2012

Impact of reduced tick sizes on the Hong Kong stock exchange

Dionigi Gerace
University of Wollongong, dionigi@uow.edu.au

Ciorstan Smark
University of Wollongong, csmark@uow.edu.au

Timothy Freestone
Australian National University

Impact of reduced tick sizes on the Hong Kong stock exchange

Abstract

Purpose - The purpose of this study is to analyze the effect of the 2005 reduction in minimum tick size in the Hong Kong Stock Exchange (HKEx). The tick size is the smallest amount by which the price of any exchange traded instrument can move.

Design/methodology/approach - This study involved univariate and multivariate (regression) analysis to observe the effect of the 2005 HKEx reduction in tick size on the volume, spread and depth of the market in affected shares. Findings - The shares affected by the reduction in tick size (those valued at over HK$30) showed a significant decline in their quoted spreads, percentage spreads and quoted depth.

Originality/value - This finding supports the case that a policy of reduced tick sizes may have the effect of improving market liquidity and contributes to the literature related to minimum price increments in financial markets.

Keywords

hong, kong, stock, exchange, tick, impact, sizes, reduced

Disciplines

Business

Publication Details

Gerace, D., Smark, C. & Freestone, T. (2012). Impact of reduced tick sizes on the Hong Kong stock exchange. Journal of New Business Ideas and Trends, 10 (2), 54-71.

Journal of New Business Ideas & Trends
2012, 10(2), pp. 54-71
"http://www.jnbit.org"

Impact of Reduced Tick Sizes on the Hong Kong Stock Exchange

Dionigi Gerace
Department of Accounting & Finance
Faculty of Commerce
University of Wollongong, Australia
Email: dionigi@uow.edu.au

Ciorstan Smark
Department of Accounting & Finance
Faculty of Commerce
University of Wollongong, Australia
Email: csmark@uow.edu.au

Timothy Freestone
Australian National University, Australia

Abstract

Purpose *– The purpose of this study is to analyze the effect of the 2005 reduction in minimum tick size in the Hong Kong Stock Exchange (HKEx). The tick size is the smallest amount by which the price of any exchange traded instrument can move.*
Design/methodology/approach *– This study involved univariate and multivariate (regression) analysis to observe the effect of the 2005 HKEx reduction in tick size on the volume, spread and depth of the market in affected shares.*
Findings *– The shares affected by the reduction in tick size (those valued at over HK$30) showed a significant decline in their quoted spreads, percentage spreads and quoted depth.*
Originality/value *– This finding supports the case that a policy of reduced tick sizes may have the effect of improving market liquidity and contributes to the literature related to minimum price increments in financial markets.*

Key words: *Diversification; HKEx; SEHK*

JEL Classifications: G14; G15
PsycINFO Classifications: 3000

Introduction

In 2005 the Hong Kong Stock Exchange (HKEx) reduced the minimum tick sizes for shares priced over HK$30. The aim of the present study is to analyze the effect of this change using daily trade and quote data. The minimum tick size is the minimum price variation possible in the trading of a financial asset (Harris, 2003). The effects of a change of the minimum tick size on market quality and liquidity have drawn significant interest from academics, industry participants and exchange operators worldwide (Frino, Lepone & Wong, 2009). There has been a trend in the last 20 years for exchanges around the world toward reducing the minimum tick size (Ahn et al., 2007). This paper is the first to examine the impact of a tick-size reduction for the Hong Kong Stock Exchange.

The current paper exploits the opportunity for a natural experiment: in 2005 and 2006 the HKEx reduced the minimum tick sizes for these securities priced above HK$30. The reductions in 2005 were known as Phase 1, while those of 2006 were known as Phase 2B. This study concentrates on Phase 1. The policy implications of this study is to add to the literature on the advisability of decreasing tick sizes. This study looked at the effect of this tick size variation on the spreads, depths, and volume levels of the affected stocks.

Theoretical Background

Aitken and Comerton-Forde (2005) examined the effects of the 1995 ASX reduction in the minimum tick for stocks priced below $0.50 and above $10. They showed that the liquidity generally increased following the tick reduction, but the result wasn't universal. They found that stocks with large relative tick sizes experienced the greatest boost to their liquidity. Those stocks with small relative tick sizes and low volume, on the other hand, suffered diminished liquidity. This paper is one of the few to study the effects of such a change in a purely order-driven market, while most study it within the context of a market with market makers. This is particularly pertinent as the securities that trade on the HKEx, and are analysed in the present study, operate under a purely order-driven market (HKEx, 2009).

Ap Gwilym et al. (2005) analysed the UK Long Gilt futures market, which underwent the process of decimalisation in 1998; this article was the first to analyse the effects of a minimum tick reduction in a futures-market setting. It was also a seminal paper in that it demonstrated the impact of decimalisation within the context of an open-outcry environment, which is a different market structure to those upon which most other studies are based. Like the open-outcry environment, a purely order-driven system like that on which the HKEx operates is, these days, a relatively unusual trading platform. Ap Gwilym et al. found that after decimalisation, the spread, measured in ticks, increased, but its monetary value declined. They found that mean trade size decreased, while volume and mean daily number of transactions increased.

Ahn et al. (2007) examined the Tokyo Stock Exchange's 1998 tick reduction and its effects on liquidity. This paper was the first to study this particular event. The TSE uses a tick size that's a step function of the share price; this allows an examination of the relationship between the magnitude of the tick-size decrease and many market-liquidity indicators – most notably, the spread. The tiered-tick regime makes this paper's findings particularly pertinent to the current paper due to the HKEx's similar tick-size regime (HKEx, 2009). Ahn et al.(2007) found significant declines in both the quoted spreads and the effective spreads. This demonstrated that the tick could even be a binding constraint to the spreads in a competitive limit-order market. This is as opposed to a market with some sort of market maker that may have some monopolistic power. The spread reductions were greatest for those firms with greater tick-size reductions, greater trading activity and a higher transitory component in the bid-ask spread. Importantly, they found no evidence of an increase in volume, though investors were more aggressive in posting quotes. They concluded that price discreteness creates economic rents for the providers of liquidity and the reductions in the spreads emanates from the reduction in rents.

Alampieski and Lepone (2009) examined the effects of a minimum tick reduction within the context of a futures market. In 2006, the Sydney Futures Exchange (SFE) halved the minimum price increment in three-year futures contracts. While there have been a myriad of papers discussing the effects of a minimum price-increment reduction on equities markets, there has been little research on futures markets. They found that after the change the quoted depth (both at the inside quotes and throughout the whole limit-order book) was reduced significantly, as were the quoted bid-ask spreads, although volume and volatility were unaffected. They also found that execution costs reduced after the change, with large institutional orders experiencing the largest reduction, suggesting that spread reduction dominates depth reduction. They concluded that a tick-size decrease improves liquidity and decreases execution costs in a futures-market setting.

Hypotheses 1 and 3 have been adapted from Aitken and Comerton-Forde (2005). In formulating these hypotheses, they were testing Harris's (1994) hypotheses. Hypothesis 2 is a natural extension of Hypothesis 1. Hypothesis 4, meanwhile, is a prediction made in Harris (1994). Finally, Hypothesis 5 is deduced from Alampieski and Lepone (2009).

Hypotheses and Research-question Development.

Harris (1994) suggests that there are two primary reasons why the bid-ask spread will decline following a reduction in the minimum tick size. First, if the initial minimum tick size is a binding constraint on the bid-ask spread, reducing the minimum tick size allowable will reduce the actual observed spreads. This is simply because the minimum tick size is by definition the lowest possible spread; hence the alternative name for minimum tick: minimum spread. Second, even if the initial minimum tick isn't a binding constraint on the actual spread, spreads may still decrease, as investors can now place limit orders at tighter prices that were previously unavailable. With the removal (or at least reduction) of this artificial ceiling on the spread, traders now have the choice to quote as they wish (presumably more optimally), which will result in a narrower spread for the stocks affected. This will be the case in a competitive, order-driven market such as the HKEx (HKEx, 2009). The percentage bid-ask spread will follow the same trend.

Hypothesis 1: *Following the minimum tick reductions there will be a reduction in both the quoted and percentage bid-ask spreads of the affected stocks.*

Seppi (1997) notes that as the price grid becomes finer (i.e.: if the minimum tick decreases), the depth will diminish. The minimum spread is considered a trading cost to liquidity demanders, and is a premium received by liquidity suppliers (Harris, 2003). If the bid-ask spread, as predicted above, is decreased after the minimum tick reduction, this will lead to a reduction in the premium paid to liquidity suppliers. In the case of the HKEx this means a decrease in premiums paid to limit-order traders, as the HKEx is an order-driven market (HKEx, 2009).

The reduced spread in conjunction with the reduced depth is a result of an upward-sloping liquidity supply curve (Bessembinder, 2003). In other words, the marginal profitability of supplying liquidity will decrease with a decreased spread, and hence liquidity providers will decrease their quantity supplied (Chakravarty, Harris & Wood, 2001). Chakravarty, Harris and Wood (2001) also advise that as the spread decreases, the quote is more likely to become stale, which increases the 'free option' embedded in a limit order. This is a cost to liquidity suppliers and therefore another reason to expect less depth.

Exactly how depth will be reduced is not immediately clear. In an attempt to maintain their premium, those who post limit orders may now move them further from the best prices, where the spread will be wider. This will decrease the depth at the best prices (Aitken & Comerton-Forde, 2005). Liquidity suppliers could also quote the same amount at the new, narrower spread and at the previous prices, meaning cumulative depth is unaffected. They could even leave the market completely (Goldstein & Kavajecz, 2000). Also, as the cost of demanding liquidity (the bid-ask spread) has been reduced, impatient investors may use market instead of limit orders (Aitken & Comerton-Forde, 2005).

Harris (1994) explains that depth may be decreased because the cost of front-running a large displayed order will have decreased. The minimum tick is the amount a trader has to pay in order to gain price-precedence. If a trader wishes to move to the front of the buy-side order queue, they must improve on the current best bid by at least one tick size. If the trader were only to match the current best bid, their buy order would be second in the order queue, as clearly it would have been entered after the existing best bid. In a market such as the HKEx, where time-precedence is enforced, the minimum tick size provides protection against quote matchers and front-runners.

Finally, Anshuman and Kalay (1998) posit that as the tick size decreases, the likelihood of a liquidity supplier trading with an informed trader increases, and this leads to their posting fewer limit orders and hence decreasing depth. In any case, the analysis of this study concentrates on the depth at the best prices, not on cumulative depth.

Hypothesis 2: *Following the minimum tick reductions there will be a reduction in the depth at the inside quotes of the affected stocks.*

Harris (1994) suggests that if transaction costs decrease (due to a decrease in the bid-ask spread), the volume traded should increase, as volume is, in part, determined by transaction costs. The spread is considered a transaction cost paid by liquidity demanders to liquidity suppliers (Harris, 2003). Harris (1994) explains that in the sense that the profit of a liquidity supplier is a rough function of the spread multiplied by the volume, this increase in volume may offset the per-share profit decline of liquidity suppliers that emanates from the decreased spread. Harris (1994) regresses volume on (amongst other variables) the relative spread, and finds the coefficient of the relative spread to be significantly negative. Ap Gwilym, McManus and Thomas (2005) postulate that an increase in negotiation costs due to the now-finer price grid may counteract the decrease in transaction costs and lead to no net effect on volume.

The majority of empirical papers have documented the fact that volume actually does not increase after a tick reduction. For instance, Ahn et al. (1998) and Huson, Kim and Mehrotra (1997) both report no increase in volume after the reduction of the minimum tick size to $0.05 on the Toronto Stock Exchange. Also, Bacidore et al. (2001) and Harris et al. (2001) show that there was no increase in volume traded on American exchanges following decimalisation. Ahn et al. (2007) finds no increase in volume on the Tokyo Stock Exchange following the 1997 tick reduction. Meanwhile, Ahn et al. (1996) and Crack (1994) report large increases in volumes following the 1992 minimum tick reductions on the American Stock Exchange. Pruitt, van Ness and van Ness (2000) study the American exchanges' move to $1/16^{ths}$ and find an increase in volume on the NYSE, but no change in volume on the AMEX and the NASDAQ. The conflicting evidence surrounding the effects on volume is noted, while the third hypothesis is as follows:

Hypothesis 3: *Following the minimum tick reductions there will be an increase in the volume traded for the affected stocks.*

Schwartz (1993) defines volatility simply as the tendency for prices to change unexpectedly. Harris (1994) does not indicate that volatility will increase or decrease after a minimum tick reduction, but does argue that limiting prices to certain discrete levels with a non-zero minimum tick causes volatility, because prices tend to differ at least somewhat from their fundamental value. This is because the fundamental value may deviate from the closest price increment. The thinking, then, is that a reduction of the minimum tick size will lower volatility. However, the degree to which the price can differ from its fair value due to discrete pricing rules is minimal. Conversely, Bennemark and Chen (2007) point out that if, following the tick reduction, depth decreases as expected, this may increase volatility as traders move further down the order book to complete their desired transaction.

Tinic (1972), Hamilton (1976) and Benston and Hagerman (1974) all find a direct relationship between spread and risk. Volatility is, of course, a common measure of risk in finance (Bodie, Kane & Marcus, 2009). More-volatile stocks will have wider spreads due to liquidity suppliers' risk aversion (Harris, 1994). But the causation does not appear to run in the other direction; therefore, if decreased spreads are observed, this should not necessarily lead to a change in volatility in the same way that decreased spreads lead to a reduction in depth. Alampieski and Lepone (2009), Chakravarty, Harris and Wood (2001) and Bacidore (1997) all report no change in the volatility of the affected stocks following minimum-spread reductions. Different proxies for volatility were used in their research, two of which are employed in the present paper.

Hypothesis 4*: Following the minimum tick reductions there will be no change in the volatility of the affected stocks.*

An issue with prior studies showing declines in both spreads and depth is determining which has a greater impact on liquidity. We estimate the price impact of trades before and after the change in tick size to examine the overall change in liquidity to check whether the execution costs decrease significantly.

Hypothesis 5*: Following the minimum tick reductions there will be a decrease in the execution costs of the affected stocks.*

Institutional Details

The Hong Kong Stock Exchange (HKEx) (also known as SEHK) is the third-largest stock exchange in Asia in terms of market capitalisation. Since October 2000, the HKEx has operated under AMS/3, the third generation of the Automatic Order Matching and Execution System. It is a fully automated and electronic order-book platform that aims to connect varying market participants in an efficient manner. Investors are able to place trading requests electronically, with these requests being automatically delivered to brokers for approval and submission to the central market. From here the orders can be matched, and, hence, trades generated. AMS/3 aims to benefit market participants by allowing them to place orders anytime and anywhere. For example, orders can be placed over the internet and using mobile phones (HKEx, 2009). The order book used in the system on the HKEx is a relatively transparent one, which displays depth to the fifth level for all investors (Pavabutr et al., 2009).

The HKEx is a predominantly order-driven market: its trading system is AMS/3, as noted above. There are no market makers on the HKEx, with the exception of securities traded under the Pilot Programme, some derivatives and exchange-traded funds. Briefly, the Pilot Programme includes securities listed on the NASDAQ and the AMEX, and are admitted into the HKEx for trading only – they have no actual public offering in Hong Kong (HKEx, 2009). This paper considers only ordinary shares listed on the Main Board of the

HKEx; thus, the presence of market makers in the few aforementioned securities will not impinge on the analysis of this paper. The absence of market makers in the trading of the securities analysed provides an excellent opportunity to examine the effects of a minimum-tick reduction on equities that are trading in what is essentially a purely order-driven market. Many other papers investigating the same topic consider the change within the context of a quote-driven market: for example, Bollen and Whaley (1998), Goldstein and Kavajecz (2000) and Ricker (1998) all study the New York Stock Exchange's change to sixteenths in 1997.

The order-precedence rules on the HKEx are fairly similar to those of many other order-driven markets, such as the Australian Securities Exchange and the Toronto Stock Exchange (ASX, 2003). These rules work on a price-time precedence basis: that is, price is the primary precedence, and time is the secondary precedence. The price-priority rule gives precedence to those traders who submit bids and asks at the best prices. The best price for a bid order is the highest price, while the best price for an ask order is the lowest price. The time-priority rule is used in cases of equal price, with orders ranked chronologically. (HKEx, 2009).

On 4 July 2005, the HKEx reduced the minimum trading spreads for securities priced over HK$30. This was Phase 1 in what was to be a planned series of minimum-tick reductions[1]. The implementation of Phase 1 followed market rehearsals during the weekends of 18 June 2005 and 25 June 2005 (HKEx, 2005). Securities priced under HK$30 did not experience any change in their minimum spreads during the Phase 1 reduction. For instance, before 4 July 2005, stocks priced greater than HK$2 but less than HK$5 had a minimum tick size of HK$0.025. They maintained the same tick size after this date. The minimum spreads of securities priced above HK$30 decreased by varying amounts. For instance, securities priced between HK$100 and HK$200 had a minimum spread of HK$0.50 before the tick reduction, and a minimum spread of HK$0.10 after. Stocks priced between HK$500 and HK$1000 initially had a minimum tick size of HK$1.00, which fell to HK$0.50. It should be noted that all minimum-tick changes, were reductions, with one exception: the spread for securities priced over HK$5000 increased from HK$2.50 to HK$5.00. On the date of change, no securities were priced over HK$5000. In total, 29 securities were affected by Phase 1. Only 23 of these were ordinary shares.

Data and Research Design

In order to test the effects of the HKEx's minimum-tick reductions on liquidity, a random sample of 40 stocks was collected for both events. Twenty stocks were chosen that were subject to the Phase 1 minimum-tick reduction, and hence were priced over HK$30 at the time of the Phase 1 minimum-spread reduction. These are henceforth known as the Phase 1 event stocks. Twenty stocks were chosen that were not subject to Phase 1 – in other words, were priced under HK$30 at the time of the minimum-tick reduction. These are henceforth known as the Phase 1 control stocks. The control groups used in this study are often described as a 'natural' control group (Frino, Lepone & Wong, 2009).

Only ordinary shares were included in the samples. Shares that changed groups throughout the sample period (i.e., broke the $HK30 barrier during Phase 1), that had a price change of more than 50% during the sample period, that were subject to a merger or that had more than 20% of the trading days with no volume traded were excluded. A simple time-series available from Yahoo Finance (2009) was used to conduct these exclusions, which mirror those of Harris (1994).

[1] A second phase took place on 24 July 2006 for small caps; tests have been run on the sample of affected stocks. Although these results are similar to those from the first phase, this paper focuses on phase 1 given its greater significance.

The data set is a relatively rich one, as it includes every quote entered and every trade made on the stocks in the samples. For each trade and quote the quantity and price were reported along with the RIC (to indicate which security it was). The trades and quotes were time-stamped. The data was sourced from the Reuters Datascope Tick History (RDTH, 2009)[2]. The quote data was filtered to remove erroneous quotes, as well as those with missing values and negative spreads. Transaction prices were also filtered for potential errors, along the lines of Chakravarty, Harris and Wood (2001).

The data collected for Phase 1covers 3 January 2005 to 6 January 2006, which basically straddles the minimum-tick reduction implementation date of 4 July 2005. As tradingwas not conducted on weekends or holidays, the total sample consists of 119 days before and after the date of the minimum-tick reduction. The main results of Phase 1 found in the current study, however, are based on a four-month sample from 4 July to 2 September 2005. Again, due to holidays and weekends, this sample amounts to a total of 40 days across the pre- and post-reduction periods. The rest of the year-long sample is then used to test the robustness of the results based upon the four-month sample. (Section 4.4 gives the results of these robustness tests.) A further robustness test, not reported, involves excluding the week of data that immediately straddles the implementation date, after the examples of Goldstein and Kavajecz (2000) and Aitken and Comerton-Forde (2005). This aims to allow for the time participants took to adjust their behaviour to the tick reduction. Finally, a very short sample of 10 days that straddles the Phase 1 tick reduction is also reported to illustrate how rapidly the market participants responded to the minimum-tick reduction.

To examine the effects of the minimum-tick reduction on the liquidity of the affected stocks, the following variables are calculated: quoted bid-ask spread, percentage bid-ask spread, quoted depth, logarithm of quoted depth, volatility and volume traded. With a complete data set of intraday activity, the data is summarised into daily averages, which smooths the data and allows a more effective comparison of stocks that may have been thinly traded (Di Marco, 2007). An arithmetic average for each of the liquidity variables is calculated on a daily basis for all 40 stocks in the sample. For each liquidity variable, the values are then averaged across all stocks in each group (control group and event group) on a pre- and post-reduction basis. Each stock is given an equal weighting in the calculation of these averages. T-statistics and the associated p-values are then calculated for each variable to determine whether or not they altered significantly in either the event group or the control group following the reduction. If any significant changes are found in the variables of the event group, the control group (assuming it shows no such significant changes) potentially allows us to infer that these changes resulted from the reduction, and not some exogenous or market-wide factor.

Quoted spread = ask price – bid price **(5.1)**

Percentage bid-ask spread =
(ask price – bid price)/quote midpoint **(5.2)**

Quoted depth = (bid size + ask size) **(5.3)**

Logarithm of quoted depth = log (quoted depth) **(5.4)**

Volatility = $\sigma_x = \sqrt{\frac{1}{n-1}\sum_{j=1}^{n}[r(s)-\bar{r}]^2}$ **(5.5)**

Volume = total volume traded **(5.6)**

Dummy = $D_t = \begin{cases} 0 \text{ if observation falls before 4/7/05} \\ 1 \text{ if observation falls after 4/7/05} \end{cases}$ **(5.7)**

[2] This database was known as TAQTIC until July 2009 (Dhaliwal 2009).

Table 1, below, displays a snapshot of the time-series of cross-sectional averages of the liquidity variables calculated for Phase 1. Averages reported for both the control group and the affected (event) group form the statistical basis upon which the univariate and multivariate analysis of Phase 1 is conducted. A number of empirical papers, such as Aitken and Comerton-Forde (2005), Goldstein and Kavajecz (2000), Bennemark and Chen (2007) and Porter and Weaver (1997), further partition their sample into groups based on volume. Harris (1994) hypothesises that the reduction of the minimum-tick size would have the greatest impact on spreads where the minimum-tick size is a binding constraint on the actual spread. The tick is more likely to act as a binding constraint on the spread for high-volume stocks (found also by Goldstein & Kavajecz, 2000).[3] While the univariate analysis of the current paper does not control for volume, this is mitigated somewhat by the inclusion of regression analysis that includes volume as both a dependent and an independent variable.

The control group in an experiment should be exactly identical to the experimental group, except for the variable being tested (Neuman, 2006). For this study, the only difference between the event and control groups, ideally, would be whether or not the group had been subject to the minimum trading spread reduction. Unfortunately, this is not the case. By their very nature, the minimum-tick reductions were conducted on the basis of price. Only high-price stocks were subject to the Phase 1 reduction, while only low-price stocks were not subject to it. Had the HKEx randomly reduced the minimum-tick sizes of some shares, it would have been possible to formulate an ideal control group. So, to the extent that the price itself may affect the liquidity of a stock, studying only Phase 1 would have meant not controlling for the effect of price level[4]. The authors randomly select a group of ordinary shares priced under HK$30 as at 4 July 2005, and therefore not subject to the minimum-tick reduction, as a natural control group.

Table 1 provides a sample of the time series of cross-sectional averages calculated for the Phase 1 reduction. Averages are reported for both the control group and the affected group. The liquidity variables used in this report are shown below. Date '0' is 4 July 2005, which was the date of the Phase 1 minimum-tick reduction. Day +1 represents 5 July 2005 and so on. While a year of data was collected, the main results of this report are based upon a four-month event window that straddles 4 July 2005. As there is no trading on weekends, this four-month sample consists of 40 trading days either side of 4 July 2005. Hence this table shows a snapshot of the beginning, middle and end of the data that formed the main results for the Phase 1 reduction.

[3] Because only 23 ordinary shares were affected by the Phase 1 change, any results obtained using these researchers' methodologies would not have been powerful due to the lack of degrees of freedom.
[4] An examination of both Phase 1 and Phase 2A can largely control for this effect. Phase 2A allows for the establishment of a particularly good natural control group, as shares under HK$2 and over HK$20 can be used; this permits better control for price level.

Table 1.
Cross-Sectional Average Sample

Date	*BAS (HK$)*	*PBAS*	*Depth*	*L_depth*	*SD of returns*	*Volume*
Event Stocks:						
-40	0.290954	0.4035%	300 225	10.42308	0.055074	3 297 616
-39	0.295838	0.3964%	311 932	10.29153	0.020458	2 505 335
-38	0.311222	0.4449%	247 486	10.09605	0.022996	2 596 617
-2	0.321792	0.4339%	340 445	10.28456	0.015061	4 279 732
-1	0.371144	0.4597%	308 174	10.13077	0.029484	4 939 750
0	0.22326	0.3033%	44 991	8.935578	0.023895	2 913 144
+1	0.216578	0.4707%	38 578	8.829488	0.024019	2 304 340
+2	0.207557	0.2812%	38 805	8.933458	0.016819	2 294 594
+38	0.206193	0.2595%	20 921	8.694579	0.023505	3 501 193
+39	0.200998	0.2772%	23 453	8.590255	0.017607	3 151 967
+40	0.214759	0.3419%	18 678	8.431814	0.031888	3 308 951
Control Stocks:						
-40	0.046522	1.0339%	847 883	11.38534	0.018235	8 834 787
-39	0.04574	1.0867%	781 242	11.20173	0.025332	5 580 264
-38	0.04825	1.0988%	601 786	11.18317	0.027074	7 771 993
-2	0.047379	1.2428%	874 296	11.41273	0.027512	11 257 252
-1	0.046121	1.145%	890 526	11.2591	0.02811	8 025 950
0	0.047021	1.0969%	483 189	11.06236	0.031058	7 115 465
+1	0.048523	1.2127%	673 343	11.22679	0.028549	10 937 314
+2	0.051491	1.3178%	662 413	10.78571	0.026069	9 065 767
+38	0.048831	1.0737%	689 206	11.01114	0.038699	13 152 450
+39	0.051938	1.01%	631 666	10.84949	0.018869	10 787 524
+40	0.055476	1.373%	672 469	10.87087	0.028746	10 912 855

Univariate Results

Univariate analysis provides basic descriptive statistics (reported in Table 2). For each variable the pre-tick reduction mean, post-tick reduction mean and percentage change between the two means is calculated and reported. The standard errors are also calculated. T-statistics, which allow us to test how the variables of both the control and event groups changed post-reduction, are calculated. If there was a change in a variable's average from pre- to post-reduction, the p-values report whether the change was statistically significant. The t-stats test the hypothesis that the change between the two periods in the given variable was zero.

The average spread for the event stocks fell from HK$0.3315 to HK$0.1770. This represents a 46.61% decrease. This reduction is significant at the 1% level – in fact its p-value is less than 0.0001. Meanwhile, the average pre-tick reduction and post-tick reduction spreads for the control stocks were HK$0.0513 and HK$0.0503, respectively. This is a decrease of 1.95%, whichis not significant at the 10% level; this indicates that the reduction in average spreads in the event stocks was caused by the minimum trading-spread reduction, not other factors. The percentage bid-ask spread is found to have decreased on average after the reduction in the minimum spreads, but only for the event stocks. The average percentage spread for the event stocks was 0.4670% and 0.2538% before and after the reduction, respectively. This represents a 45.65% decrease in the proportional spread, which is significant at the 1% level. The average percentage spread for the control stocks was 1.2034% before and 1.1518% after the reduction. This change in the control stocks is not significant at the 10% level, suggesting that the reduction in the average percentage spread of the event stocks resulted from the Phase 1 reductions. These findings are expected and support both Harris's (1994) predictions and a myriad of empirical papers' findings. It is not surprising that the average quoted spread is much more for the event sample than for the control sample: the event stocks are higher priced (>HK$30), while the controls are cheaper (<HK$30). Graph A.1 in Appendix 1 illustrates the BAS of both samples around the time of the Phase 1 reduction, clearly showing a decrease in the BAS of the event sample and little change in that of the control sample.

The average depth for the event stocks fell from 332 803 to 28 109. This is a huge decrease of 91.55%.This reduction is significant at the 1% level. The control sample's depth fell from 790 532 to 600 902 following the tick reduction. This is a fall of 23.99%. However, this decrease is not significant at the 10% level. This suggests that the decrease in the event stocks' depth resulted from the minimum-tick reduction.

The volume in the pre-implementation period was 55 285 997, while in the post-implementation period it was 64 736 205. This represents an increase of 17.09%, which is statistically significant only at the 10% level. The control stocks, however, also experienced an increase in volume traded. The volume of the controls was 168 286 372 and 233 879 482 pre- and post-reduction, respectively. This increase is significant at the 5% level. This finding suggests that the traded volume of the event stocks may not have been augmented due to the minimum-tick reduction, but instead may have resulted from market-wide factors.

The average standard deviation of the returns in the pre-tick reduction period was 2.77%, while the post-tick reduction average was 3.52%, an increase of 27.24%.This change is not significant at the 10% level. The control stocks also experienced an increase in standard deviation, with the pre-reduction average being 2.75% and the post-reduction average 3.23%. This increase is significant at the 1% level. The fact that the event stocks' standard deviation did not change significantly is in line with expectations and the empirical findings of most papers. Bessembinder (2003), though, did find a reduction in volatility for affected stocks after a reduction of minimum-tick sizes on the NYSE. However, the change in the standard deviation of the control stocks of the present study was certainly unexpected, and prompted the examination of robustness tests and larger and smaller event windows.

Table 2 presents results for the various liquidity variables. There were 20 event stocks in the sample; this constituted most of the ordinary shares that were subject to the Phase 1 minimum tick reduction – that is, those ordinary shares trading on the HKEx that were priced over HK$30 at the time of the tick reduction(4 July 2005). The control stocks are a group of randomly selected ordinary shares priced under HK$30 at the time of reduction, and were therefore not subject to it – they acted as a natural control group. There were also 20 stocks in the control group. None of the stocks changed groups during the sample period. These results are based on a sample of approximately *four months* straddling the tick reduction. The sample period was from 4 July 2005 to 2 September 2005. For each of the variables, the average represents the average over each of the stocks in the sample. Each stock had an equal weighting. The averages are then compared on a pre- and post-minimum tick reduction basis to see if there is a significant difference.

Table 2.
Phase 1 Descriptive Statistics: Pre and Post Comparison of Liquidity Variables

Variable	Pre-implementation average	Post-implementation average	Percentage change
Event Stocks:			
Quoted bid-ask spread	HK$0.3315	HK$0.1770	-46.61%***
Percentage bid-ask spread	0.4670%	0.2538%	-45.65%***
Depth	332 803	28 109	-91.55%***
Log of depth	10.12838	8.701446	-14.09%***
Standard deviation of returns	2.7737%	3.5291%	27.24%
Volume	55 285 997	64 736 205	17.09%*
Control Stocks:			
Quoted bid-ask spread	HK$0.0513	HK$0.0503	-1.95%
Percentage bid-ask spread	1.2034%	1.1518%	-4.29%
Depth	790 532	600 902	-23.99%
Log of depth	11.12208	11.13483	0.11%
Standard deviation of returns	2.7517%	3.2323%	17.47%***
Volume	168 286 372	233 879 482	38.98%**

***Significant at 1% level **Significant at 5% level *Significant at 10% level

Multivariate Results

Univariate analysis can only state what happened to variables and suggest correlations between variables. In order to infer causal relationships among the variables, regression analysis is required (Kennedy, 2008). More specifically, the regressions allow us to determine if the minimum-tick reductions *caused* any of the observed changes in the liquidity variables. Also, regression analysis allows us to control for the effects of the liquidity variables on one another. A number of regressions are run using the liquidity variables to determine the interrelations among the variables and establish causal relationships. The regressions are split up into four sets. These sets are split into pairs to allow a simpler exposition of the analysis. The following regressions are run:

$$\mathbf{BAS_t = \beta_0 + \beta_1\, Depth_t + \beta_2\, Sigma_t + \beta_3\, Dummy_t + \varepsilon_t} \quad (7.1)$$
$$\mathbf{PBAS_t = \beta_0 + \beta_1\, Depth_t + \beta_2\, Sigma_t + \beta_3\, Dummy_t + \varepsilon_t} \quad (7.2)$$
$$\mathbf{Log\_Depth_t = \beta_0 + \beta_1\, PBAS_t + \beta_2\, Sigma_t + \beta_3\, Dummy_t + \varepsilon_t} \quad (7.3)$$
$$\mathbf{Log\_Depth_t = \beta_0 + \beta_1\, BAS_t + \beta_2\, Sigma_t + \beta_3\, Dummy_t + \varepsilon_t} \quad (7.4)$$
$$\mathbf{BAS_t = \beta_0 + \beta_1\, Volume_t + \beta_2\, Sigma_t + \beta_3\, Dummy_t + \varepsilon_t} \quad (7.5)$$
$$\mathbf{PBAS_t = \beta_0 + \beta_1\, Volume_t + \beta_2\, Sigma_t + \beta_3\, Dummy_t + \varepsilon_t} \quad (7.6)$$
$$\mathbf{Volume_t = \beta_0 + \beta_1\, PBAS_t + \beta_2\, Sigma_t + \beta_3\, Dummy_t + \varepsilon_t} \quad (7.7)$$
$$\mathbf{Volume_t = \beta_0 + \beta_1\, BAS_t + \beta_2\, Sigma_t + \beta_3\, Dummy_t + \varepsilon_t} \quad (7.8)$$

Where BAS is quoted depth, PBAS is percentage bid-ask spread, Sigma is volatility and a dummy variable takes the value of 1 if the observation falls beyond the event date, and zero otherwise. The inclusion of the dummy variable reveals the extent to which the reduction in the minimum tick size altered liquidity, and allows us to assess the validity of the univariate results. The sign of the coefficient of the dummy variable in the results should be the same as that of the variable's coefficient in the univariate results.

Equations (7.1) and (7.2) use quoted spread, volatility (Sigma) and a dummy variable as explanatory variables. Equation (7.1) has the bid-ask spread as the dependent variable, while Equation (7.2) uses the percentage bid-ask spread as the dependent variable. Both equations show that the dummy variable is significant for both events at the 1% level and has the expected negative sign, in line with the univariate results. The negative sign on the dummy variable supports the univariate results: the spreads (both the quoted spread and the percentage spread) diminished following the minimum-tick reduction. More specifically, holding depth and volatility constant, the minimum-tick reduction caused a HK$0.224 decrease in the BAS of the affected stocks. Equation (7.1) of Phase 1 shows that the volatility of the stock has a p-value of 0.3063, which is insignificant and thus does not explain any change in the bid-ask spread. This result is supported by the univariate results showing no change in the volatility of the stocks following the Phase 1 implementation. This is expected, as many other empirical papers have found that volatility will not change significantly following a minimum-spread reduction.

Equations (7.1) and (7.2) show that the explanatory variable depth was a significant cause of the BAS and PBAS reductions, which is expected. The sign of the coefficient of the depth is negative, which is also expected. An increase in depth will decrease spreads because of an increase in competition among liquidity suppliers. Lee, Mucklow and Ready (1993) note the inverse relation that exists between spreads and depth, asthey widen the spread and decrease the depth in response to increased concerns surrounding trading with an informed trader, so as to control for adverse selection costs. Harris (1994) refers to this as the 'asymmetric information hypothesis'; his regression results also find a negative coefficient of depth. Harris (1994) cites Ye and Harris (1994), who also find a negative relationship between spreads and depth, as when the risk of trading with an informed trader increases, liquidity suppliers decrease size and increase spreads.

Equations (7.3) and (7.4) both regress the logarithm of quoted depth on the volatility and a dummy variable. The only difference between the two equations is that Equation (7.3) uses the percentage spread as a regressor while Equation (7.4) uses the spread. The dummy variables for both equations are significant at the 1% level and have the expected negative sign. These results support both the theory and the univariate result that the quoted depth (in this case the *logarithm* of the quoted depth) would decrease after the minimum-tick reduction. More specifically, these results suggest that after controlling for volatility and spreads, the reductions caused decreases in the depth of the stocks affected by both events. The volatility variable used in Equations (7.3) and (7.4) is not significant at the 5% level, indicating that the volatility did not cause the observed reduction in the quoted depth. Both the percentage bid-ask spread (7.3) and the bid-ask spread (7.4) are found to have caused the reduction in the depth. Harris (1994) regresses depth on the relative spread and finds this negative relationship for the reasons mentioned above. Equations (7.5) and (7.6) illustrate the negative relationship between the spread and volume.

Equation (7.5) has the bid-ask spread as the dependent variable, while Equation (7.6) uses the percentage bid-ask spread as the dependant variable. The explanatory variables for both equations are the same: volume, volatility and the dummy variable. Harris (1994) suggests that when spreads are regressed on volume the expected sign is negative. These equations support the theory. Harris (1994) explains that the spread is considered a trading cost; as per simple demand theory, as the price (in this case proxied by the bid-ask spread) decreases, the quantity demanded (proxied by volume) should increase, all other things being equal. Harris (1994) extends the analysis by saying that a minimum tick (the smallest spread possible) is more likely to be a binding constraint for actively traded stocks, and hence, high-volume stocks should experience the biggest spread reductions. This matches the results from Equations (7.5) and (7.6).

Equation (7.5) also shows that perhaps some of the decrease in the spread is caused by a decrease in the volatility of the stock. The volatility is not significant at the 10% level, but it is feasible that volatility has a causal relationship with the spread. Harris (1994) explains that a more volatile stock is indeed more likely to have a wider spread, because liquidity providers are risk-averse (and hence the spread is compensation for providing liquidity). In market microstructure theory, the spread is considered to consist of three components: inventory-holding costs, adverse-selection costs and order-processing costs (Frino & Segara, 2008). The adverse-selection costs represent the risk of trading with an informed trader (as opposed to an uninformed trader – a liquidity trader). The decreased volatility may be decreasing the adverse-selection component of the spread and hence decreasing the overall width of the spread.

Finally, the dummy variables of Equations (7.5) and (7.6) are as expected. They are both significantly negative, which supports the results of the descriptive statistics that both the bid-ask spread (7.5) and percentage bid-ask spread (7.6) decreased after the minimum-tick reduction. More specifically, after controlling for volume and volatility, the minimum-tick reduction caused a decrease in the spreads. Equation (7.7) regresses volume on volatility, percentage bid-ask spread and a dummy variable, which as usual, takes a value of 1 for after the change and 0 for before. Equation (7.8) is essentially the same as (7.7), except that it uses the bid-ask spread as an independent variable instead of the percentage bid-ask spread.

For the Phase 1 reduction both regressions have a negative coefficient for the dummy variable, which suggests that the volume traded actually decreased after the Phase 1 implementation, after controlling for spreads and volatility. For Phase 1, Equation (7.8)'s dummy variable, though, is not significant, while Equation (7.7)'s dummy is significant at the 1% level. This suggests that after controlling for PBAS and volatility, the tick reduction caused a decrease in the volume traded. The t-statistics of both the percentage bid-ask spread (7.7) and the bid-ask spread (7.8) are significant at the 1% level. Their signs are both negative, as expected. The negative signs indicate that the decrease in the spreads (both the simple spread and the percentage spread) caused an increase in the volume.

Harris (1994) posits that a decrease in the spread should lead to an increase in the volume traded because trading has now become less expensive, as the spread is considered a trading cost. This is in line with what we observe from Equations (7.7) and (7.8). The final explanatory variable in Equations (7.7) and (7.8) is volatility, again defined as the standard deviation of the daily returns. An interesting, but expected, finding of the regressions is that an increase in volatility caused an increase in volume. The coefficient of the volatility is significant at the 5% level in Equations (7.7) and (7.8) for Phase 1. Harris (1994) posits that there exists a positive relationship between trading volume and volatility, as '…high volatility is said to attract traders'. Many papers have documented a positive correlation between volume and volatility, including Crouch (1970), Epps (1975) and Westerfield (1977). Karpoff (1987) provides a good synthesis of the literature surrounding the relationship. While correlation was long ago established, only later was a causal relation between volume and volatility established. Darrat, Zhong and Cheng (2008) empirically find bi-way causality between the two variables and note that the sequential information arrival hypothesis of Copeland (1976) predicted this relationship. Results are shown in Table 3.

Execution Costs

To provide a more comprehensive assessment of the change in liquidity after the increase in minimum tick (i.e. whether the change in bid-ask spreads dominates the change in quoted depth), we calculate the price impact of executing orders. Trades are classified as buyer- and seller-initiated using the method of Ellis et.al. (2000). Each trade is classified into four mutually exclusive quartiles based on trade size. The first quartile contains the smallest 25% of trade sizes and the fourth quartile contains the largest 25% of trade sizes. Consistent with Gemill (1996), the transaction price five trades prior to the trade is used as the pre-trade benchmark, where the price impact of each trade is measured as the basis-point change from the pre-trade benchmark price to the trade price. This is averaged across each day and then across each sample period.

Panel A of Table 4 shows the results of the price-impact analysis for both the event and control stocks with a price between $HK 30 and $HK 9995 with a data window of four months around the change. There is a significant decrease in execution costs across all quartiles for the seller-initiated trades during day trading, while only the third and fourth quartiles show a significant decrease in execution costs. For purchases, execution costs for the first quartile during day trading show a significant increase of 1.74%; no significant change appears for the second quartile; the third quartile shows an average of 0.047 basis points before the tick decrease and 0.017 basis points after, a significant change; and the fourth quartile exhibits a significant decrease in price impact, from 0.0001 to -0.1 basis points. For sales, in the first and second quartiles, price impact decreases by 0.076 and 0.073 basis points respectively, while the third and fourth quartiles show a significant decrease of 0.08 and 0.126 basis points.

For one year around the change data, all four quartiles experience a decrease in execution costs for both purchase- and sell-initiated trades. On the purchase side, the first and second quartiles show significant decrease of -0.71 and -0.043 respectively; the third shows a negative change of -0.12 although insignificant; and the fourth quartile exhibits a significant decrease of -0.062. The sales side shows significant decreases in price impact: -0.037, -0.8 and 0.08 for the first, third and fourth quartiles, respectively; the second quartile shows only a minimal variation. The last column of Table 4 shows the price impact for all \ stocks in both the event and control samples, which amplifies the results given by the quartile groups. These results support Alampieski and Lepone (2009), who report a reduction in execution costs after the tick-size reduction on the SFE.

Broad market movements may be driving this reported increase in execution costs. As for the control sample with a price range between $HK 30 and $HK 9995 (similar to the event sample), there is no evidence of price impact, as all differences between the before and after samples for both event and control are nil, except for the fourth quartile on the buy side. These outcomes still hold when the sample is extended to a one-year data window around the event day.

In Table 3 Panel A presents estimates for Equations 7.1, 7.2, 7.3, and 7.4; Panel B presents estimates for Equations 7.5, 7.6, 7.7, and 7.8 as defined below. The sample size used is four months in length.

Table 3.
Regression-Equation Estimates (Four-Month Sample)

	Intercept	*BAS*	*PBAS*	*Volume*	*Depth*	*Sigma*	*Dummy*
Panel A:							
BAS	0.84**				-0.05**	-0.038	-0.22***
PBAS	0.01**				-0.001***	-0.001	-0.0001***
Volume	5,409,752***		-5.782E8***			1,508,504**	-756,786***
Depth	11.61**		-317.81***			0.44*	-2.11***
Panel B:							
BAS	0.36***			-8.59E-9***		-0.056	-0.146***
PBAS	0.01***			-154E-12***		-0.001	-0.002***
Volume	3,708,700	-2,051,791***				1,727,797**	-32.018
Depth	10.96	-2.48***				0.497*	-1.84***

****Significant at 1% Level*
***Significant at 5% level*
**Significant at 10% level*

Execution Costs

Price impact results are presented in Table 4, for the before and after the change in tick size for the event stocks with a price range between $X and $Y and the control stocks with a price range between $W and $Q. Panel A shows results for a two months before and two months after data window, where the pre-event sample period extends from 5th May, 2005 to 4th July 2005, while the post-event sample period extends from 5th July 2005 to 5th September 2005 for both the event and control sampleswhile. Panel B shows results for a six months before and six months after data window, where the pre-event sample period extends from 5th January, 2005 to 4th July 2005, while the post-event sample period extends from 5th July 2005 to 5th January 2006 for both the event and control samples. Trades are classified as buyer and seller initiated using the methodology of Ellis et al. (2000). The price impact of each trade is measured as the change from the transaction price five trades prior to the trade price. This is averaged across each day and then across each sample period. Each trade is classified into four mutually exclusive quartiles based on trade size. The first quartile contains the smallest 25% of trade-sizes and the fourth quartile contains the largest 25% of trade-sizes. Price impact is reported in basis points.

Table 4.
Execution Costs

	Quartile 1		*Quartile 2*		*Quartile 3*		*Quartile 4*		*All*	
	Buy	*Sell*	*Buy*	*Sell*	*Buy*	*Sell*	*Buy*	*Sell*	*Buy*	*Sell*
A – 4 Months Around										
Event Stocks Before	0.023	0.0195	0.0135	0.0235	0.0467	0.0111	0.0047	0.038	0.0001	0.0158
Event Stocks After	0.0404	0.0955	0.0245	0.0964	0.0172	0.0917	-0.015	0.1638	-0.01	0.0763
Difference	0.0174*	0.076**	0.011	0.0729**	-0.0295*	0.0806**	-0.197*	0.1258**	-0.0101**	0.0605**
Control Stocks Before	0.0001	0.0018	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0000	0.0055
Control Stocks After	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000
Difference	0.0001	0.0018	0.0000	0.0000	0.0001	0.0000	0.0001**	0.0000	0.0000	0.0055*
B – 12 Months Around										
Event Stocks Before	0.016	0.007	0.003	-0.004	-0.075	0.015	-0.01	0.015	-0.009	0.009
Event Stocks After	-0.69	0.044	-0.037	0.012	-0.195	0.095	-0.072	0.095	-0.247	0.054
Difference	-0.71*	0.037**	-0.043**	0.016	-0.12	0.8**	-0.062**	0.08**	-0.238**	0.045**
Control Stocks Before	-0.0007	0.007	0.0005	0.00002	0.00024	0.0000	0.0000	0.0000	-0.00012	0.002
Control Stocks After	0.00002	-0.00004	0.0004	0.00003	0.00014	0.0000	0.0000	0.0000	-0.00011	0.00001
Difference	0.00072	-0.007	-0.0001	0.00001	-0.0001	0.0000	0.0000	0.0000	0.000015	-0.002

*** Significant at less than 1%*
**Significant at less than 5%*

Robustness Tests

To control for seasonal patterns and to provide a more robust analysis of the impact of a reduction in minimum-tick size on liquidity, a year-on-year analysis is conducted. The post period is compared to the period 4 July 2004 to 4 November 2004. Descriptive statistics support the original findings, with bid-ask spreads exhibiting a significant reduction of 0.349 basis points, while the control sample shows an significant increase in spread. The decrease in depth at the best prevailing quotes and in the visible limit-order book supports earlier results. After controlling for seasonal patterns in trading, there is still no significant change in volatility, while volume is significantly greater. When controlled for seasonal patterns, results support the initial findings.

Regression results support the reduction in bid-ask spreads after the tick-size reduction, with the change dummy-variable coefficients significantly negative. The move to a reduction of spread is associated with significantly lower depth levels (both best and visible). A comparison of execution costs of institutional trades between the post period and the period 4 July 2004 to 4 November 2004 supports the findings of the improvement in execution quality from the traditional pre-post analysis. For both purchases and sales, all quartiles experience a statistically significant reduction in execution costs, consistent with earlier findings.

Conclusion

The key findings of this study were that stocks that were subject to the minimum tick reduction experienced a significant decrease in both the quoted and percentage spreads; a significant decrease in the depth at the inside quotes; no alteration in the volatility of the stocks affected by the reduction; and no increase in volume.The impact of a reduction in minimum price increment in financial markets draws considerable attention from academics and market practitioners. The majority of research in this area is centred on equities markets; however, evidence from this research is mixed. Actively traded securities generally benefit from a lower tick size, whereas liquidity in infrequently traded instruments is adversely affected by a tick-size reduction. Several studies find that execution costs for institutional investors are lower, whereas other studies find significant increases in trading costs. The single study in order-driven markets like the Hong Kong Stock Exchange provides inconclusive evidence as to the impact on liquidity. Results indicate that bid-ask spreads are significantly reduced after the change. Quoted depth, both at the best quotes and visible in the order book, is significantly lower after the tick reduction. While trading volume is increased, price volatility is not significantly affected. Execution costs are reduced after the change, with large institutional buy and sell orders experiencing the most significant reduction. This suggests that the reduction in bid-ask spreads dominates the reduction in quoted depth. These results are robust to seasonal patterns and to trading in substitute contracts. We conclude that a tick-size reduction improves liquidity in this setting.

Reference List

Ahn, H., Cai, J., Chan, K & Hamao, Y. (2007). Tick size change and liquidity provision on the Tokyo Stock Exchange, *Journal of Japanese International Economies*, 21(2), 173-194, ScienceDirect, accessed 14/7/09, http://www.sciencedirect.com/

Ahn, H., Cao, C., & Choe, H. (1996). Tick size, spread and volume, *Journal of Financial Intermediation*, 50(1), 2-22, ScienceDirect, accessed 22/6/09, http://www.sciencedirect.com/

Ahn, H., Cao, C., & Choe, H. (1998). Decimalization and competition among stock markets: evidence from the Toronto Stock Exchange cross-listed securities, *Journal of Financial Markets*, 1(1), 51-87, ScienceDirect, accessed 22/6/09, http://www.sciencedirect.com/

Aitken, M. & Comerton-Forde, C. (2005). Do reductions in tick sizes influence liquidity?, *Accounting & Finance*, 45(2), 174-184, Wiley InterScience, accessed 1/4/09, http://www.interscience.wiley.com/

Alampieski, K and Lepone, A (2009). Impact of a tick size reduction on liquidity: evidence from the Sydney Futures Exchange, *Accounting & Finance,* .49(1), 1-20, Wiley InterScience, accessed 13/3/09, http://www.interscience.wiley.com/

Anshuman, VR and Kalay A (1998). Market Making with Discrete Prices, *The Society for Financial Studies*, 11(1), 81-109, Oxford Journals, accessed 2/12/09, http://www.oxfordjournals.org/

ap Gwilym, O, McManus, I and Thomas, S (2005). Fractional Versus Decimal Pricing: Evidence from the UK Long Gilt Futures Market, *The Journal of Futures Markets*, 25(5), 419-442, Wiley InterScience, accessed 15/4/09, http://www.interscience.wiley.com/

ASX (2003). ASX Market Reforms – enhancing the liquidity of the Australian equity market, accessed 29/10/2009, http://www.asx.com.au/about/pdf/ASX_MARKET_REFORMS.pdf

Bacidore, J (1997). The Impact of Decimalization on Market Quality: An Empirical Investigation of the Toronto Stock Exchange, *Journal of Financial Intermediation*, 6(2), 92-120, accessed 4/7/09, Social Science Research Network, http://www.ssrn.com/

Bacidore, J (2001). Decimalization, adverse selection, and market maker rents, *Journal of Banking & Finance*, 25(5), 829-855, ScienceDirect, accessed 16/6/09, http://www.sciencedirect.com/

Bennemark, K and Chen JF (2007). Does Tick Size Matter? – Evidence from the Stockholm Stock Exchange, MFin thesis, Stockholm School of Economics, Stockholm, Sweden, accessed 01/10/09, http://www.uppsatser.se/uppsats/aa55da20ca/

Benston, GJ and Hagerman, RL (1974). Determinants of bid-asked spreads in the over-the-counter market, *Journal of Financial Economics*, 1(4), 353-364, ScienceDirect, accessed 27/7/09, http://www.sciencedirect.com/

Bessembinder, H (2003., Trade Execution Costs and Market Quality after Decimalization, *Journal of Financial and Quantitative Analysis*, 38(4), 747-777, Cambridge Journals, accessed 5/5/09, http://journals.cambridge.org/

Bodie, Z, Kane, A and Marcus AJ (2009). *Investments*, 8th edn, McGraw-Hill Irwin, New York, New York, USA.

Bollen, NPB and Whaley, RE (1998). Are "teenies" better?, *Journal of Portfolio Management*, 25, 10-24, accessed 28/10/09, http://www2.owen.vanderbilt.edu/nick.bollen/

Chakravarty, S, Harris, S and Wood, R (2001). Decimal Trading and Market Impact, Working Paper no. 1154, Purdue University, accessed 15/5/2009, http://ideas.repec.org/s/pur/prukra.html

Copeland TE, (1976). A Model of Asset Trading under the Assumption of Sequential Information Arrival, *The Journal of Finance*, 31(4), cited in Darrat, AF, Zhong, M and Cheng, LTW 2008, 'Intraday volume and volatility relations with and without public news', *Journal of Banking and Finance*, vol.31, no.9, pp2711-2729, ScienceDirect, http://www.sciencedirect.com/

Crack, TF (1994). Tinkering with ticks: choosing minimum price variation for U.S. equity markets, Working Paper, Massachusetts Institute of Technology, Cambridge, accessed 16/5/09, http://www.kelleyschool.com/files.htm

Crouch, RL (1970). A Nonlinear Test of the Random-Walk Hypothesis, *American Economic Review*, 60(1),199-202, cited in Karpoff, JM 1987, 'The Relation Between Price Changes and Trading Volume: A Survey', *The Journal of Financial and Quantitative Analysis*, vol.22, no.1, pp109-126, JSTOR, accessed 1/12/09, http://www.jstor.org/

Darrat, AF, Zhong, M and Cheng, LTW (2008). Intraday volume and volatility relations with and without public news, *Journal of Banking and Finance*, 31(9), 2711-2729, ScienceDirect, http://www.sciencedirect.com/

Dhaliwal, B (2009). *TaqTic is now Reuters Datascope Tick History*, blog, accessed 15/8/09, http://blogs.ntu.edu.sg/library/business/index.php/2009/07/taqtic-is-now-reuters-datascope-tick-history/

Di Marco, EM (2007). An Empirical Study of Market Manipulation Cases in the Australian Stock Market, Honours Thesis, University of Wollongong.

Ellis, K., Michaely, R., O'Hara, M., (2000). The Accuracy Of Trade Classification Rules: Evidence From Nasdaq, *Journal of Financial And Quanitative Analysis* 35, 529 – 552.

Epps, TW (1975). Security Price Changes and Transaction Volumes: Theory and Evidence, *American Economic Review*, 65(4), 586-597, cited in Karpoff, JM 1987, 'The Relation Between Price Changes and Trading Volume: A Survey', *The Journal of Financial and Quantitative Analysis*, vol.22, no.1, pp109-126, JSTOR, accessed 1/12/09, http://www.jstor.org/

Frino, A and Segara, R (2008). *Trade Execution Arbitrage and Dealing in Australia,* Pearson, Camberwell, Australia.

Frino, A, Lepone, A and Wong JB (2009). The Effects of Reducing the Minimum Tick on Market Quality, research sponsored by Sydney Futures Exchange, accessed 25/9/2009, www.sirca.org.au/files/files/Papers/Paper6.pdf

Gemmil, G. , (1996). Transparency and Liquidity: A Study of Block Trades in The London Stock Exchange Under Different Publication Rules, *Jounal of Finance* 51, 1765 – 1790.

Goldstein, MA, Kavajecz, KA (2000). Eights, sixteenths, and market depth: changes in tick size and liquidity provision on the NYSE, *Journal of Financial Economics,* 56(1), 125-149, ScienceDirect, accessed 14/5/09, http://www.sciencedirect.com/

Hamilton, JL (1976). Competition, scale economies, and transaction cost in the stock market, *Journal of Financial and Quantitative Analysis*, 11(5), 779-802, Cambridge Journals, accessed 11/8/09, http://journals.cambridge.org/

Harris, J, Smith, J and Wu, S (2001). The impact of decimalization on the Nasdaq stock market, Final report to the SEC, accessed 12/4/09, http://www.sec.gov/

Harris, LE (1994). Minimum Price Variations, Discrete Bid-Ask Spreads, and Quotation Sizes, *The Review of Financial Studies,* 7(1), 149-178, JSTOR, accessed 22/3/09, http://www.jstor.org/

Harris, LE (2003). *Trading and Exchanges*, Oxford University Press, New York, New York, USA.

HKEx (2005). *HKEx Sets Date for Reduction of Minimum Trading Spreads for Shares Trading Above $30 and Changes in AMS/3 Trading Parameters*, media release, accessed 13/3/09, http://www.hkex.com.hk/news/hkexnews/2005.htm

HKEx (2009). *Investors Education – FAQ*, accessed 18/11/09, http://www.hkex.com.hk/invedu/faq/faqhkex.htm

Huson, M, Kim, Y and Mehrotra, V (1997). Decimal quotes, market quality, and competition for order flow: evidence from the Toronto Stock Exchange, Working Paper, University of Alberta, Alberta, Canada, accessed 12/7/09, http://www.business.ualberta.ca/Departments/FMS/ResearchCentres/FinanceWorkingPapers.aspx

Karpoff, JM (1987). The Relation Between Price Changes and Trading Volume: A Survey, *The Journal of Financial and Quantitative Analysis*, 22(1), 109-126, JSTOR, accessed 1/12/09, http://www.jstor.org/

Kennedy, PK (2008). *A Guide to Econometrics*, 6th edn, Blackwell Publishing, Carlton, Australia.

Lee, CMC, Mucklow, B and Ready MJ (1993). Spreads, Depths, and the Impact of Earnings Information: An Intraday Analysis, *The Review of Financial Studies*, 6(2), 345-374, Oxford Journals, accessed 21/11/09, http://www.oxfordjournals.org/

Neuman, WL (2006). *Social Research Methods – Qualitative and Quantitative Approaches*, 6th edn, Pearson Education, Boston, Massachusetts, USA.

Pavabutr, P, Thammasat, B and Tian, G (2009). Liquidity Provision in Asian Equity Markets, Working Paper, University of Bangkok and University of New South Wales, accessed 30/10/2009, http://www.postf.org/upload/200931915537138_1.pdf

Porter, DC and Weaver, DG (1997). Tick Size and Market Quality, *Financial Management*, 26(4), 5-26, Proquest, accessed 17/10/09, http://www.proquest.com/en-US/

Pruitt, SW, van Ness, BF and van Ness RA (2000). The Impact of the Reduction in Tick Increments in Major US Markets on Spreads, Depth, and Volatility, *Review of Quantitative Finance and Accounting*, 15(2), 153-167, SpringerLink, accessed 4/11/09, http://www.springerlink.com/

Reuters Datascope Tick History (2009), accessed 29/9/09-26/11/09, https://tickhistory.datascope.reuters.com/DataScope/login.jsp

Ricker, JP (1998). Breaking the eighth: sixteenths on the New York Stock Exchange, Working Paper, San Francisco University, Social Science Research Network, accessed 1/11/09, http://www.ssrn.com/

Schwartz, R (1993). *Reshaping the Equity Markets – A Guide for the 1990s*, Business One Irwin, New York, New York, USA.

Seppi, DJ (1997). Liquidity Provision with Limit Orders and a Strategic Specialist, *The Review of Financial Studies*, 10(1), 103-150, Oxford Journals, accessed 1/12/09, http://www.oxfordjournals.org/

Tinic, SM (1972). The economies of liquidity services, *Quarterly Journal of Economics*, 86(1), JSTOR, accessed 28/7/09, http://www.jstor.org/

Westerfield, R (1977). The Distribution of Common Stock Price Changes: An Application of Transactions Time and Subordinated Stochastic Models, *Journal of Financial and Quantitative Analysis*, 1(5), 743-765, cited in Karpoff, JM 1987, 'The Relation Between Price Changes and Trading Volume: A Survey', *The Journal of Financial and Quantitative Analysis*, vol.22, no.1, pp109-126, JSTOR, accessed 1/12/09, http://www.jstor.org/

Yahoo Finance (2009). accessed 12/4/09-25/11/09, http://au.finance.yahoo.com/

Ye, J and Harris LE (1994). The Specialist's Optimal Quotation Strategy, Working Paper, University of Southern California, cited in Harris, LE 1994, 'Minimum Price Variations, Discrete Bid-Ask Spreads, and Quotation Sizes', *The Review of Financial Studies,* vol.7, no.1, pp149-178, JSTOR, accessed 22/3/09, http://www.jstor.org