Review of Pacific Basin Financial Markets and Policies
Vol. 11, No. 4 (2008) 591–616

Impact of Tick-Size Reduction on the Market Liquidity — Evidence from the Emerging Order-Driven Market

Tzung-Yuan Hsieh* **and Shaung-Shii Chuang†**
Department of Business Administration
National Cheng Kung University, Taiwan
1, University Road, Tainan, Taiwan 701
**tyhsieh@mail2000.com.tw*
†*sschuang@mail.ncku.edu.tw*

Ching-Chung Lin
Department of Business Administration
Kao Yuan University, Taiwan 1821
Chong-Shan Road, Lujhu Township
Kaohsiung County, Taiwan 821
cclin@cc.kyu.edu.tw

Empirical studies on the influence of tick-size reduction towards market liquidity have focused almost exclusively on quote-driven markets in developed nations, and generally their findings are based on time periods of less than one year. This work investigates the influence of tick-size reduction and the relaxations of binding-constraint probability on market liquidity in the Taiwanese stock market, an emerging order-driven market, starting on March 1, 2005. The empirical results show that the spread, depth, market liquidity, and binding-constraint probability all decrease following the tick-size reduction, especially for low-priced stocks. These results can be attributed to relaxation of binding constraints. Additionally, stocks that are frequently traded, have larger market capitalization, or have restrictive binding constraints, experience considerable declines in spread, depth, and market liquidity following tick-size reduction. Trading activity plays an important role in explaining changes in spread, depth, market liquidity, and binding constraints. Thus, tick-size reduction in the Taiwanese Stock Market can increase market efficiency and reduce the investors' trading costs.

Keywords: Binding-constraint probability; depth; market liquidity; spread; tick-size reduction.

JEL Classification: G14, G15

*Corresponding author.

1. Introduction

Tick size, which is the lowest increment to investor's quoting, is an indicator of market competitiveness (Chung *et al.*, 2004; Ap Gwilym *et al.*, 2005). Tick-size reduction can enhance the market quality, price discovery, and price competition (Harris, 1991; Ronen and Weaver, 2001). Therefore, several major exchanges have recently adjusted tick sizes to increase their competitiveness, including the Toronto Stock Exchange in April 1996, the Tokyo Stock Exchange in July 2000, the New York Stock Exchange (NYSE) in January 2001, and the NASDAQ (National Association of Securities Dealers Automated Quotations) in April 2001. The actions taken by these major exchanges show that tick-size reductions have become an important trend during the past decade. In order to bring the Taiwanese stock market into conformity with international practices and enhance its competitiveness, the Taiwan Stock Exchange Corporation (TSEC) also reduced tick sizes on March 1, 2005 in an attempt to reduce the cost of immediacy (bid-ask spread). This study takes this action by the TSEC as an opportunity to investigate the effect of tick-size reductions on market liquidity in an emerging order-driven market.

Tick size is the minimum price variation that investors can quote when trading, and thus acts as a constraint on trading price. The spread decreases following the removal of this constraint (Bourghelle and Declerck, 2004; Chung *et al.*, 2004). However, since liquidity providers derive their profits from the spread, their profits suffer following tick-size reduction. As a consequence, fewer orders are placed, which leads to reduced market depth (Bacidore, 1997; Porter and Weaver, 1997). Previous empirical studies (Harris, 1991, 1994; Biais *et al.*, 1995; Bacidore, 1997; Chordia *et al.*, 2001; Chung *et al.*, 2001; Bessembinder, 2003; Chakravarty *et al.*, 2004; Smith *et al.*, 2006) have all reported that tick-size reduction can reduce spread, but reached less uniform conclusions regarding market depth.[1] In addition, both Chung *et al.* (2004), and Bourghelle and Declerck (2004) found that stocks with greater pre-period binding constraints subsequently experienced larger declines in spread and depth. They believed this phenomenon occurred as a result of relaxations in binding constraints following the tick-size reduction.

Generally, market liquidity increases with increasing depth while spread decreases; otherwise, a conclusive answer cannot be reached regarding the

[1]By and large, they have identified an adverse effect on overall market depth. However, following a tick-size reduction in AMEX, Ahn *et al.* (1996) and Ronen & Weaver (2001) found that depth did not decrease with a decreasing spread.

effect of tick-size reduction on market liquidity. To solve the ambiguous conclusions regarding the effect of tick-size reduction on market liquidity, Bollen and Whaley (1998) took the ratio of depth to spread as a proxy of market liquidity and indicated that tick-size reduction could increase market liquidity. Despite numerous earlier studies using various measures to examine this and related questions, a conclusive answer remains elusive. Therefore, this study uses a similar proxy to measure market liquidity in an emerging order-driven market.

This study examines the influence of tick-size reduction on market liquidity for the Taiwanese stock market, focusing on the tick-size reduction implemented on March 1, 2005. Compared to previous studies, this investigation makes several valuable contributions to the existing literature. First, numerous studies have examined the influence of tick-size reduction on developed quote-driven markets, but less research has been conducted for order-driven markets (Lau and McInish, 1995; Chan and Hwang, 2001), especially in emerging markets.

Second, although this study pursues the same goals as Chung *et al.* (2004), namely examining the determinants of spread, depth, and binding-constraint probability, Chung *et al.* failed to identify any of the long-term effects of tick-size reduction owing to a study period of just two months. Investors need more time to fully adjust their quoting behavior to fit the new tick-size regulations, and thus longer study periods are required for the influence of tick-size reduction on market liquidity to be fully revealed (Chung *et al.*, 2004). Additionally, stocks in emerging markets display greater synchronicity in price movement than those in developed markets, due to both herding behavior and the relatively easy price manipulation associated with less stringent regulatory scrutiny (Lee *et al.*, 1993; Chang *et al.*, 2000; Morck *et al.*, 2000). Therefore, the influence of tick-size reduction on spread and depth should be larger for the TSEC owing to the larger information asymmetry characteristic of an emerging market.

In response to the above concerns, this work attempts to achieve the following four objectives: (1) to understand the key factors that influence on the spread, depth, market liquidity, and binding constraint during the pre- and post-reduction periods; (2) to assess the influence of tick-size reduction on overall market liquidity and binding constraints; (3) to assess whether the variations in spread, depth, market liquidity, and binding constraint are influenced by pre-period stock characteristics; and (4) to examine whether the variations in spread, depth, market liquidity, and binding constraints can still be explained by the pre-period binding constraints after controlling

for the concurrent changes in stock characteristics. The main findings of this investigation are as follows.

The empirical results show that volatility and trading activity are important factors in explaining spread, depth, market liquidity, and binding constraints during both the pre- and post-reduction periods. Furthermore, the spread, depth, market liquidity, and binding-constraint probability all decreased following the 2005 tick-size reduction, consistent with the previous findings (Harris, 1994; Lau and McInish, 1995; Chan and Hwang, 2001; Chung *et al.*, 2004) no matter whether in the hybrid-driven or order-driven markets. The magnitudes of the declines in these measures are larger for stocks with low price, low risk, or larger market capitalization because the declines in binding constraints are also larger for such stocks. Moreover, frequently traded stocks also experience larger declines in spread, depth, and market liquidity owing to increased market competition. Additionally, stocks with greater pre-period binding constraints experience larger declines in spread, depth, and market liquidity following tick-size reduction, consistent with the findings of Chung *et al.* (2004). Meanwhile, the variations in these measures are also influenced by the simultaneous changes in number of trades. For example, the variations in binding-constraint probability are positively correlated with the changes in trading activity. Finally, trading activity is important in explaining the changes in spread, depth, market liquidity, and binding-constraint probability even after controlling other concurrent changes of stock characteristics. However, after controlling other concurrent changes of stock characteristics, binding-constraint probability is not important in explaining these changes, inconsistent with the results of Chung *et al.* (2004).

The remainder of this paper is organized as follows. Following the introduction, Section 2 presents the hypotheses development. Section 3 then presents data and variable measurements. Subsequently, Section 4 presents the empirical findings. Finally, Section 5 presents the conclusions.

2. Hypotheses Development

2.1. *Spread and depth*

The impact of tick-size reduction on spread is determined by whether tick size constrains the spread. Generally, if the tick-size increment exceeds the equilibrium spread, the tick size constrains the spread; otherwise, the spread remains unaffected. Although tick size does not necessarily influence spread, previous studies universally indicated a reduction in transaction

costs following tick-size reduction (Harris, 1991, 1994; Goldstein and Kavajecz, 2000; Chung *et al.*, 2001; Bessembinder, 2003; Chakravarty *et al.*, 2004; Chung *et al.*, 2004; Smith *et al.*, 2006).

Tick-size reduction reduces bid-ask spreads and enables investors to place orders at tighter spreads. Hence, investors respond to tick-size reduction by shifting their limit orders further from the best bid and ask price (Goldstein and Kavajecz, 2000), thus reducing liquidity supply as the spread shrinks. Furthermore, when uninformed traders face increased risk of losses compared to informed traders, they will attempt to protect themselves by lowering the depth of their quotes. Consequently, after tick-size reduction, liquidity suppliers will hide more of their orders to avoid quote matchers and the associated potential losses (Harris, 1994). Previous studies have indicated that tick-size reduction can reduce spread and depth (Ahn *et al.*, 1996; Goldstein and Kavajecz, 2000; Chung *et al.*, 2001; Bourghelle and Declerck, 2004). This study thus expands on this previous work by examining whether these effects of tick-size reduction on spread and depth also occur in TSEC. Hypothesis 1 is thus established as follows.

Hypothesis 1: Tick-size reduction can reduce spread and depth in TSEC.

2.2. *Binding-constraint probability*

Stock price may be constrained by tick size if the equilibrium spread is lower than the tick-size increment prior to the tick-size reduction. Spread thus can be expected to decrease following the relaxation of binding constraints. Reduced spread leads to reduced profits and thus to reduced market depth (Goldstein and Kavajecz, 2000; Gibson *et al.*, 2003). Furthermore, the magnitudes of changes in spread and depth related to distortions arising from increased tick size are positively correlated with pre-period binding constraints (Kandel and Marx, 1997). Restated, stocks with greater pre-period binding constraints are expected to experience larger declines in spread and depth (Ronen and Weaver, 2001; Bourghelle and Declerck, 2004; Chung *et al.*, 2004). Additionally, because low-priced stocks are generally more constrained by tick size (Chung *et al.*, 2004), they are expected to experience larger declines in spread and depth following the 2005 tick-size reduction. The following hypotheses are thus proposed.

Hypothesis 2: Binding-constraint probability decreases following tick-size reduction.

Hypothesis 3: Low-priced stocks experience larger declines in spread and depth than high-priced stocks.

Hypothesis 4: Declines in spread and depth are positively correlated with pre-period binding-constraint probability.

3. Data and Variable Measures

3.1. *Data*

This investigation uses intraday transaction and quote data to examine the effect of tick-size reduction on various aspects of market liquidity. The intraday data and stock characteristics used in this work are taken from the *TEJ* (Taiwan Economic Journal) database and only include common stocks. The period from March 1, 2005 to March 4, 2005 is excluded because it takes time for investors to adjust their quoting behavior in response to tick-size changes. The sample period covers a one-year window extending from September 1, 2004 to August 31, 2005. Meanwhile, the pre-reduction period (hereinafter referred to as the pre-period) runs from September 1, 2004 to February 28, 2005, while the post-reduction period (hereinafter referred to as the post-period) runs from March 7, 2005 to August 31, 2005. The pre- and post-period contain 120 and 124 trading days, respectively.

To minimize data error, various sampling criteria are used to exclude the following stocks: (1) firms experiencing delisting, stock splits, or temporary trading halts during the sample periods; (2) issues whose intraday prices (namely the highest price and lowest price) included prices that placed the issue in multiple tick-size regimes during the sample period[2]; (3) issues with fewer than 10 transactions per day[3] (Van Ness *et al.*, 2001); and (4) the spread was negative or missing. Furthermore, because the opening and closing prices were determined by batch trading, the related submission strategies may differ from those for trades during other periods (Biais *et al.*, 1999). These two observations were excluded for each trading day (Bourghelle and Declerck, 2004).

In the Taiwanese stock market, stocks in different price regimes apply different tick sizes. Based on the above exclusion criteria, the final "event group" sample that experienced tick-size reduction consisted of 192 stocks,

[2]This limitation can be used to compare the two periods when identical stocks exist in both the pre- and post-period.

[3]Bourghelle and Declerck (2004) suggested at least five trades daily, while Van Ness *et al.* (2001) proposed a minimum number of 10 trades daily to avoid infrequently traded stocks.

Table 1. Tick-size rule before and after tick-size reduction.

Regime	Price Range (NT$)		Tick size (NT$)	Relative Tick Size (Tick Size/Price Range)	
	Pre	Post		Pre (%)	Post (%)
1	0∼5	0∼10	0.01	0.20∼	0.10∼
2	5∼15	10∼50	0.05	0.33∼1.00	0.10∼0.50
3	15∼50	50∼100	0.10	0.20∼0.66	0.10∼0.20
4	50∼150	100∼500	0.50	0.33∼1.00	0.10∼0.50
5	150∼1,000	500∼1,000	1.00	0.10∼0.66	0.10∼0.20
6	1,000∼	1,000∼	5.00	0.50∼	0.50∼

*The pre-period runs from September 1, 2004 to February 28, 2005, while the post-period runs from March 7, 2005 to August 31, 2005.

which was divided into two groups. Group 1 contains stocks whose tick sizes changed from (New Taiwan Dollar) NT$0.05 to NT$0.01, while Group 2 contains stocks whose tick sizes changed from NT$0.1 to NT$0.05. According to Table 1, the relative tick size before the tick-size reduction is approximately 0.20%∼1.00%, over that of a post reduction relative tick size of approximately 0.10%∼0.50%. After making the exclusions, as detailed above, the final "event group" sample comprised 192 stocks, including 45 in Group 1 and 147 in Group 2.

This investigation examines the effect of tick-size reduction on market liquidity. However, it is difficult to distinguish whether the effects identified result from tick-size reduction or general market trends. To avoid confusion associated with other contemporaneous market trends, a control group was put together to serve as a benchmark for making comparisons with the event group. Stocks in Regime 2, which experienced no change in tick size during the study period, served as a control group.[4] After applying the above exclusion criteria, the control group (Group 3) sample comprised 25 stocks.

3.2. *Market trading mechanism*

The TSEC is an electronic order-driven market, without market makers and with individual investors accounting for the largest part (70%). The trading prices in TSEC are determined by the investors. The public limit order is in fact the only type of order in the market, which is the price-time precedence

[4]During the study periods, some stocks with prices ranging from 0∼5 experienced no tick-size change. However, this group contained only 15 firms, and the number of trades for the stocks was few. Besides, all stocks in other price ranges conformed to the above exclusion criteria.

rule, and the minimum trading units are 1,000 shares. Meanwhile, the TSEC adopts a multiple tick-size system, with the tick size different for different price ranges, positively related with the stock price. There are six tick-size regimes. The relative tick size (tick size divided by stock price) of the pre-period was between 0.20%∼1.00%, while the relative tick size of the post-period was between 0.1%∼0.5%. There are five trading days (from Monday to Friday) in a week in TSEC. The orders are fed into the computerized trading system at 8:30 a.m., but are not executed until trading begins at 9:00 a.m. The opening price is determined by the price-size precedence rule. As for the closing price, all orders are accumulated in an order book during the pre-closing period from 13:25 p.m. to 13:30 p.m., and the closing price is determined by means of a call auction at 13:30 p.m. During this trading process, the order and trading information are revealed to the public on real-time integrated terminals.

3.3. *Variable measures*

3.3.1. *Dependent variables*

This work uses percentage quoted spread[5] ($\%\,Q.S.$) and percentage effective spread[6] ($\%\,E.S.$) to measure trading cost[7] (Huang and Stoll, 2001). Furthermore, depth is measured using volume and dollar value,[8] respectively, and market liquidity is defined as the ratio of dollar depth to quoted spread. Subsequently, the percentage of quoted spreads which are equal to one tick size during the pre-period or post-period is defined as the binding-constraint probability (Ronen and Weaver, 2001; Bourghelle and Declerck, 2004; Chung *et al.*, 2004). The above measures are averaged using the trade-by-trade data to yield the daily average. Next, the daily average measures for each stock are averaged across the total number of trading days to yield the pre-period (post-period) mean for each stock. Finally, the results are averaged across stocks to obtain a final market mean.

[5]The quoted spread refers to the difference between the ask and bid quotes.

[6]The effective spread is defined as the difference between the trade price and the bid-ask price midpoint.

[7]$\%\,QS_{i,t} = 2(Ask_{i,t} - Bid_{i,t})/(Ask_{i,t} + Bid_{i,t})$; $\%\,ES_{i,t} = 2|Trade_{i,t} - (Ask_{i,t} + Bid_{i,t})/2|/((Ask_{i,t} + Bid_{i,t})/2)$; where $\%\,QS_{i,t}$ denotes the percentage quoted spread for stock i at time t; $\%\,ES_{i,t}$ represents the percentage effective spread for stock i at time t; $Ask_{i,t}$ is the ask price for stock i at time t; and $Bid_{i,t}$ is the bid price for stock i at time t.

[8]The volume depth comprises the sum of the number of shares quoted at the best bid price and the ask price, while the dollar depth comprises the sum of the number of shares times their respective prices at both the bid and ask price.

3.3.2. *Other explanatory variables*

To control for the confounding factors, the following explanatory variables[9] are included in this analysis: stock price (P), market capitalization (MV), trading volume (Vol), number of trades (T), trading value (TV), trade size in shares[10] (TS), trade size in dollars[11] (TD), and return volatility (σ). With the exception of return volatility, the stock characteristic variables are derived via a two stage process. First, the daily average for each stock is determined by averaging the daily trading closing values for each stock across the pre-period or post-period. Next, the results are averaged across stocks to obtain a final market mean. The volatility measure is defined as the standard deviation of return before or after the tick-size reduction.

Firms with large market capitalization or those that are frequently traded generally attract more attention from analysts and investors than other issues (Harris, 1994; Van Ness *et al.*, 2001). Trading information can be revealed via the market and the spread should thus be decreased owing to increased competition and information transparency. However, spread may be constrained by the tick size, especially for low-priced stocks (Chung *et al.*, 2004). Besides, less risky stocks usually have less risk premium, but stock price may be constrained by the larger tick size, leading to a larger spread. Therefore, stocks with low risk, low price, frequent trading, or large market capitalization, are expected to exhibit larger declines in spread following the relaxation of binding constraints (Goldstein and Kavajecz, 2000; Chung *et al.*, 2004). Finally, because liquidity suppliers face reduced profits after the tick-size reduction, the decreases in depth are expected to be greater for low-priced, frequently traded, large market capitalization, or low-risk stocks.

3.4. *Cross-sectional analysis*

To examine the influence of tick-size reduction on each measure, the individual measures are defined as the ratio of post-period measure to pre-period measure.[12] The influence of outliers can be reduced following a logarithmic

[9]Previous studies have listed that these variables are the major determinants of spread and depth (e.g., Harris, 1994 and Chung *et al.*, 2004). Here, the pre-period data are used to avert the endogenous problems.

[10]Trade size in shares refers to the measure that the daily share volume is divided by the number of trades.

[11]Trade size in dollars refers to the measure that the daily dollar volume is divided by the number of trades.

[12]Scale dependence across stocks can be adjusted using the ratio (Smith *et al.*, 2006).

transformation (Smith *et al.*, 2006). Therefore, Liquidity Trading Ratio (LTR) can be defined as follows.

$$LTR_i = \ln(\overline{X}_{i,\text{post}}/\overline{X}_{i,\text{pre}}), \tag{1}$$

where $\overline{X}_{i,\text{post}}$ denotes the average measure of stock i during the post-period.

This work applies the t-test to examine whether the mean of LTR is smaller than 0 or not. The mean of LTR is smaller than 0, indicating a reduction in the measure following the tick-size reduction.[13] Furthermore, if the changes of the values in control group are not significantly influenced or the declines in Group 1 exceed those in the control group, the changes in the event group can be attributed to the tick-size reduction; otherwise, the changes may result from other factors. To determine whether these changes persist in different stock characteristics, the samples are further classified into sub-samples according to the pre-period stock characteristics. If the results persist after controlling the stock characteristics, stronger support will exist for the changes resulting from the tick-size reduction. Simultaneously, a situation in which the declines in market liquidity, spread, depth, and binding-constraint probability in Group 2 still exist implies that the effect still exists in other tick-size regimes.

3.5. *Descriptive statistics of stock characteristics*

Table 2 lists the stock characteristics during the pre- and post-period. Nearly all stock characteristic values decrease in the event group, consistent with the findings of Chakravarty *et al.* (2004). For example, trading activity can be divided into daily number of trades, daily trading volume, and daily trading value. Notably, all three measures of trading activity decrease in the event group, especially for low-priced stocks. Additionally, in the event group, trade size in dollars or in shares also decreases. The above results thus demonstrate that market depth is expected to decrease in the event group. Furthermore, because the reduction in price discreteness can reduce the bid-ask bounce effect (Harris, 1991), risk and turnover rate decrease, consistent with the findings of Ronen and Weaver (2001). In contrast, following the tick-size reduction, a nearly opposite, though insignificant, trend occurs,

[13]Using the Shapiro–Wilk test or Kolmogorov–Simirnov test, this study confirms that the changes of these variables, including the stock characteristics, spread, depth, binding-constraint probability, and market liquidity, follow the normal distribution. The p-value in each measure all exceeds 0.90. Therefore, they are not significant at 1%, explaining why the results of the t-test are more appropriate than the nonparametric results.

Table 2. Descriptive statistics of stock characteristics.

		Group 1			Group 2			Group 3		
		Pre-period	Post-period	*Diff* (%)	Pre-period	Post-period	*Diff* (%)	Pre-period	Post-period	*Diff* (%)
Average stock price (NT$)	(1)	7.95	6.78	−16.26**	23.88	23.52	−2.21	11.60	12.62	9.04**
Market capitalization (in million NT dollars)	(2)	4,389.74	3,473.92	−16.11**	33,937.96	33,470.08	−1.70	6,669.37	7,052.74	8.42**
Daily trade volume (1000 shares)	(3)	3,316.39	1,791.44	−56.77**	7,394.64	5,436.41	−12.78*	2,307.83	2,821.67	28.08
Daily trade value (NT$ 1000)	(4)	29,668.82	13,149.27	−74.3**	212,016.90	155,630.00	−17.65**	30,970.77	42,198.86	37.30
Daily number of trades (trades)	(5)	491.31	302.93	−47.56**	1408.55	1119.07	−10.58**	381.81	528.70	27.92
Trade size in dollars (NT$ 1000) (4)/(5)	(6)	47.14	36.95	−23.40**	112.76	105.66	−5.52**	61.98	66.05	8.59
Trade size in shares (1000 shares) (3)/(5)	(7)	5.74	5.31	−6.56**	3.88	3.80	−1.07	4.81	4.81	0.94
Turnover rate (%)	(8)	71.25	39.64	−57.44**	92.21	79.04	−15.83**	44.40	83.09	27.23
Return volatility (%)	(9)	2.13	1.88	−13.81**	1.91	1.81	−6.67**	1.52	1.74	9.00
Sample size (n)		45			147			25		

This table lists descriptive statistics relating to stock characteristics for the event and control sample. Return volatility is measured using the standard deviation of daily return. Meanwhile, the other stock characteristics are calculated based on the daily closing value. The difference (*Diff*) is calculated as ln (post-period mean/pre-period mean). The pre-period runs from September 1, 2004 to February 28, 2005, while the Post-period runs from March 7, 2005 to August 31, 2005. Group 1 contains stocks with tick size reducing from 0.05 to 0.01. Moreover, Group 2 contains stocks with tick size changing from 0.1 to 0.05. Finally, Group 3 comprises stocks with tick size that remains constant (0.05) during the pre- and post-period.

* and **indicate significance at the 0.05 and 0.01 level, respectively.

with all the above measures increasing in the control group. On the whole, these analytical results demonstrate that some changes in spread, depth, market liquidity, and binding-constraint probability may result from changes in stock characteristics. Hence, changes in stock characteristics should thus be included in the latter regression analysis in Section 4.2.

4. Empirical Results

This section examines the effects of tick-size reduction on spread, depth, market liquidity, and binding-constraint probability. First, the descriptive statistics are discussed, and then regression analyses are performed during the pre- and post-period. Furthermore, the effects of tick-size reduction on the changes of spread, depth, market liquidity, and binding-constraint probability are also examined. Finally, after controlling concurrent changes of stock characteristics, the following discussion addresses whether the pre-period binding constraints still determine the changes in spread, depth, market liquidity, and binding-constraint probability.

4.1. *Summary statistics for spread, depth, market liquidity, and binding-constraint probability*

Section 4.1.1 presents the summary statistics on spread, depth, market liquidity, and binding-constraint probability, while Section 4.1.2 presents the summary statistics where the samples are further partitioned into sub-samples based on the pre-period stock characteristics and binding constraints.

4.1.1. *Descriptive statistics on spread, depth, market liquidity, and binding-constraint probability*

Table 3 details the changes in spread, depth, market liquidity, and binding-constraint probability, and further compares the differences during the pre- and post-period. The results demonstrate that the reductions in quoted spread in Group 1 exceed those in Group 2. As the tick size differs between the two groups, the percentage effective spread and percentage quoted spread are used to measure trading costs to avoid the influence of scale difference. The subsequent analysis thus only considers the percentage effective spread and percentage quoted spread.

Additionally, the spread decreases following the relaxation of binding constraints because stock price may be constrained by tick size during the

Table 3. Descriptive statistics of spread, depth, market liquidity, and binding constraints.

		Group 1			Group 2			Group 3			1 vs. 3
		Pre-period	Post-period	*Diff* (%)	Pre-period	Post-period	*Diff* (%)	Pre-period	Post-period	*Diff* (%)	*Diff* (%)
Q.S. (*NT$*)	(1)	0.0574	0.0308	−69.01**	0.1300	0.0819	−46.88**	0.0701	0.0645	−7.33*	−61.68**
% E.S.	(2)	0.6663	0.4053	−56.32**	0.4053	0.2670	−43.35**	0.4982	0.4341	−13.06**	−43.26**
% Q.S.	(3)	0.7220	0.4610	−51.90**	0.4480	0.3010	−42.14**	0.5608	0.4814	−14.00**	−37.90**
Dollar depth (*NTS 1000*)	(4)	1,844.15	331.80	−149.05**	10,589.38	3,805.93	−68.75**	2,161.74	1,923.37	1.07	−149.20**
Relative profit (*tick-size/price*)	(5)	6.26	1.49	−143.87**	3.5600	1.8900	−64.50**	3.99	3.70	−7.10**	−141.77**
Market Liquidity (*4*)/(*1*)	(6)	35,434.71	21,140.72	−36.41*	95,119.32	70,493.54	−8.59*	37,535.94	36,187.59	−0.39	−36.02*
Binding constraints (%)	(7)	87.35	38.53	−89.82**	83.1800	65.3900	−27.76**	69.06	77.92	19.39	−109.20**
Sample size (*n*)			45			147			25		

This table shows the descriptive statistics for the event and control sample. The *Q.S.*, *% Q.S.*, and *% E.S.* represent the quoted spread, percentage quoted spread, and percentage effective spread, respectively. The *Dollar depth* is defined as the sum of the number of shares times their respective price, including both the bid and ask price. The *Market liquidity* is defined as ratio of dollar depth divided by *Q.S.* The pre-period runs from September 1, 2004 to February 28, 2005 and the post-period runs from March 7, 2005 to August 31, 2005. Group 1 contains stocks whose tick size changed from 0.05 to 0.01. Group 2 comprises stocks whose tick size changed from 0.1 to 0.05. Finally, Group 3 contains stocks whose tick size remained unchanged (0.05) during the study period.

* and **indicate significance at the 0.05 and 0.01 level, respectively.

pre-period. Moreover, relative profits decrease following the tick-size reduction and the magnitudes of the declines in the event group are larger than those in the control group. Investors thus quote the spread at a smaller depth to avoid potential losses (Chung *et al.*, 2001). Consequently, the dollar depth[14] decreases in the event group, especially for low-priced stocks, but increases in the control group. From the above discussions, the results provide supports for Hypotheses 1 and 3, indicating that both the spread and depth decrease following the tick-size reduction, especially for low-priced stocks. The results are consistent with previous studies (e.g., Hameed and Terry, 1998).

Since the previous summary statistics indicate that trading activity decreases in the event group, as do both spread and depth, the tick-size reduction may benefit investors submitting small orders but harm traders submitting large orders, especially for low-priced stocks (Jones and Lipson 1999; Goldstein and Kavajecz, 2000). Additionally, the above result demonstrates that the control group exhibits decreased spreads but increased depths, indicating that market liquidity in the control group may increase. However, the results of the tick-size reduction for the event group show that both the spread and depth decrease, therefore, leading to ambiguous conclusions on the effect of tick-size reduction on market liquidity. To resolve this problem, this study defines market liquidity as the ratio of the depth in dollars to the quoted spread, similar to the measures used by Bollen and Whaley (1998). The analytical results demonstrate that the market liquidity decreases significantly in the event group.

Furthermore, the binding constraint probability decrease in the event group, but increase insignificantly in the control group, supporting Hypothesis 2 that the binding-constraint probability decreases following the tick-size reduction. Moreover, the magnitudes of the declines in binding-constraint probability in Group 1 exceed those in Group 2, indicating that low-priced stocks experience larger declines in binding constraint probability.

Finally, because the declines in spread are significant in both the event and control groups, the effect of tick-size reduction on spread is ambiguous. This study thus tests whether the magnitudes of the decline of spread in Group 1 significantly exceed those in the control group. The analytical results demonstrate that the magnitudes of the decline of spread in Group 1 significantly exceed those in the control group, demonstrating

[14]Volume depth also exhibits similar results, which are omitted here for brevity.

that the tick-size reduction can efficiently reduce spread. Furthermore, the tick-size reduction leads to declines in spread, depth, market liquidity, and binding-constraint probability in Group 2, indicating that the effect of tick-size reduction still exists in other tick-size regimes. Consequently, tick-size reduction in TSEC can reduce binding constraints, and further reduce the spread and depth, especially for low-priced stocks, consistent with the previous findings (e.g., Bourghelle and Declerck, 2004; Chung *et al.*, 2004).

4.1.2. *Descriptive statistics classified by the pre-period stock characteristics*

The empirical results in Section 4.1.1 indicated that the effect of tick-size reduction on market liquidity may differ based on different stock characteristics, consistent with the previous findings (Harris, 1994; Bollen and Whaley; 1998). The changes in these variables thus are studied by further partitioning the samples into five sub-samples based on the pre-period stock characteristics (including market capitalization, number of trades, trade size in shares, return volatility, and binding-constraint probability). Owing to the relatively small sample size of Group 1 (45 stocks), it is classified into just two sub-samples, with sizes of 22 and 23, respectively. Meanwhile, Group 2 has a sample size of 147, and is equally divided into three sub-samples, each containing 49 firms. The results are shown in Table 4.[15]

Because large firms generally attract more attention from investors and analysts (Atiase, 1985; Kang and Stulz, 1996), information asymmetry among investors is therefore lower for these stocks. Consequently, stock price can accurately reflect trading information, but may be constrained by the large tick size before the tick-size reduction. Accordingly, following the relaxation of the binding constraints, trading information can be revealed through the market without distortion by tick size, reducing the spread. The liquidity supplier provides less quantity at the given price owing to the reduced profits. Consequently, in the event group, stocks with large market capitalization experience larger declines in spread and depth following the tick-size reduction. Furthermore, in Panels B and C, frequently traded stocks experience larger declines in spread owing to intensified market competition

[15] All the sub-samples do not follow the normal distribution using the Shapiro–Wilk test (or Kolmogorov–Simirnov test). Because the results of median tests are the same as those of mean tests, the median results are omitted for the sake of brevity.

Table 4. Descriptive statistics classified by pre-period stock characteristics and binding-constraint probability.

	Group 1		Group 2		
	L	H	L	M	H
			Panel A: Market capitalization		
% E.S.	-0.4054^{**}	-0.7141^{**}	-0.3070^{**}	-0.4136^{**}	-0.5800^{**}
% Q.S.	-0.3760^{**}	-0.6557^{**}	-0.3193^{**}	-0.3844^{**}	-0.5608^{**}
Depth in dollar	-1.2336^{**}	-1.7361^{**}	-0.3113^{**}	-0.7257^{**}	-1.0254^{**}
Market liquidity	0.2102^{*}	-0.5114^{**}	0.1836^{**}	-0.1114	-0.3301^{**}
Binding-constraint probability	-1.0793^{**}	-0.7250^{**}	-0.4341^{**}	-0.3059^{**}	-0.0929^{**}
			Panel B: Number of trades		
% E.S.	-0.3768^{**}	-0.7415^{**}	-0.3467^{**}	-0.4094^{**}	-0.5445^{**}
% Q.S.	-0.3482^{**}	-0.6823^{**}	-0.3623^{**}	-0.3784^{**}	-0.5237^{**}
Depth in dollar	-1.1713^{**}	-1.7957^{**}	-0.2777^{**}	-0.7096^{**}	-1.0751^{**}
Market liquidity	-0.1725^{*}	-0.5474^{**}	0.2547^{**}	-0.1070	-0.4051^{**}
Binding-constraint probability	-1.1222^{**}	-0.6839^{**}	-0.4185^{**}	-0.2894^{**}	-0.1250^{**}
			Panel C: Trade size in shares		
% E.S.	-0.3639^{**}	-0.7538^{**}	-0.3195^{**}	-0.4010^{**}	-0.5800^{**}
% Q.S.	-0.3367^{**}	-0.6933^{**}	-0.3233^{**}	-0.3796^{**}	-0.5615^{**}
Depth in dollar	-1.1996^{**}	-1.7686^{**}	-0.4521^{**}	-0.6196^{**}	-0.9907^{**}
Market liquidity	-0.1725	-0.5474^{**}	0.0960	-0.0334	-0.3204^{**}
Binding-constraint probability	-1.0810^{**}	-0.7233^{**}	-0.4594^{**}	-0.2682^{**}	-0.1052^{**}
			Panel D: Volatility		
% E.S.	-0.5750^{**}	-0.5519^{**}	-0.4665^{**}	-0.4058^{**}	-0.4282^{**}
% Q.S.	-0.5265^{**}	-0.5118^{**}	-0.4562^{**}	-0.3996^{**}	-0.4086^{**}
Depth in dollar	-1.5210^{**}	-1.4612^{**}	-0.6821^{**}	-0.6330^{**}	-0.7473^{**}
Market liquidity	-0.4278^{**}	-0.3032^{**}	-0.0588	-0.0541	0.1448^{*}
Binding-constraint probability	-0.9458^{**}	-0.8527^{**}	-0.2542^{**}	-0.3116^{**}	-0.2671^{**}
			Panel E: Binding-constraint probability		
% E.S.	-0.3590^{**}	-0.7585^{**}	-0.3559^{**}	-0.4012^{**}	-0.5435^{**}
% Q.S.	-0.3344^{**}	-0.6955^{**}	-0.3648^{**}	-0.3761^{**}	-0.5235^{**}
Depth in dollar	-1.1609^{**}	-1.8057^{**}	-0.4902^{**}	-0.5702^{**}	-1.0020^{**}
Market liquidity	-0.1568^{*}	-0.5624^{**}	0.1045	-0.0065	-0.3559^{**}
Binding-constraint probability	-1.1149^{**}	-0.6909^{**}	-0.4241^{**}	-0.3051^{**}	-0.1036^{**}

This table lists the mean relative difference [ln(post-period mean/pre-period mean)] classified based on the pre-period stock characteristics and binding constraints. Furthermore, Group 1 comprises stocks whose tick size changed from 0.05 to 0.01, while Group 2 comprises stocks whose tick size changed from 0.1 to 0.05. The sub-samples L and H in Group 1 are classified according to stock characteristics, and the sample sizes are 22 and 23, respectively. According to pre-period stock characteristics, the sub-samples L, M, and H in Group 2 are classified into equal sample sizes, and their sample sizes are 49. L/M/H indicates the sub-samples, which are partitioned according to the low/medium/high stock characteristics, respectively.

* and **indicate significance at the 0.05 and 0.01 level, respectively.

(Goldstein and Kavajecz, 2000; Chung *et al.*, 2004).[16] Additionally, depth is also reduced as investors attempt to avoid potential losses.

Similarly, stocks with high pre-period binding constraints display large declines in spread and depth following the tick-size reduction, consistent with the findings of Chung *et al.* (2004), and supporting Hypothesis 4. Additionally, the relations between stock characteristics and changes in binding constraints appear negative. For example, stocks which are infrequently traded or have lower market capitalization experience larger declines in binding constraints after the tick-size reduction.

Summarizing the above, the conclusions remain unaltered after examining the sub-samples classified by pre-period stock characteristics. The magnitudes of the declines in depth and spread in Group 1 remain larger regardless of stock characteristics. Moreover, the declines in binding-constraint probability following the tick-size reduction are especially large for low-priced or infrequently traded stocks, consistent with the previous findings (Bourghelle and Declerck, 2004; Chung *et al.*, 2004).

4.2. *Regression results*[17]

The determinants of spread, depth, and binding-constraint probability during the pre-period or post-period are discussed in Section 4.2.1. First, the above results indicate that the market liquidity and binding-constraint probability decrease, and the stock characteristics also decrease following the tick-size reduction. Hence, these reductions may not be directly attributable to the changes in tick size. That is, other explanatory variables may be driving these changes. The explanatory variables are included to control the additional effects to yield robust results, which are shown in Sections 4.2.2 and 4.2.3.

4.2.1. *Determinants of spread, depth, and binding constraints during the pre- and post-periods*

The stock characteristics, including stock price (P), number of trades (T), trade size in shares (TS), and standard deviation of stock return (σ), are regressed in terms of spread, depth, market liquidity, and binding-constraint

[16]Given that the results classified by the trading volume, trade size in dollars, and trading value are also similar, they are omitted here for brevity.

[17]Coefficients in the regression analysis are adjusted by the White's correction for heteroscedasticity.

probability. The results are listed in Equation (1) of Table 5, and the following models are developed.[18]

$$X = \alpha_0 + \alpha_1 \ln(P) + \alpha_2 \ln(T) + \alpha_3 \ln(TS) + \alpha_4 \ln(\sigma) + \varepsilon, \tag{2}$$

where X represents the dependent variables, including spread, depth, market liquidity, and binding-constraint probability.[19]

According to the results listed in Panels A and B of Table 5, frequently traded stocks generally have small spreads during both the pre- and post-period. A possible explanation for this phenomenon is that higher trading volume increases the ease of matching buyers and sellers (Chung *et al.*, 1999), which explains why the spread is smaller. Furthermore, high risk stocks generally have higher risk premiums, and thus larger spreads. Panel C thus demonstrates that the trading activity is positively correlated with the depth in dollars,[20] during both the pre- and post-period. This result is consistent with the previous descriptive statistics in Section 4.1.2. Additionally, since liquidity suppliers face greater information uncertainty for high risk stocks, they supply smaller quantities to limit potential losses. Consequently, depth is lower for high risk stocks. Similarly, the results for market liquidity in Panel D resemble those in Panel C. Further, in Panel E, the estimated coefficient for the number of trades is significant and positive, showing that frequently traded stocks are more constrained by tick size. Finally, because high risk stocks are subject to large amplitude of price change, they are not constrained by tick size. Consequently, low-risk stocks are more constrained by tick size, consistent with the previous findings of Chung *et al.* (2004).

Additionally, in Equation (2) of Table 5, the variable "binding-constraint probability" is included into Equation (1) of Table 5 to evaluate whether after controlling the stock characteristics the spread, depth, and market liquidity can be explained by the binding-constraint probability. The results show that only *%Q.S.* and depth in dollars are significantly negative with the binding-constraint probability after controlling the concurrent stock characteristics. The market liquidity is negatively related with the binding-constraint probability, but is insignificant.

[18]There are only four variables included in the model because of the multi-collinearity problem.

[19]Given that the stock price in Group 1 is lower than that in Group 2, the dummy variable is omitted, and the variable "P" is used instead, thus avoiding the multi-collinearity problem.

[20]The result of depth in volumes is similarly the same as the result of depth in dollars, and therefore is omitted for brevity.

Table 5. Regression analysis during the pre- and post-period.

	Equation	Intercept	ln(P)	ln(T)	ln(TS)	ln(σ)	*Bind*	Adj. R^2
				Panel A: *% Q.S.*				
Pre	1	0.01401**	−0.00178**	−0.00082**	0.00065*	0.00100**		72.52%
	2	0.01786**	−0.00261**	−0.00014	0.00080**	0.00039	−0.00664**	86.68%
Post	1	0.00940**	−0.00011	−0.00124**	0.00087*	0.00158**		69.26%
	2	0.00946**	−0.00011	−0.00126**	0.00086*	0.00159**	−0.00008	69.09%
				Panel B: *% E.S.*				
Pre	1	0.01121**	−0.00174**	−0.00049**	0.00080**	0.00088**		71.01%
	2	0.01456**	−0.00247**	0.00009	0.00094**	0.00035	−0.00576**	85.35%
Post	1	0.00760**	−0.00023	−0.00092**	0.00079**	0.00130**		67.28%
	2	0.00781**	−0.00024	−0.00097**	0.00074*	0.00134**	0.00030	67.19%
				Panel C: *Depth in dollars*				
Pre	1	−59,937.45**	3,699.69	8,419.34**	10,454.61*	−16,823.90*		47.70%
	2	−20,334.85	−4,922.03	15,375.00**	12,037.94**	−23,120.92**	−68,283.16**	62.60%
Post	1	−23,051.20**	1,111.13	3,011.97**	5,121.34**	−5,106.55**		50.46%
	2	−28,275.38**	1,439.39	4,293.89**	6,214.19**	−6,212.17**	−7,713.98*	52.41%
				Panel D: *Market liquidity*				
Pre	1	−463,910.4**	−6,764.93	87,834.53**	86,112.05	−185,485**		52.38%
	2	−263,177.8*	−50,465.7	123,095.0**	94,137.4*	−217,402**	−346,105*	56.70%
Post	1	−417,600.0**	4,284.87	62,369.33**	99,226.81**	−106,350.9**		50.89%
	2	−517,027.1**	10,532.19	86,766.73**	120,025.9**	−127,393.1**	−146,812*	52.70%
				Panel E: *Binding-constraint probability*				
Pre	1	0.5799**	−0.1262**	0.1018**	0.0231	−0.0922		57.09%
Post	1	−0.6772**	0.0425	0.1661**	0.1416**	−0.1433**		75.21%

This table presents regression analysis on the spread, depth, market liquidity, and binding-constraint probability during the pre- and post-period. Panels A and B display these analyses for *% Q.S.* and *% E.S.* Panel C analyzes depth in dollars; Panel D displays the analysis for market liquidity, and Panel E displays the analysis of binding-constraint probability. The independent variables include average daily stock price (P), average daily number of trades (T), average trade size in shares (TS), standard deviation of stock return (σ), and binding-constraint probability (*Bind*).

* and **indicate significance at the 0.05 and 0.01 level, respectively.

To summarize, regardless of whether it is pre- or post-period, volatility and trading activity are the most important factors in explaining the spread, depth, and market liquidity, consistent with the findings of Chung *et al.* (2004).

4.2.2. *Determinants of changes in spread, depth, market liquidity, and binding-constraint probability*

Previous descriptive statistics in Section 4.1.2 demonstrate that spread, depth, market liquidity, and binding-constraint probability decrease following tick-size reduction. Although previous results obtained from examination of sub-samples classified by pre-period stock characteristics persist, this is only a univariate analysis. The results may be biased owing to the failure to simultaneously control the influence of other factors. Consequently, regression analysis is performed in which explanatory variables are limited to the pre-period data to avoid the endogenous problem.

$$\ln(\overline{X}_{\text{post}}/\overline{X}_{\text{pre}}) = \beta_0 + \beta_1 \ln(P_{\text{pre}}) + \beta_2 \ln(T_{\text{pre}}) + \beta_3 \ln(TS_{\text{pre}}) + \beta_4 \ln(\sigma_{\text{pre}}) + \varepsilon, \quad (3)$$

where $X_{\text{pre}}(X_{\text{post}})$ is the pre-period (post-period) variables, namely, P_{pre} is the pre-period stock price.

Panels A to C in Table 6 reveal that the magnitudes of changes in spread (depth) are negatively correlated with the number of trades and trade size in shares, implying that after the tick-size reduction, frequently traded stocks experience larger declines in spread (depth) than those of infrequently traded stocks. This is consistent with the previous results shown in Section 4.1.2. Additionally, although low-priced stocks also experience larger declines in spread and depth, the relationship of stock price with the changes of spread is insignificant. Furthermore, the declines in market liquidity are only significantly influenced by the number of trades, and the relationship of number of trades with the changes of market liquidity is negative (see Panel D). Finally, Panel E reveals that the magnitudes of the declines of binding constraints are positively correlated with stock price and number of trades, indicating that low-priced or frequently traded stocks exhibit more trading information but may be constrained by tick size during the pre-period.

The above results can be interpreted as relaxations of binding constraints because low-priced or frequently-traded stocks are more constrained by tick size during the pre-period (Gibson *et al.*, 2003; Chung *et al.*, 2004). Consequently, for low-priced or frequently-traded stocks, the spread, depth, and

Table 6. Determinants of changes in spread, depth, market liquidity, and binding-constraint probability.

Intercept	$\ln(P_{\text{pre}})$	$\ln(T_{\text{pre}})$	$\ln(TS_{\text{pre}})$	$\ln(\sigma_{\text{pre}})$	Adj. R^2
		Panel A: *% Q.S.*			
−0.0828	0.0666	−0.0619**	−0.1677*	0.1187	18.52%
		Panel B: *% E.S.*			
−0.0565	0.0800	−0.0710**	−0.1846*	0.1141	23.40%
		Panel C: *Depth in dollars*			
−0.6340	0.5460**	−0.2318**	−0.3017	0.1325	41.89%
		Panel D: *Market liquidity*			
0.7624	0.1789	−0.1812**	−0.2214	0.0594	31.06%
		Panel E: *Binding-constraint probability*			
−2.4305**	0.3774**	0.1368**	0.0836	−0.1218	48.92%

This table performs regression analysis for the changes in spread, depth, market liquidity, and binding-constraint probability on the pre-period stock characteristics. Panels A to B detail the analysis for *% Q.S.* and *% E.S.* Furthermore, Panel C illustrates the analysis for *Depth in dollars*, Panel D displays the results for *Market liquidity*, and Panel E lists the results for *Binding-constraint probability*. The independent variables include average daily stock price (P), average daily number of trades (T), average trade size in shares (TS), and standard deviation of stock return (σ).

* and **indicate significance at the 0.05 and 0.01 level, respectively.

market liquidity decline more following the relaxation of binding constraints. Moreover, trading activity is the important factor in explaining the changes of spread, depth, market liquidity, and binding-constraint probability.

4.2.3. *Regression analysis — relationships in spread, depth, market liquidity, and binding-constraint probability and pre-period binding-constraint probability.*

This section analyzes whether changes in dependent variables are affected by the pre-period binding constraints after controlling the concurrent changes of other stock characteristics. Table 7 lists the results and the models are as follows.

$$\begin{aligned}\ln(\overline{X}_{\text{post}}/\overline{X}_{\text{pre}}) = {} & \gamma_0 + \gamma_1 D + \gamma_2 \ln(P_{\text{post}}/P_{\text{pre}}) + \gamma_3 \ln(T_{\text{post}}/T_{\text{pre}}) \\ & + \gamma_4 \ln(TS_{\text{post}}/TS_{\text{pre}}) + \gamma_5 \ln(\sigma_{\text{post}}/\sigma_{\text{pre}}) \\ & + \gamma_6 Bind_{\text{pre}} + \gamma_7 X_{\text{pre}} + \varepsilon, \end{aligned} \tag{4}$$

where D denotes an indicator variable that equals 1 for stocks in Group 2, and 0 in Group 1.

Table 7. Regression analysis — relationships in spread, depth, market liquidity, and binding-constraint probability and pre-period binding-constraint probability.

Equation	intercept	D	$\Delta \ln(P)$	$\Delta \ln(T)$	$\Delta \ln(TS)$	$\Delta \ln(\sigma)$	$Bind_{\text{pre}}$	X_{pre}	Adj. R^2
				Panel A: Δ *% E.S.*					
1	-0.6615^{**}	0.2148^{**}	-0.5555^{**}	-0.1091^{*}	0.5026^{**}	0.0795			24.27%
2	0.2668	0.0176	-0.4645^{**}	-0.1504^{*}	0.5203^{**}	0.1307	-0.5567^{*}	-65.8327^{**}	32.65%
				Panel B: Δ *% Q.S.*					
1	-0.6382^{**}	0.1998^{**}	-0.5448^{**}	-0.1518^{**}	0.4244^{*}	0.0988			27.70%
2	-0.1486	0.1364^{*}	-0.4588^{**}	-0.1905^{**}	0.4262^{*}	0.1395	-0.4233	-16.4061	30.77%
				Panel C: Δ *Depth in dollars*					
1	-1.1313^{**}	0.4957^{**}	0.4431	0.5437^{**}	1.3927^{**}	-0.4549^{**}			69.89%
2	-1.3130^{**}	0.5935^{**}	0.4855^{*}	0.5072^{**}	1.2634^{**}	-0.4093^{**}	0.2123	$-8.8 \times 10^{-6^{**}}$	75.30%
				Panel D: Δ *Market liquidity*					
1	-0.0480	0.0080	0.0947	0.6537^{**}	0.9714^{**}	-0.5357^{**}			83.54%
2	-0.1159	0.0335	0.1176	0.6393^{**}	0.9487^{**}	-0.5176^{**}	0.0886	$-3.3 \times 10^{-7^{*}}$	84.55%
				Panel E: Δ *Binding-constraint probability*					
1	-0.9204^{**}	0.6450^{**}	-0.3136	0.1088	-0.4214^{*}	0.0333			45.17%
2	-1.4931^{**}	0.6690^{**}	-0.4763^{*}	0.1893^{*}	-0.3828^{*}	-0.0436	0.6597		50.83%

This table applies regression analysis to the changes in spread, depth, market liquidity, and binding-constraint probability. Panels A to B investigate the analysis of the changes in *% E.S.* and *% Q.S.* Panel C shows the depth analysis in dollars, Panel D illustrates the market liquidity analysis, and Panel E displays the analysis of the binding-constraint probability. The independent variables include changes in average daily stock price (P), average daily number of trades (T), average trade size in shares (TS), standard deviation of stock return (σ), pre-period binding-constraint probability ($Bind_{\text{pre}}$), and pre-period dependent variable (X_{pre}). D is 1 for stocks in Group 2, and 0 otherwise. Finally, X_{pre} is the pre-period dependent variables, namely, the X_{pre} in Panel A is pre-period *% E.S.*

* and **indicate significance at the 0.05 and 0.01 level, respectively.

First, Equation (1) in Table 7 investigates the effects of changes in stock characteristics on changes of spread, depth, market liquidity, and binding-constraint probability. In Panels A and B, the changes in spread are significantly influenced by the concurrent changes in stock price and trading activity. Next, Panel C shows that the depth changes are also influenced by the concurrent changes in stock characteristics, and moreover the influence is significant in all cases. Furthermore, with the exception of stock price, the changes in market liquidity resemble those for depth, which is shown in Panel D.

Equation (2) in Table 7 is then used to analyze whether declines of these variables (spread, depth, market liquidity, and binding-constraint probability) are influenced by pre-period binding-constraint probability after controlling the concurrent changes in stock characteristics and pre-period dependent variables. The analytical results show that the changes of spread, depth, and market liquidity cannot be significantly explained by the pre-period binding-constraint probability with the exception of changes in $\%E.S.$ Besides, in Panel E, the changes in binding constraints also cannot be significantly explained by the pre-period binding constraints, despite the coefficients remaining positive, inconsistent with the previous findings of Chung *et al.* (2004). Additionally, the changes of spread, depth, and market liquidity are significantly negative with the pre-period spread, depth, and market liquidity, respectively.

Finally, nearly all the intercepts are significantly negative, supporting the idea that the spread, depth, market liquidity, and binding-constraint probability decrease after tick-size reduction. In addition, the decreases in low-priced stocks are larger than the decreases in high-priced stocks, and although the variable "D" in some equations is insignificant, it is still positive.

5. Conclusions

This paper examines the influence of tick-size reduction on market liquidity in the TSEC on March 1, 2005, and examines how market liquidity is influenced by stock characteristics and binding-constraint probability. Although this investigation examines the same problem as Chung *et al.* (2004), they only examined a period of two months, failing to identify the long term influence of tick-size reduction on market liquidity. Furthermore, the TSEC is a pure order-driven market rather than a hybrid-driven market, as in the earlier study. However, order-driven markets have become the most popular

trading type globally (Brockman and Chung, 1999), but there are relatively few empirical studies of such markets. Consequently, it is worthwhile to examine whether the impact of tick-size reduction on market liquidity in TSEC, an emerging order-driven market, resembles that identified by previous empirical studies for hybrid-driven markets (Chung *et al.*, 2004).

The empirical results show that the spread, depth, market liquidity, and binding-constraint probability decrease following the tick-size reduction, and the declines are larger for low-priced or low-risk stocks. Next, because stocks with large market capitalization or those with more frequently traded tend to be obvious targets for investors and analysts, and because trading information can be revealed faster over the market for such stocks rather than those with a lower market capitalization, they experience larger declines in spread, depth, market liquidity, and binding-constraint probability after the tick-size reduction. The above results are consistent with the previous findings in both hybrid- or order-driven markets (Lau and McInish, 1995; Chan and Hwang, 2001; Chung *et al.*, 2004). Furthermore, the magnitudes of the declines in binding-constraint probability for the TSEC exceed those for the NYSE (Chung *et al.*, 2004). However, there are some inconsistencies with the findings of Chung *et al.* (2004), such as stocks with fewer pre-period binding constraints experience larger percentage declines in binding constraints following the tick-size reduction, and the declines in spread and depth are not significantly affected by the pre-period binding constraints after including the concurrent changes in stock characteristics.

Because the TSEC adopts a multiple tick-size system, in which tick sizes are positively related to the stock price, the relative tick size is more stable than that of the hybrid-driven market, which adopts the same tick size for all stocks (e.g., NYSE). Furthermore, retail investors in the TSEC, who are usually the short-term traders, contribute about 70% of trading value. Hence, short-term trading is reduced due to the reduced spread and depth, which may be one of the reasons causing the decreased trading activity in TSEC after the tick-size reduction. Next, the previous studies indicate that tick-size reduction benefits small orders but harms large orders (e.g., Goldstein and Kavajecz, 2000). Therefore, the current tick-size regulation seems more appropriate than the previous one for the TSEC. However, the market liquidity for low-priced stocks declines more. If the government authority wants to increase market liquidity, it might try to increase the tick size for low-priced stocks. Therefore, whether the step-function tick size in TSEC is appropriate or not, especially for low-priced stocks, should be reconsidered.

Acknowledgements

The authors are thankful to the suggestions from two anonymous referees. The financial support is from the National Science Council in Taiwan (Project #: NSC 96-2416-H-244-003)

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