the bands. For example, if Stock X moves from PB1 to PB2, PB1 will experience a natural decline in trading activities and vice versa for PB2. This is likely to distort any results. Similarly, descriptive statistics for the Full Sample Period (*Most Frequent Band*) were not provided as the methodology for this analysis requires the removal of trades when it does not fall within the most frequent band. The omission of these trades is likely to distort any analysis of trading activities using this methodology and is thereby removed to avoid bias.

Table 5-2: Percentage Change in Daily Turnover, Number of Trades and Average Trade Value						
Price Band	Results for Selected Period (24/09/07 - 24/03/08)					
	Daily Turnover (Mean) Change (%)	Daily Number of Trades (Mean) Change (%)	Average Value (SGD) Per Trade (Mean) Change (%)	Daily Turnover (Median) Change (%)	Daily Number of Trades (Median) Change (%)	Average Value (SGD) Per Trade (Median) Change (%)
1	-7.98	215.15**	-37.94**	-15.27	279.27**	-36.82**
2	29.75**	314.82**	-23.53**	33.65**	650.74**	-23.93**
3	40.39**	250.59**	-26.51**	40.82**	335.81**	-25.81**
4	2.11	88.49**	-24.43**	-2.53	92.91**	-24.89**

** Significance at the 1% level

5.2. Descriptive Statistics for Bid-Ask Spreads and Market Depth

Table 5-3 presents a comparison of the bid-ask spreads around the implementation of the tiered reduction by the Singapore Exchange. Results indicate that bid-ask spreads are significantly tighter after the reduction in minimum tick for all affected stocks. This is consistent with hypothesis H1 and previous studies analyzing the impact of tick size reduction in liquid markets, such as Goldstein and Kavajecz (2000) and Jones and Lipson (2001). Specifically, we observe that bid-ask spreads for PB1 decline, falling between 67.7% to 73.0% across the three analyses. Similarly, PB2 experiences a reduction in spreads ranging from 69.7% to 75.6%, and PB3 experiences a reduction in spreads ranging from 37.8% to 42.7%. Results are statistically different from zero at the 1% level in all three analyses for the affected stocks. Control group stocks (PB4) experience minimal bid-ask spread changes, with the *All Observations* (0.64%) and *Most Frequent* (-2.66%) analyses not statistically different from zero at the 1% level. The *Restricted*

Analysis exhibits a statistically significant 20.0% *increase* in spreads. These results suggest that the reduction in spreads is isolated to the affected stocks.

Results also indicate that stocks which experience larger tick size reduction also experienced the most significant reduction in minimum tick. For example, if we compare the change in bid-ask spreads of stocks in PB1 and PB2 which experienced a reduction of 80%[19] of their original spreads to PB3 which experienced a 50% decline. We observed that stocks in PB1 and PB2 experienced reductions in spreads that are on average 29.9% to 33.5% more than those in PB3. Table 5-5 provides the T-statistics for the difference in means between price bands. Consistent with our observations, we noted a statistically significant difference between the comparison of all price bands except for the interaction between PB1 and PB2. This confirms that the reductions in bid-ask spreads for both PB1 and PB2 is similar in magnitude and are both statistically larger than PB3. Overall, these results provides evidence to support hypothesis 2 that stocks which experience larger reduction in the minimum tick will experience larger declines in bid-ask spreads.

Table 5-4 presents results of the examination of quoted depth at the best prevailing quotes for the three analyses. Consistent with hypothesis H3, we observe significant declines in depth at the prevailing bid and ask quotes ranging from 72.3% to 92.4% for the affected stocks. Stocks in PB1 experience a decline ranging from 91.0% to 92.2%, stocks in PB2 experience reductions of 89.6% to 92.4%, and stocks in PB3 experience reductions from 72.3% to 80.4% across the three analyses. These reductions are consistent with previous

[19] The minimum tick was reduced from $0.1 to $0.02 and $0.05 to $0.01 for both PB1 and PB2, respectively, which amounts to an 80% reduction. Similarly for PB3, it was reduced from $0.02 to $0.01 which indicates a 50% decline.

literature in equities markets, such as Bessembinder (2003), who finds a 74 percent reduction in NBBO quoted volumes for the most liquid stocks on the NYSE. Similar to the results for bid-ask spreads, results from the control group (PB4) show that market depth does not change significantly after the change in minimum tick. These results suggest that the reduction in market depth is isolated to the affected stocks.

While the decline in depth is consistent with the findings of prior studies, it is noteworthy that the magnitude of the reduction is sizeable. Specifically, we observed that the largest falls in quoted depth are experienced by PB1 and PB2 which experienced the greatest reduction in minimum tick (and the subsequent availability of more price intervals). Consistent with the bid-ask spreads findings, Table 5-5 confirms that the reductions in market depth for both PB1 and PB2 is similar in magnitude and are both statistically larger than PB3. Overall, these results provide empirical evidence to support hypothesis H4 which indicates that the decline in depth is highly correlated to the size of the tick reduction.

Table 5-3 : Descriptive Statistics on Bid-Ask Spreads									
This table presents results for time-weighted bid-ask spreads pre and post the reduction in minimum tick. The *pre-period* is the period prior to the 24 December, 2007 event, and the *post-period*, after. The sample *all observation* includes all trades for the two-year period from 30th June, 2006 to 30th June, 2008. The *most frequent* sample includes all trades for the two-year period from 30th June, 2006 to 30th June, 2008 but remove trades that do not reside in the most frequent price band of a stock. The *restricted period* sample includes all trades for the 3-month period from 23rd September, 2007 to 23rd March, 2008, stocks that fluctuate between price bands are removed. Groups are denoted PB1 for stocks above $10, PB2 for stocks between $5 and $9.95, PB3 for stocks between $3 and $4.98, and PB4 for stocks below $3. Stocks in PB4 which are not affected by the reduction in minimum tick are utilized as controls. Change (%) represents the percentage change after the reduction of the minimum tick.									
	All Observations (30/06/06 - 30/06/08)			Most Frequent (30/06/06 - 30/06/08)			Restricted Period (23/09/07 - 23/03/08)		
	Pre-Period	Post-Period	Change (%)	Pre-Period	Post-Period	Change (%)	Pre-Period	Post-Period	Change (%)
Price Band 1 (PB1)	0.66966	0.18063	-73.03	0.65684	0.17992	-72.61	0.50525	0.16307	-67.72**
Price Band 2 (PB2)	0.76149	0.18605	-75.57	0.71255	0.17806	-75.01	0.64452	0.19500	-69.74**
Price Band 3 (PB3)	0.54967	0.31831	-42.09	0.53648	0.30732	-42.72	0.49724	0.30918	-37.82**
Price Band 4 (PB4, Control)	0.63053	0.63454	0.64	0.65932	0.64177	-2.66	0.60571	0.72742	20.09**

Note: Tests of significant only available for restricted period due to matching methodology.
**Significance at the 1% level

Table 5-4 : Descriptive Statistics on Market Depth (Best Prevailing Level)									
This table presents results for the market depth at the best prevailing level, pre and post the reduction of the minimum ticks. The *pre-period* is the period prior to the 24 December, 2007 event, and the *post-period*, after. The sample *all observation* includes all trades for the two-year period from 30th June, 2006 to 30th June, 2008. The *most frequent* sample includes all trades for the two-year period from 30th June, 2006 to 30th June, 2008 but remove trades that do not reside in the most frequent price band of a stock. The *restricted period* sample includes all trades for the 3-month period from 23rd September, 2007 to 23rd March, 2008, stocks that fluctuate between price bands are removed. Groups are denoted PB1 for stocks above $10, PB2 for stocks between $5 and $9.95, PB3 for stocks between $3 and $4.98, and PB4 for stocks below $3. Stocks in PB4 which are not affected by the reduction in minimum tick are utilized as controls. Change (%) represents the percentage change after the reduction of the minimum tick.									
	All Observations (30/06/06 - 30/06/08)			Most Frequent (30/06/06 - 30/06/08)			Restricted Period (23/09/07 - 23/03/08)		
	Pre	Post	Change (%)	Pre	Post	Change (%)	Pre	Post	Change (%)
Price Band 1	5,641,230	510,187	-90.96	5,781,093	510,398	-91.17	6,405,390	502,037	-92.16**
Price Band 2	3,484,812	362,458	-89.60	4,665,211	366,648	-92.14	5,280,941	403,033	-92.37**
Price Band 3	1,150,766	318,644	-72.31	1,338,880	289,886	-78.35	1,737,564	340,640	-80.40**
Price Band 4	713,831	655,025	-8.24	718,686	667,989	-7.05	615,984	617,045	0.17

Note: Tests of significant only available for restricted period due to matching methodology.
**Significance at the 1% level

Table 5-5: Results for T-Test Between Price Bands (Bid-Ask Spreads)		
Restricted Period (23/09/07 - 23/03/08)		
	Bid-Ask Spread	Market Depth
PB1 and PB2	4.27	0.09
PB1 and PB3	-33.03	-11.93
PB1 and PB4	-73.37	-14.80
PB2 and PB3	-35.56	-12.02
PB2 and PB4	-75.31	-14.82
PB3 and PB4	-38.92	-9.82

Note: Tests of significant only available for restricted period due to matching methodology.
**Significance at the 1% level

5.2.1. Multivariate Results for Bid-Ask Spreads and Market Depth

Harris (1994) identifies several factors (volume and volatility) that affect bid-ask spreads and quoted depth. Table 5-7 presents results from bid-ask spread regressions. Panels A, B and C (presenting results for PB1, PB2 and PB3, respectively) indicate that the reduction in bid-ask spreads for stocks affected by the minimum tick change is significant after controlling for volume and volatility. This supports the univariate results, suggesting that the reduction in tick size contributes significantly to the decrease in bid-ask spreads for the affected stocks. We also observe (Panel D) that after controlling for volume and volatility, bid-ask spreads for the control stocks exhibit a significant increase. Results are robust across all three analyses, and consistent with univariate results, the reduction in bid-ask spreads is unique to the affected stocks (and is consistent with hypothesis H1).

In addition, a comparison of the coefficients between the affected stocks shows that bid-ask spread reductions for stocks in PB1 and PB2 (which experienced larger tick reductions) are more than double than for stocks in PB3. This again confirms that the decline in spreads is greater for stocks that have a larger decrease in tick size, and is consistent with hypothesis H2.

Table 5-6 presents results from the best depth regressions. Results confirm that the reduction in minimum tick negatively impacts on depth for the affected stocks, consistent with hypothesis H3. Similar to results documented for bid-ask spreads, it is observed that PB1 and PB2 (relative to PB3) experience a greater drop in depth at the best prevailing level, which is consistent with hypothesis H4. Interestingly, it is also observed that depth at the prevailing quotes in the control group (PB4) also experience a decrease in the best depth. Results are consistent across all three analyses. A possible explanation for the general decrease in market depth for all stocks, and exacerbated decline in depth for the affected stocks, is the ongoing global financial crisis. Given that the sample period includes this period of adverse market conditions, it is likely that a portion of the decrease in market depth at the best prevailing level is attributable to this event. To isolate the effects of this event on the study, and to control for broad market movements, we adopt a method analogous to Chordia, Roll and Subrahmanyam (2000).

Table 5-7: Regression Estimates for Bid-Ask Spreads

The table presents results from the following regression model:

$$BASi = \alpha 0 + \alpha 1 Change + \alpha 2\ Ln(DailyVolumec) + \alpha 3 Volatilityc + \varepsilon$$

The dependant variable in this equation is the time-weighted average bid-ask spread of the affected stocks, where *i* equals to PB1, PB2 and PB3. *BASi* is the average time-weighted bid-ask spread, *Change* is a dummy variable equal to 1 for the period post-change and 0 otherwise, *Ln(DailyVolumec)* is the natural logarithm of the average daily volume of the *control group* and *Volatilityc* is the daily volatility of the *control group*, calculated as the log difference between daily high and low prices. The equations are estimated separately for the 3 analyses, (a) All, (b), Most Frequent Band and (c) Restricted Period.

Panel A: Regression Statistics for Price Band 1

	All Observations (30/06/06 - 30/06/08)		Most Frequent (30/06/06 - 30/06/08)		Restricted Period (23/09/07 - 23/03/08)	
	OLS Estimates	*T-stats*	OLS Estimates	*T-stats*	OLS Estimates	*T-stats*
Intercept	-0.53	-4.32	1.07**	34.69	1.26	6.11
Change	-0.46	-67.15	-0.48**	-48.69	-0.47	-76.45
Ln(Volume)	0.14	10.06	-0.04**	-10.32	-0.07	-3.05
Ln(Volatility)	-0.50	-5.08	0.03	0.56	0.35	2.02
Adj. R-Sq.	0.92		0.27		0.98	
F-Statistic	3271.72		810.42		2662.58	

Panel B: Regression Statistics for Price Band 2

	All Observations (30/06/06 - 30/06/08)		Most Frequent (30/06/06 - 30/06/08)		Restricted Period (23/09/07 - 23/03/08)	
	OLS Estimates	*T-stats*	OLS Estimates	*T-stats*	OLS Estimates	*T-stats*
Intercept	1.08	8.40	1.76**	30.42	1.05	4.55
Change	-0.59	-83.53	-0.56**	-78.96	-0.56	-82.12
LnVolume	-0.03	-2.35	-0.12**	-16.64	-0.03	-1.27
LnVolatility	-0.19	-1.83	0.02	0.34	0.01	0.06
Adj. R-Sq.	0.93		0.60		0.99	
F-Statistics	3949.43		2093.71		3176.56	

Panel C: Regression Statistics for Price Band 3						
	All Observations (30/06/06 - 30/06/08)		Most Frequent (30/06/06 - 30/06/08)		Restricted Period (23/09/07 - 23/03/08)	
	OLS Estimates	*T-stats*	OLS Estimates	*T-stats*	OLS Estimates	*T-stats*
Intercept	0.63	9.64	0.76**	13.16	0.97	5.83
Change	-0.23	-63.77	-0.19**	-28.45	-0.23	-47.24
LnVolume	-0.01	-1.40	-0.02**	-3.38	-0.05	-2.61
LnVolatility	0.13	2.44	0.70**	6.35	0.49	3.53
Adj. R-Sq.	0.89		0.10		0.96	
F-Statistics	2275.28		280.31		980.34	
Panel D: Regression Statistics for Price Band 4						
	All Observations (30/06/06 - 30/06/08)		Most Frequent (30/06/06 - 30/06/08)		Restricted Period (23/09/07 - 23/03/08)	
	OLS Estimates	*T-stats*	OLS Estimates	*T-stats*	OLS Estimates	*T-stats*
Intercept	-1.14**	-10.99	-0.48**	-14.51	1.49**	5.40
Change	0.06**	9.88	0.08**	13.99	0.05**	5.65
LnVolume	0.20**	17.20	0.14**	36.77	-0.11**	-3.44
LnVolatility	-0.04	-0.51	0.53**	9.54	0.80**	3.44
Adj. R-Sq.	0.26		0.04		0.47	
F-Statistics	100.24		516.31		36.84	

* Significance at the 5% level

** Significance at the 1% level

Table 5-6: Regression Estimates for Market Depth

The table presents results from the following regression models:

$$Ln(BestDepthi) = \alpha 0 + \alpha 1Change + \alpha 2\ Ln(DailyVolumec) + \alpha 3Volatilityc + \varepsilon$$

The dependant variable is the average best depth of the affected stocks, where *i* equals to PB1, PB2 and PB3. *Ln(BestDepthi)* represents natural logarithm of daily depth at the prevailing bid and ask quotes and *Change* is a dummy variable equal to 1 for the period post-change and 0 otherwise, *Ln(DailyVolumec)* is the natural logarithm of the average daily volume of the *control group* and *Volatilityc* is the daily volatility of the *control group*, calculated as the log difference between daily high and low prices. The equation is estimated separately for the 3 analyses, (a) All, (b), Most Frequent Band and (c) Restricted Period.

Panel A: Regression Statistics for Price Band 1

	All Observations (30/06/06 - 30/06/08)		Most Frequent (30/06/06 - 30/06/08)		Restricted Period (23/09/07 - 23/03/08)	
	OLS Estimates	*T-stats*	OLS Estimates	*T-stats*	OLS Estimates	*T-stats*
Intercept	12.35	14.55	-2.46**	-17.47	12.43	6.16
Change	-2.18	-46.36	-1.31**	-29.51	-2.17	-36.46
Ln(Volume)	0.27	2.79	2.03**	110.86	0.26	1.08
Ln(Volatility)	-2.46	-3.63	0.23	1.09	-3.14	-1.85
Adj. R-Sq.	0.83		0.67		0.94	
F-Statistic	1390.71		4541.96		669.16	

Panel B: Regression Statistics for Price Band 2

	All Observations (30/06/06 - 30/06/08)		Most Frequent (30/06/06 - 30/06/08)		Restricted Period (23/09/07 - 23/03/08)	
	OLS Estimates	*T-stats*	OLS Estimates	*T-stats*	OLS Estimates	*T-stats*
Intercept	13.28	9.85	-6.10**	-15.11	12.06	6.64
Change	-1.92	-25.70	-1.42**	-28.54	-2.14	-39.80
LnVolume	0.06	0.40	2.40**	47.81	0.23	1.10
LnVolatility	-0.48	-0.44	-1.15*	-2.53	-3.26	-2.13
Adj. R-Sq.	0.58		0.47		0.95	
F-Statistics	394.59		1214.01		797.28	

Panel C: Regression Statistics for Price Band 3						
	All Observations (30/06/06 - 30/06/08)		Most Frequent (30/06/06 - 30/06/08)		Restricted Period (23/09/07 - 23/03/08)	
	OLS Estimates	*T-stats*	OLS Estimates	*T-stats*	OLS Estimates	*T-stats*
Intercept	4.14	4.17	0.15	0.51	3.81	2.01
Change	-0.95	-17.22	-0.76**	-23.16	-0.97	-17.34
LnVolume	1.01	8.97	1.46**	41.41	1.03	4.63
LnVolatility	-4.34	-5.46	-2.87**	-5.23	-4.78	-2.98
Adj. R-Sq.	0.56		0.30		0.83	
F-Statistics	370.74		1034.46		200.42	
Panel D: Regression Statistics for Price Band 4						
	All Observations (30/06/06 - 30/06/08)		Most Frequent (30/06/06 - 30/06/08)		Restricted Period (23/09/07 - 23/03/08)	
	OLS Estimates	*T-stats*	OLS Estimates	*T-stats*	OLS Estimates	*T-stats*
Intercept	6.87**	10.18	5.81**	57.72	4.92**	3.00
Change	-0.11**	-3.00	-0.31**	-18.18	-0.27**	-5.53
LnVolume	0.58**	7.63	0.62**	54.17	0.83**	4.28
LnVolatility	-2.52**	-4.66	-0.17	-1.00	-4.95**	-3.57
Adj. R-Sq.	0.20		0.11		0.51	
F-Statistics	71.72		1324.99		40.94	

* Significance at the 5% level

** Significance at the 1% level

Table 5-7 presents bid-ask spread results using the Chordia, Roll and Subrahmanyam (2000) methodology. Results indicate that after controlling for spreads in unaffected stocks (PB4), there is a significant reduction in the bid-ask spreads of the affected stocks (PB1, PB2 and PB3), as indicated by the significantly negative coefficient on the dummy variable. This confirms both the univariate and initial regression results; the reduction in bid-ask spreads occurs only in the affected stocks. Similar to the initial regression, the coefficient of PB1 and PB2 are approximately double that of PB3.

Results of the best depth regressions are presented in Table 5-8. After controlling for depth using unaffected stocks in PB4, best depth for affected stocks (PB1, PB2 and PB3) is significantly lower after the reduction in minimum tick. These results demonstrate that after controlling for broad market movements, there is a statistically significant decrease in depth at the best prevailing level for stocks affected by the change in minimum tick. These results provide supporting evidence to the initial regression results, and are consistent with hypothesis, H3. The decline in best depth is larger for PB1 and PB2, relative to PB3, which is consistent with hypothesis H4.

Table 5-7: Regression Estimates for Bid-Ask Spreads

The table presents results from the following regression model:

$$BAS_i = \alpha_0 + \alpha_1 Change + \alpha_2 ControlBAS_i$$

The dependant variable in this equation is the time-weighted average bid-ask spread of the affected stocks, where *i* equals to PB1, PB2 and PB3. *BASi* is the average time-weighted bid-ask spread, *Change* is a dummy variable equal to 1 for the period post-change and 0 otherwise, *ControlBASi* represents the control market bid-ask spread measures and the dummy variable. The equations are estimated separately for the 3 analyses, (a) All, (b), Most Frequent Band and (c) Restricted Period.

Panel A: Regression Statistics for Price Band 1

	All Observations (30/06/06 - 30/06/08)		Most Frequent (30/06/06 - 30/06/08)		Restricted Period (23/09/07 - 23/03/08)	
	OLS Estimates	*T-stats*	OLS Estimates	*T-stats*	OLS Estimates	*T-stats*
Intercept	0.37**	17.39	0.52**	20.29	0.57**	7.40
Change	-0.51**	-101.56	-0.49**	-54.50	-0.04**	-5.46
Control	0.49**	14.66	0.31**	9.19	0.13	1.07
Adj. R-Sq.	0.92		0.78		0.29	
F-Statistic	5349.68		1494.16		24.47	

Panel B: Regression Statistics for Price Band 2

	All Observations (30/06/06 - 30/06/08)		Most Frequent (30/06/06 - 30/06/08)		Restricted Period (23/09/07 - 23/03/08)	
	OLS Estimates	*T-stats*	OLS Estimates	*T-stats*	OLS Estimates	*T-stats*
Intercept	0.75**	31.93	0.73**	19.97	0.76**	18.55
Change	-0.59**	-108.24	-0.60**	-47.57	-0.56**	-75.55
Control	0.04	1.08	0.16**	3.40	0.00	0.00
Adj. R-Sq.	0.93		0.72		0.99	
F-Statistic	5878.45		1131.50		4737.18	

Panel C: Regression Statistics for Price Band 3

	All Observations (30/06/06 - 30/06/08)		Most Frequent (30/06/06 - 30/06/08)		Restricted Period (23/09/07 - 23/03/08)	
	OLS Estimates	*T-stats*	OLS Estimates	*T-stats*	OLS Estimates	*T-stats*
Intercept	0.56**	46.91	0.48**	29.49	0.54**	17.38
Change	-0.23**	-82.25	-0.19**	-33.15	-0.22**	-40.01
Control	-0.02	-1.18	0.14	6.53	0.03	0.51
Adj. R-Sq.	0.89		0.56		0.96	
F-Statistic	3386.41		555.49		1308.02	

* Significance at the 5% level

** Significance at the 1% level

Table 5-8: Regression Estimates for Depth						
The table presents results from the following regression model: *Ln(BestDepthi) = α0 + α1Change + α2 Ln(BestDepthc) + ε* The dependant variable is the average best depth of the affected stocks, where *i* equals to PB1, PB2 and PB3. *Ln(BestDepthi)* represents natural logarithm of daily depth at the prevailing bid and ask quotes and *Change* is a dummy variable equal to 1 for the period post-change and 0 otherwise, *Ln(BestDepthc)* represents the control market natural logarithm of daily depth measures and the dummy variable. The equation is estimated separately for the 3 analyses, (a) All, (b), Most Frequent Band and (c) Restricted Period.						
Panel A: Regression Statistics for Price Band 1						
	All Observations (30/06/06 - 30/06/08)		Most Frequent (30/06/06 - 30/06/08)		Restricted Period (23/09/07 - 23/03/08)	
	OLS Estimates	*T-stats*	OLS Estimates	*T-stats*	OLS Estimates	*T-stats*
Intercept	9.51**	20.64	10.51**	13.27	8.94**	5.75
Change	-2.15**	-59.91	-1.54**	-24.65	-0.30**	-5.33
Control	0.43**	11.10	0.24**	3.37	0.49**	3.73
Adj. R-Sq.	0.85		0.55		0.30	
F-Statistic	2375.11		536.24		25.51	
Panel B: Regression Statistics for Price Band 2						
	All Observations (30/06/06 - 30/06/08)		Most Frequent (30/06/06 - 30/06/08)		Restricted Period (23/09/07 - 23/03/08)	
	OLS Estimates	*T-stats*	OLS Estimates	*T-stats*	OLS Estimates	*T-stats*
Intercept	10.88**	14.21	13.75**	12.43	7.82**	8.23
Change	-1.86**	-31.20	-1.57**	-18.05	-1.99**	-38.95
Control	0.24**	3.81	-0.07	-0.75	0.52**	6.42
Adj. R-Sq.	0.58		0.29		0.96	
F-Statistic	609.30		176.43		1571.81	
Panel C: Regression Statistics for Price Band 3						
	All Observations (30/06/06 - 30/06/08)		Most Frequent (30/06/06 - 30/06/08)		Restricted Period (23/09/07 - 23/03/08)	
	OLS Estimates	*T-stats*	OLS Estimates	*T-stats*	OLS Estimates	*T-stats*
Intercept	6.67**	11.74	2.96**	4.80	4.28**	4.31
Change	-1.15**	-25.84	-0.75**	-15.39	-0.85**	-15.95
Control	0.52**	10.94	0.82**	15.01	0.69**	8.25
Adj. R-Sq.	0.56		0.56		0.87	
F-Statistic	559.98		543.58		410.05	

* Significance at the 5% level

** Significance at the 1% level

5.3. Simulated Market Impact Costs

The decline in both bid-ask spreads and quoted depth provides a confounding effect on market quality after the reduction in minimum tick. A drop in the spread indicates that the cost of executing a trade decreases for traders, while the simultaneous decline in quoted depth might suggest that liquidity is reduced. Depending on their liquidity demands, traders can be faced with either increased or decreased costs. For example, liquidity demanders trading sizes less than or equal to the reduced quoted depth will realize a transaction cost decrease. For liquidity demanders trading sizes larger than the reduced quoted depth, the improved bid and ask prices apply only to a portion of their required size. Absent additional liquidity provision, for the remainder of their trades, the sequence of prices and depths further into the limit order book also apply. For larger sized orders, inferences about transaction costs cannot be made without examining how liquidity further into the limit order book is affected by the tick reduction. To understand the aggregate impact how this has affected market liquidity, we examine change in market impact costs facing different liquidity demanders.

Price impact, as defined by Domowitz, Glen and Madhavan (2001), is the difference between the price after execution and a pre-trade benchmark price, assuming the trade does not occur. For the purposes of this study, we adopt the simulation methodology used in Goldstein and Kavajecz (2000) to analyze the change in liquidity provision and expected market impact costs. Results for the simulated market impact costs from executing different parcels of trades (notional value) in basis points are provided in Table 5-9 for the three analyses, *All Observations*, *Most Frequent* and *Restricted Period*. Market impact costs in the simulation are taken as the value-weighted cost of executing the different parcels of trades (in notional value) less the best quoted price divided by the best quoted price. If the order is a buy (sell), we simulate the fulfilling of orders against the cumulative ask (bid) available depth (in notional value) to compute the value-weighted cost of executing a trade. Both sides of the orders are observed to be statistically similar for our sample period.

Results in Table 5-9 indicate, that on average, for PB1, the expected costs of executing smaller parcels of trades (between $10,000 and $50,000) increase by 0.35 to 3.9 basis points across the three analyses. For large trades (> $100,000), there is a decrease in market impact costs ranging from 2.12 to 14.74 basis points, and that as trade size increases, the reduction in market impact also increases. Results are statistically significant for the $10,000, $500,000 and $1,000,000 parcels at the 5% level and significant at 1% for the remaining trade parcels[23]. These results provide some evidence that traders of large orders benefit from the change in minimum tick sizes through reduced transaction costs.

To provide a more meaningful comparison, we compare changes in PB1 stocks to those in the control group, PB4 (Panel D). Results from Panel D indicate that stocks that are not affected by the change in minimum tick size experience a general increase of 0.13 to 31.13 basis points across different trade sizes, with the increase in costs escalating as trade size increases. These findings are consistent with broad market conditions of stock exchanges worldwide that have been affected by the global financial crisis. In conjunction with the results from Panel D, large demanders of liquidity in PB1 benefit from the changes as they can expect to incur lower transaction costs from trade execution. Investors trading small parcels experience marginal

[23] Tests of significant only available for restricted period due to matching methodology.

increases, which are generally consistent with broad market changes, and suggest no significant change in transaction costs beyond overall market increases.

Panel B of Table 5-9 provides the expected market impact costs for stocks in PB2. Results suggest that the expected market impact costs have increased for all parcels of trades in this price band, with increases ranging from 0.10 to 32.23 basis points. Transaction costs increase monotonically as trade sizes increases (with the only exception being trades at $1,000,000 where the increase is smaller than $500,000). Results are observed to be statistically significant at the 1% level for $50,000, $100,000, $500,000 and significant at the 5% level for $1,000,000. Comparing these results to the control group, the percentage increase[24] for each trade parcel is higher than those experience by the control group (PB4). These results suggest that market liquidity is decreased for stocks in PB2.

Panel C of Table 5-9 provides the expected market impact costs for stocks in PB3. Consistent with the results in Panel B, it is observed that there is a percentage increase in the market impact costs across all trade parcels (with all higher than the control group). The increases in expected transaction costs range from 0.59 to 44.78 basis points. Similar to stocks in PB2, it appears that immediate demanders of liquidity in PB3 faced increased transaction costs after the reduction in minimum tick.

[24] Percentage increase is calculated by [(Post Simulated Market Impact Costs - Pre Simulated Market Impact Costs) / Pre Simulated Market Impact Costs] * 100.

Table 5-9: Simulated Market Impact Costs for Different Parcels of Trades (Notional Value)									
Panel A: Simulated Market Impact Costs (in Basis Points) for Price Band 1									
	All Observations (30/06/06 - 30/06/08)			Most Frequent (30/06/06 - 30/06/08)			Restricted Period (23/09/07 - 23/03/08)		
Trade Size (Notional Value)	Pre	Post	Change (Basis Points)	Pre	Post	Change (Basis Points)	Pre	Post	Change (Basis Points)
$10,000	0.57	1.70	1.13	0.65	1.81	1.16	0.57	0.92	0.35*
$25,000	4.28	7.58	3.30	4.31	7.60	3.29	4.14	7.03	2.89**
$50,000	11.54	12.50	0.96	11.78	12.69	0.91	11.03	14.92	3.90**
$100,000	20.20	14.85	-5.35	20.45	15.02	-5.43	21.02	18.90	-2.12**
$500,000	33.83	22.90	-10.93	33.90	23.04	-10.86	28.44	25.31	-3.13*
$1,000,000	37.86	23.23	-14.63	38.01	23.28	-14.74	28.17	24.57	-3.60*
Panel B: Simulated Market Impact Costs (in Basis Points) for Price Band 2									
	All Observations (30/06/06 - 30/06/08)			Most Frequent (30/06/06 - 30/06/08)			Restricted Period (23/09/07 - 23/03/08)		
Trade Size (Notional Value)	Pre	Post	Change (Basis Points)	Pre	Post	Change (Basis Points)	Pre	Post	Change (Basis Points)
$10,000	0.42	1.13	0.70	0.51	1.19	0.68	0.61	0.71	0.10
$25,000	1.94	4.59	2.65	2.09	4.76	2.67	2.73	3.77	1.04
$50,000	4.18	9.86	5.68	4.28	9.96	5.68	5.66	9.78	4.11**
$100,000	8.14	18.11	9.97	8.26	18.22	9.95	10.61	19.98	9.37**
$500,000	28.13	51.04	22.92	28.34	51.12	22.79	29.46	61.69	32.23**
$1,000,000	39.64	47.32	7.68	39.66	47.35	7.70	39.91	55.42	15.51*

Panel C: Simulated Market Impact Costs (in Basis Points) for Price Band 3									
	All Observations (30/06/06 - 30/06/08)			Most Frequent (30/06/06 - 30/06/08)			Restricted Period (23/09/07 - 23/03/08)		
Trade Size (Notional Value)	Pre	Post	Change (Basis Points)	Pre	Post	Change (Basis Points)	Pre	Post	Change (Basis Points)
$10,000	2.03	2.61	0.59	2.13	2.76	0.64	1.80	3.06	1.25**
$25,000	4.98	7.81	2.82	5.13	7.94	2.80	4.48	8.78	4.30**
$50,000	9.39	16.95	7.55	9.57	17.10	7.52	8.61	18.88	10.28**
$100,000	16.87	32.72	15.85	17.08	32.81	15.73	15.94	37.38	21.44**
$500,000	53.32	76.06	22.74	53.54	76.24	22.70	54.99	99.77	44.78**
$1,000,000	59.46	71.20	11.74	59.68	71.39	11.72	57.78	84.47	26.69**
Panel D: Simulated Market Impact Costs (in Basis Points) for Price Band 4									
	All Observations (30/06/06 - 30/06/08)			Most Frequent (30/06/06 - 30/06/08)			Restricted Period (23/09/07 - 23/03/08)		
Trade Size (Notional Value)	Pre	Post	Change (Basis Points)	Pre	Post	Change (Basis Points)	Pre	Post	Change (Basis Points)
$10,000	6.94	7.37	0.43	7.04	7.56	0.52	7.81	7.94	0.13
$25,000	15.08	18.22	3.13	15.20	18.28	3.07	17.08	19.60	2.52
$50,000	27.08	33.59	6.50	27.25	33.67	6.42	30.82	37.26	6.44**
$100,000	46.63	58.28	11.65	46.75	58.31	11.56	51.77	66.96	15.19**
$500,000	96.41	122.78	26.37	96.54	122.96	26.43	103.03	134.16	31.13**
$1,000,000	114.66	125.62	10.96	114.78	125.68	10.91	122.31	144.17	21.86*

* Significance at the 5% level
** Significance at the 1% level

Conclusion

This study examines the effects of reducing the minimum tick size on market quality. Using a sample of the Top 100 stocks by market capitalization traded on the Singapore Exchange, we observe that the bid-ask spreads and market depth of the affected stocks decrease significantly. Furthermore, stocks that experience a large reduction in minimum tick sizes (i.e. more price intervals) experience a larger decline in both the bid-ask spreads and depth. Regression analysis supports this conclusion and shows that after controlling for broad market movements and other exogenous factors, bid-ask spreads and market depth falls significantly for affected stocks after the reduction in minimum tick size.

Given that a simultaneous reduction in bid-ask spreads and market depth have potentially conflicting effects on transaction costs, we simulate expected market impact costs to examine the net effects of the changes, and also analyze how liquidity provision has changed. Results from the simulations indicate that for stocks in the first price band (PB1), large liquidity demanders (trades above $100,000) are likely to experience lower market impact costs (ranging from 2.12 to 14.74 basis points), while small traders are expected to experience a slight increase (between 0.35 to 3.9 basis points). These results are *not* consistent with the findings of Goldstein and Kavajecz (2000) who document that small parcels of trades tend to benefit more from a reduction in minimum tick size, as the decline in depth does not affect them to the same extent[28].

[28] Goldstein and Kavajecz (2000) show that depth on the NYSE limit order book declined throughout the book after the tick reduction from eighths to sixteenths. Bacidore, Battalio, and Jennings (2003), however, find that while displayed liquidity on the NYSE declined after decimalization, the execution quality for all order sizes did not deteriorate. They suggest that non-displayed liquidity available on the exchange floor explains this result. Bacidore et al. (2003) and Chan and Hwang (2001) point out that the results of Goldstein and Kavajecz (2000) are likely to be explained by specialists "stepping ahead of the book" more frequently after the tick size reduction. As the Singapore Exchange is an order driven market without the hidden order facility (see Aitken and Comerton-Forde, 2005), it is unlikely that these factors will distort the results.

Other than in the first stock price band, there is a general increase in market impact costs across all other stocks, both affected stocks and control stocks. Examining the results from the control group, we observed that there is an increase in market impact costs ranging from 0.13 to 31.13 basis points across the different trades size. The simulated increase in costs grows proportionately higher as the trade size increases (with the exception of trades at $1,000,000 where the costs declined compared to trades at $500,000).

In summary, we document results consistent with prior findings that the bid-ask spreads and market depth of affected stocks decrease significantly after a reduction in the minimum tick. We also find evidence that the magnitude of the decline in both bid-ask spread and market depth is proportionate to the reduction in minimum tick size. However, changes to trading activities are not related to the size of the tick reduction. Rather, we observed that market participants prefer equities where they can charge a high premium at the minimum tick (e.g. PB3) and stocks where the initial capital outlay is lower (PB2 and PB3). It is also observed that simulated market impact costs have generally increased across all groups (except large trades in PB1) which may be indicative of the adverse market condition facing stock exchanges worldwide during the sample period.

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