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Decimalization and competition among stock markets: Evidence from the Toronto Stock Exchange cross-listed securities

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Abstract

We study the impact of Toronto Stock Exchange (TSE) decimalization on the competition for order flow. For TSE stocks cross-listed on the NYSE/AMEX, spreads decrease by 27% on the TSE and do not change on the NYSE/AMEX. For TSE stocks cross-listed on Nasdaq, spreads decline by 16% and 8% on the TSE and Nasdaq, respectively. However, order flow does not migrate from U.S. markets to the TSE. Our results indicate that the savings in TSE transaction costs do not offset the benefits of trading on the NYSE/AMEX, and that Nasdaq dealers might not operate as efficiently as perfect competition warrants.

JEL classification: G10; G18; G20

Keywords: Cross-listed stocks; Fractional and decimal trading systems; Tick size; Bid–ask spread and depth; Competition

1. Introduction

On April 15, 1996, all Canadian stock exchanges switched from a fractional to a decimal trading system. The change to decimalization was intended to reduce

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trading costs and strengthen the competitive position of the Canadian equity markets. As the Toronto Stock Exchange (TSE) stated:

> When decimal trading begins, the Canadian securities industry will gain a critical, competitive edge in the world arena. The TSE expects this bold, revolutionary step to increase our trading volume and market share by enhancing the TSE's competitiveness with U.S. markets. When the world invests in Canada, the world invests in companies listed on the TSE.[1]

In the U.S., a recent study by the Security and Exchange Commission (SEC) also concludes that the current fractional pricing should be revised in favor of a decimal pricing system (SEC Market 2000 Study, 1994). Currently, among the top 20 exchanges in the world, those in the U.S. are the only exchanges that use fractional pricing. This paper examines whether reducing tick size by an exchange strengthens the competitiveness of the exchange in a global equity market where the same stock is traded on more than one exchange. To accomplish this purpose, we focus on TSE stocks that are cross-listed and actively traded on U.S. stock markets. Academics and policy makers predict that switching to a decimal trading system will reduce trading costs, make the exchange more competitive, and attract order flow of cross-listed stocks traded on other exchanges with larger tick sizes and higher trading costs (Foerster and Karolyi, 1993; Freedman, 1989; SEC Market 2000 Study, 1994). However, there is little empirical evidence to support these claims. This paper provides a direct test of these predictions.

Many TSE stocks are cross-listed on the New York Stock Exchange (NYSE), the American Stock Exchange (AMEX), or the National Association of Security Dealer Automated Quotation/National Market System (Nasdaq/NMS). The number of these stocks (189 stocks in total) accounts for 15% of all TSE stocks, however, their dollar trading volume accounts for as much as 90% of the total trading volume of all TSE stocks in 1995 (these figures include trading volume on the TSE only).[2] Thus, maintaining a liquid market for these cross-listed stocks is critical to the survival of the TSE. For stocks cross-listed in Canada and the U.S., Canadian exchanges have lost market share to U.S. markets (*The Wall Street Journal*, April 15, 1996). The TSE decimalization experiment is intended to be an important impetus to entice order flows for cross-listed stocks away from U.S. markets. It should be noted that the issue here is not the decimalization itself, but the reduction of the tick size caused by the decimalization, which is likely to reduce trading costs. In Canada, the decimalization reduced the tick size from C$0.125 to C$0.050 for stocks traded at or above C$5.

[1] See The Toronto Stock Exchange (1996b).

[2] See The Toronto Stock Exchange (1996a).

We estimate trading costs, trading volume, and market depth surrounding the switch to the decimal trading system by using transaction data from the TSE, NYSE, AMEX and Nasdaq. Three mutually exclusive samples are constructed for the analysis: (1) TSE stocks that are not cross-listed on these U.S. markets; (2) TSE stocks cross-listed on U.S. markets and traded on the TSE; and (3) TSE stocks cross-listed and traded on U.S. markets.[3] The second and third samples are further partitioned into two groups based on where they are cross-listed, with NYSE and AMEX or Nasdaq.[4] We use two benchmark (control) samples. The first consists of NYSE/AMEX stocks that share similar stock characteristics with TSE stocks that are cross-listed on the NYSE/AMEX. The second consists of Nasdaq stocks that share similar characteristics with TSE stocks that are cross-listed on Nasdaq. The two benchmark samples allow us to separate the effect of the decimalization from the effect of other factors that are unrelated to the decimalization.

The primary finding is that order flows for the cross-listed stocks do not migrate from U.S. markets to the TSE, even though both quoted and effective spreads on the TSE fall significantly after decimalization. The reduction in the effective spreads on the TSE are 27% and 16%, respectively, for TSE stocks cross-listed on the NYSE/AMEX and Nasdaq. Neither the quoted nor the effective spreads decrease significantly on the NYSE/AMEX for the cross-listed TSE stocks. Further, there is no evidence that the NYSE and AMEX lose trading volume to the TSE. On the other hand, cross-listed stocks traded on Nasdaq experience an 8% decline in the spread, and trading volume is unaffected. In short, while the TSE decimalization does not appear to increase the competition between the TSE and the NYSE/AMEX, it does intensify the competition between the TSE and Nasdaq.

We interpret these results as follows: First, investors may have found that the savings in transaction costs on the TSE are not sufficient to offset the benefits of trading on the NYSE/AMEX. These benefits include the ease of trading and superior execution of blocks. Second, Canadian brokers and U.S. market

[3] Transaction data for the first and second samples are obtained from the Toronto Stock Exchange database. The bid and ask prices are quoted on the TSE in Canadian dollars. Transaction data for the third sample is from the TAQ database. The bid and ask prices are quoted on the NYSE/AMEX or Nasdaq in U.S. dollars. TSE stocks refer to stocks that are listed on the Toronto Stock Exchange, including Canadian stocks and foreign stocks. There are 66 foreign stocks listed on the TSE during the sample period, of which 40 are U.S. issues, 6 are U.K. issues, and the remaining 20 issues are from several different countries. However, foreign stocks are not actively traded on the TSE. After we impose filters on the initial sample of TSE stocks, as discussed in Section 4.1, all foreign stocks are excluded. As a result, samples (1)–(3) consist of Canadian stocks only.

[4] The trading mechanism of the AMEX is similar to that of the NYSE, thus we combine stocks cross-listed on the NYSE and AMEX. Excluding stocks cross-listed on the AMEX leads to similar results reported in the paper.

makers and dealers might not be willing to trade on the TSE for their own benefits. The practice of payment-for-order flow is prohibited in Canada (e.g., between Canadian brokers and Canadian dealers), but allowed in the U.S. (e.g., between Canadian brokers and U.S. dealers). Canadian brokers might prefer forwarding the order to Nasdaq dealers for execution in exchange for the payment. On the other hand, U.S. market makers and dealers might execute the trade of TSE cross-listed stocks on the NYSE, AMEX, or Nasdaq to earn spread profits and commissions. Third, Nasdaq dealers might not be operating as efficiently as the perfect competition warrants. Otherwise, it would be difficult for them to reduce the spread, even under external pressure from the TSE.

This paper is closely related to several prior studies. Harris (1994) provides detailed predictions on how the spread, volume, and depth will change if the tick size is reduced from $\$\frac{1}{8}$ to $\$\frac{1}{16}$. Ahn et al. (1996) examine empirically the actual impact of the tick size change on the AMEX stocks affected by the 1992's tick rule change. Bacidore (1997) studies the effect that TSE decimalization has on market quality, and finds that liquidity is not adversely affected by decimalization. Chordia and Subrahmanyam (1995) study the effects of a finite tick size and the practice of payment-for-order flow on the competition between NYSE and non-NYSE market makers. They find that, in the U.S., orders do not flow to the least cost provider of market making service. Harris (1996) investigates the empirical relation between tick size and order exposure by using order data from the Paris Bourse and the TSE. For stocks listed on the NYSE, Lee (1993) finds that the price obtained on similar adjacent trades can differ by location of execution. Weaver (1996) examines different changes in market quality across two trading systems on the TSE. Harris (1997) provides an excellent review of the argument for and against decimalization and recent evidence. This study differs from existing work in that it examines the impact of the tick-size change on the competition for order flow between Canadian and U.S. equity markets where the same stocks are actively traded in both countries.

The rest of the paper is organized as follows: Section 2 explains the trading mechanism of the TSE and the importance of the cross-listed stocks on the TSE. Section 3 develops empirically testable hypotheses. Section 4 describes the data, and Section 5 presents the empirical results. Section 6 provides interpretations of the results, and Section 7 concludes.

2. The Toronto Stock Exchange and cross-listed stocks

The Toronto Stock Exchange is the tenth largest stock exchange in the world and the largest exchange in Canada. In 1995, the TSE dollar (share) volume constituted 81% (58%) of the total dollar (share) volume traded in Canada.

The TSE, like the NYSE, is a nonprofit organization owned by its member firms. The TSE has two parallel trading systems, a floor trading system and an

automated trading system. The floor trading system is similar to that of the NYSE. Each TSE stock is allocated to a registered trader, who resembles the NYSE specialist. A registered trader's primary responsibility is to make an orderly market for the assigned stock by stabilizing stock prices and maintaining minimum spreads. The latter system is called the Computer Assisted Trading System (CATS). According to Huang and Stoll (1991) and Schwartz (1993), about 20% of the TSE volume is executed on CATS. Active stocks are traded mainly on the floor of the TSE.

Among the 1258 stocks listed on the TSE in 1995, 189 stocks are cross-listed on the NYSE, AMEX, or Nasdaq. While some TSE stocks are also cross-listed on other exchanges, their trading volumes pale in comparison to those stocks cross-listed on the NYSE, AMEX or Nasdaq. In 1995, TSE stocks cross-listed on the U.S. markets accounted for as much as 90% (C$187,029 million) of the total dollar volume of all TSE stocks (C$207,685 million).[5] In share volume, the cross-listed stocks accounted for 78% (12,308 million shares) of the TSE total volume (15,757 million shares). These figures include trading volumes on the TSE only. In addition, trades executed on the NYSE, AMEX and Nasdaq consisted of a significant portion of the total trades for all cross-listed TSE stocks. Of the total trading volume of C$336,327 million in cross-listed stocks in 1995, 55.6% of trades were executed on the TSE, and 19.0%, 1.7% and 10.4% were executed on the NYSE, AMEX, and Nasdaq, respectively. That is, the trading volume on the NYSE, AMEX, and Nasdaq accounted for about one third of the total volume for the cross-listed stocks.

As these figures indicate, the TSE is faced with fierce competition from U.S. stock markets. Thus, to make the TSE more competitive in the global market, the TSE has ruled that the registered traders should be exempt from the stabilization requirements when they deal with the cross-listed stocks, which comprised more than 25% of the trading on the U.S. markets in the preceding year. However, despite this effort, the TSE market share for the cross-listed stocks has been declining, while the U.S. market share has been increasing in recent years. Since 1991, the NYSE/AMEX/Nasdaq market share, as measured by dollar and share volumes, has increased from 23.2% to 31.1% and from 19.5% to 23.2%, respectively. The decline in Canadian market share in the cross-listed stocks is one important reason why Canadian exchanges chose to adopt the decimal trading system.

3. Testable hypotheses

The hypotheses tested in this paper can be broadly divided into two classes: The first class of hypotheses predicts the impact of the TSE tick size change on

[5] See The Toronto Stock Exchange (1996a).

the TSE. The second is concerned with the impact of the TSE tick-size change on U.S. markets for the cross-listed TSE stocks. While we are primarily interested in the second class of hypotheses, we will also test the first to provide a general perspective.

3.1. The impacts of decimalization on the TSE

The first set of hypotheses is the same as that developed by Harris (1994). Since the tick size sets the lower bound of the quoted bid–ask spread, a reduction in the tick size is likely to decrease the spread, which will increase trading volume since trading is less expensive. However, the reduction in the spread also makes market makers less willing to trade because the provision of liquidity is less profitable and the probability of trading with informed traders increases (Anshuman and Kalay, 1997). Thus, we can expect market depths (quotation sizes) to decrease. In summary, spreads are expected to decline, trading volume to rise, and market depths to fall after the TSE switches from a fractional to a decimal trading system.

3.2. The impact of the TSE decimalization on U.S. markets

The second set of hypotheses is concerned with the external effect of the TSE decimalization. These hypotheses are based on the assumption that both the U.S. and Canadian markets are open trading environments in which both domestic and foreign investors can access either of the markets with few legal and practical constraints. In fact, arbitrage-motivated cross-border trading is popular for stocks that are cross-listed in both countries.[6] In addition, because the exchange rate is stable, currency risk is relatively low when converting Canadian dollars to U.S. dollars or vice versa.[7]

As discussed in the previous section, trading costs for cross-listed stocks should be lower on the TSE in the post decimalization period. All else equal,

[6] NYSE specialist firms and Nasdaq member firms often form alliances with TSE member firms and execute trades on the TSE via their Canadian parters. For example, Troster Singer Co., a division of Spear, Leeds, and Kellogg (the largest NYSE specialist firm), allies with Midland Walwyn Capital Inc., a TSE member firm. Both firms routinely participate in cross-border arbitrage and send the order to the other country for execution. Another example is that Toronto Dominion Bank, the parent company of Toronto Dominion Securities Inc. (a large TSE member firm) and Evergreen Inc. (a large discount brokerage firm in Canada), acquired Waterhouse Security, a U.S. discount brokerage firm that has operations on the NYSE and Nasdaq. Thus, Canadian dealers can easily access the U.S. market and execute trades on the NYSE, AMEX, and Nasdaq.

[7] For example, the exchange rate varies from C$1.3554 to C$1.3823 per U.S. dollar during the sample period. The average and the standard deviation of the exchange rate are 1.3669 and 0.0065, respectively.

investors should prefer to trade these cross-listed stocks on the TSE rather than on a U.S. market. Thus, the decrease in trading costs on the TSE should intensify the competition for order flow between the TSE and U.S. markets.

How U.S. market makers and specialists respond to the heightened competition from the TSE depends upon whether the U.S. markets operate efficiently. If U.S. markets operate efficiently in a competitive environment, the U.S. market makers and specialists may not have the capacity to adjust trading costs, since reducing the spread would be impossible, because the tick size on U.S. markets is binding, or difficult because the market makers would have to accept below-zero economic profits. If the market makers and specialists on U.S. markets are not compensated for their liquidity service, they could be less willing to trade the cross-listed stocks, which would reduce market depths. Consequently, order flows for the cross-listed stocks would migrate from the U.S. markets to the TSE, and the trading volume on U.S. markets would decline. On the other hand, if U.S. market makers and specialists make lucrative profits from trading cross-listed stocks, they could counter the pressure from the TSE by reducing the bid-ask spread. As profitability decreases, U.S. market makers and specialists may be less willing to trade these cross-listed stocks, thereby, reducing market depths. It is difficult to predict how trading volume could change, because the reduction of the spread might counteract the pressure from the TSE. The predictions discussed so far should apply to all U.S. equity markets on which TSE stocks are cross-listed, including the NYSE, the AMEX and Nasdaq,

The last hypothesis concerns Nasdaq dealers' response to the TSE decimalization. Recently, Christie and Schultz (1994) found that Nasdaq dealers tend to avoid odd-eighth quotes, resulting in higher spread for Nasdaq issues relative to matched sample of NYSE stocks. Christie and Schultz attribute this evidence to implicit collusion among dealers. Kandel and Marx (1997) suggest that the avoidance of odd-eighth quotes is used as a coordination device to increase spreads. Godek (1996) argues that this avoidance is caused by preference trading, which occurs when the order flows are routed to chosen dealers who might not post the best quote, but who promise to trade at the best quoted price.[8] Recently, the SEC conducted an investigation of the operations and activities of the Nasdaq market and concluded that 'The investigation revealed that the Nasdaq market has not always operated in an open and freely competitive manner' (SEC, 1996). If the Nasdaq market does not operate as efficiently as perfect competition warrants, we would expect that Nasdaq dealers would be likely to reduce the spread of the cross-listed TSE stocks in response to the TSE decimalization.

[8] See Christie, Harris and Schultz (1994), Barclay (1997), Bessembinder (1997) and Huang and Stoll (1996) for additional evidence and discussion.

4. Data

4.1. Sample selection

The intraday data used in this paper comes from two sources. The transaction information for all TSE stocks is compiled by the Toronto Stock Exchange. This information includes trading prices, bid and ask quotes, volume, and quotation sizes for all stocks. For the cross-listed TSE stocks traded on the NYSE/AMEX/Nasdaq, we use the Trade and Quote (TAQ) database. Trades and quotes from the TSE are eliminated if they are flagged as errors, odd lots, delayed sales, delayed delivery, cancelled, or special terms. For the TAQ data, we eliminate trades flagged as errors and nonstandard delivery. We also eliminate quotes that are not labeled 'Best Bid and Offer'-eligible, i.e., closing quotations, trading halts, pre-opening indications, and nonfirm quotations.

The sample period spans five months from February 1 to June 30, 1996, which is divided into two subperiods of approximately equal length, the pre-event period (February 1, 1996 to April 14, 1996) and post-event period (April 16, 1996 to June 30, 1996). The event date is April 15, 1996, the day on which the Toronto Stock Exchange adopted a decimal trading system.

We construct five mutually exclusive stock samples, three from the TSE and two from U.S. markets. To construct the first three samples of TSE stocks, we eliminate stocks based on the following exclusion criteria: (1) non-common stocks; (2) stocks delisted by the TSE during the 30-day periods before and after April 15, 1996; (3) stocks that experienced a split during the sample period; (4) stocks with an average price below C$5 during the pre-event period; and (5) stocks with less than 60 transactions during the five-month sample period. The TSE decimalization uniformly affects the stocks priced at or above C$5: the tick size is reduced from C$0.125 to C$0.05.[9] These stocks are actively traded on the TSE. Among the 1258 securities traded on the TSE, 809 stocks meet the first four criteria, but the last criterion eliminates an additional 296 stocks. We partition the remaining 513 TSE stocks into three samples:

1. *TSE-NYA*: TSE stocks cross-listed on the NYSE/AMEX, but all data are derived from trading on the TSE (64 stocks).
2. *TSE-NAS*: TSE stocks cross-listed on Nasdaq, but all data are derived from trading on the TSE (65 stocks).

[9] For penny stocks and the 367 stocks priced between C$1–3, there is no change in the tick size. For 120 TSE stocks priced between C$3–5, the tick size is reduced from C$0.05 to C$0.01. We find that stocks in the price range of C$3–5 respond differently to the tick size change from stocks priced above C$5. The results are available upon request.

3. *TSE-pure*: TSE stocks that are not cross-listed on U.S. markets (384 stocks). Since the stocks included in the first two samples are also traded in the U.S., we have two more samples of stocks that are traded on U.S. markets:
4. *NYA*: The same stocks as those in sample (1), but all data are derived from trading on the NYSE/AMEX (64 stocks).
5. *NAS*: The same stocks as those in sample (2), but all data are derived from trading on Nasdaq (65 stocks).

4.2. Control samples

In conducting our study, it is important to isolate factors that are unrelated to the decimalization, but which can affect the microstructure variables. We initially attempt to match stocks between *TSE-NYA*/*TSE-NAS* and *TSE-pure*, but fail to obtain a meaningful matched sample. The reason we could not find a match is that stocks in the latter sample are relatively inactive compared to those in the former two samples. Thus, we are not able to conduct a formal test on whether the former two samples behave differently from the latter. As a result, we construct pair-wise matched samples for the TSE stocks traded on U.S. markets. This enables us to control for factors that, while unrelated to decimalization, can affect trading costs and volume over time.

Since we have two samples of TSE stocks that are traded on U.S. markets, *NYA* and *NAS*, we construct two control samples:

(4a) *NYA-control*: Control sample from the NYSE/AMEX (64 stocks).
(5a) *NAS-control*: Control sample from Nasdaq (65 stocks).

The matching procedure is similar to that used in Huang and Stoll (1996), who compare execution costs on the NYSE and Nasdaq by matching stocks from two markets, and that used in Cao et al. (1997), who examine trading costs among NYSE specialist firms. Specifically, for each TSE stock traded on the NYSE/AMEX (or Nasdaq), we find a stock from the pool of the NYSE/AMEX (or Nasdaq) stocks that are not cross-listed on the TSE. The matching variables are average share price, daily average number of trades, daily average share volume, and daily average dollar volume. The literature finds that these variables are important determinants of the spread. The specific procedure is as follows: For each stock traded on the NYSE/AMEX (or Nasdaq), we compute the average values of the four matching variables from the pre-decimalization period. For a target stock in the *NYA* (or *NAS*) sample, we identify all stocks outside the *NYA* (or *NAS*) sample and whose prices are different from the price of the target stock by no more than 20%. For each pair of target stock and identified stocks, we calculate the sum of squares of the percentage difference in each matching variable. For a cross-listed stock i and a potential matching stock

j, we calculate

$$\left(\frac{price_i - price_j}{(price_i + price_j)/2}\right)^2 + \left(\frac{Ntrade_i - Ntrade_j}{(Ntrade_i + Ntrade_j)/2}\right)^2 + \left(\frac{Svol_i - Svol_j}{(Svol_i + Svol_j)/2}\right)^2 + \left(\frac{Dvol_i - Dvol_j}{(Dvol_i + Dvol_j)/2}\right)^2, \quad (1)$$

where *price*, *Ntrade*, *Svol* and *Dvol* are averages of prices, daily number of trades, daily share volume, and daily dollar volume on the NYSE/AMEX (or Nasdaq) from pre-decimalization period. The matching stock with the lowest sum of squares is chosen as the matched stock.

5. Empirical results

For the following empirical work, we focus on TSE stocks cross-listed on the NYSE, AMEX, or Nasdaq. We are interested in the behavior of several market microstructure variables during the period surrounding the TSE decimalization. These variables are the quoted bid–ask spread, the effective spread, trading volume, and the ask and bid sizes per quote. To test the hypotheses developed in Section 3, we first calculate the time-series averages of a given variable in the pre-decimalization and post-decimalization periods for each stock. Next we calculate the cross-sectional means, standard errors, and the medians from the time-series averages for each period. Two statistical tests, the t-test and non-parametric Wilcoxon test, are used to test whether the change in the variable from pre- to post-decimalization period is significant.

5.1. Sample characteristics

Table 1 provides cross-sectional means, standard deviations, and medians of the quoted spread, effective spread, proportional quoted spread, proportional effective spread, share price, daily dollar trading volume, daily number of trades, daily share volume, ask size, and bid size per quotes calculated from the $2\frac{1}{2}$-month period prior to the decimalization. If a stock is traded in Canada, the spreads are given in Canadian cents, and the price and dollar volume in Canadian dollars. For a stock traded in the U.S., the spreads are given in U.S. cents, and the price and dollar volume in U.S. dollars.[10]

Panels A and B of Table 1 show that the average share prices are C$25.15 and C$15.61 on the TSE for the stocks cross-listed on the NYSE/AMEX and

[10] For U.S. cents and dollars, we simply use the terms cents and dollars in subsequent discussions.

Nasdaq, respectively. These values convert to \$18.35 and \$11.39 by using the average exchange rate of C\$1.37 per U.S. dollar from the pre-decimalization period. Panels D1 and E1 show that the average prices of the same stocks traded on the NYSE/AMEX and Nasdaq are \$18.40 and \$11.44, respectively. Thus, trading prices are very close in both countries.

By contrast, the quoted bid–ask spreads (and effective spread) differ dramatically for the same stocks traded on different markets. For the stocks cross-listed on the NYSE/AMEX and Nasdaq, the average quoted spreads are 21.76 and 33.48 Canadian cents (equivalent to 15.88 and 24.43 U.S. cents), respectively, on the TSE, which are much smaller than 30.55 and 34.40 cents on the NYSE/AMEX and Nasdaq. Such differences in spreads might reflect differences in the market structure between the TSE and U.S. markets.

Daily trading volume (both in dollars and shares) and daily number of trades reveal that the TSE is faced with strong competition from the NYSE, AMEX and Nasdaq. For example, the median dollar trading volume on the NYSE/AMEX is about 27% ($\$752.64 \times 1.37/3800.07$) of that on the TSE, and the median volume on Nasdaq is about 37% ($\$226.28 \times 1.37 \times 50\%/414.32$) of that on the TSE.[11] The quotation depths on the TSE is nearly twice as much as large on the NYSE/AMEX.[12]

Panel C shows that TSE stocks not cross-listed on U.S. markets are relatively inactive. Although the average price is similar to those stocks cross-listed on Nasdaq, the median daily trading volume (both in dollars and in shares) and the median daily number of trades are much smaller. For this reason, we are unable to match cross-listed stocks with TSE stocks not cross-listed on U.S. markets.

Panels D1 and D2 show that the stock characteristics of the *NYA* sample and its control sample *NYA-control* are similar. For the *NYA* sample, the average stock price is \$18.40, the daily dollar volume is \$5.25 million, and the daily number of trades is 77 trades. For the control sample *NYA-control*, these statistics are \$18.54, \$5.33 million and 76 trades, respectively. In Panels E1 and E2, we provide summary statistics of the *NAS* sample and its control sample *NAS-control*. The difference in share price, trading volume and trading frequency between these two samples is also small. For example, for the *NAS* sample, the average price is \$11.44, the daily dollar volume is \$1.59 million and the daily number of trades is 51 trades. For the control sample *NAS-control*, these statistics are \$11.38, \$1.56 million and 53 trades, respectively. These results suggest that our procedure of constructing the control samples is reasonable.

[11] Prior studies, including Atkins and Dyl (1996), and Gould and Kleidon (1994), point out that actual trading volume on Nasdaq is about 50–65% of reported Nasdaq volume due to the dealer effect on reported volume. We use 50% in the calculation.

[12] We do not analyze quotation depths on Nasdaq because bid and ask sizes recorded on the TAQ database are not meaningful. See the TAQ data manual.

Table 1
Characteristics of sample stocks traded on the TSE, NYSE/AMEX, and Nasdaq

This table reports summary statistics for the quoted spread, effective spread, proportional quoted spread, proportional effective spread, share price, daily dollar volume, daily number of trade, daily share volume, ask-size per quote, and bid-size per quote for stocks in the sample. For a given stock, summary statistics are calculated using intraday transaction data from the $2\frac{1}{2}$-month period prior to April 15, 1996, the day on which the TSE switched to a decimal trading system. The quoted spread is the difference between the ask and bid quotes. The effective spread is calculated as $2|p_t - q_t|$ where p_t is the price at time t and q_t is the midpoint of bid and ask quotes in effect at t. The proportional quoted (effective) spread is the quoted (effective) spread divided by quote midpoint. For quoted and effective spreads, the statistics are given in Canadian cents for stocks traded on the TSE and in U.S. cents for stocks traded on the NYSE/AMEX or Nasdaq. The proportional spreads are given in percent. For share price and daily dollar volume, the statistics are given in Canadian dollars for stocks traded on the TSE and in U.S. dollars for stocks traded on the NYSE/AMEX or Nasdaq.

	Quoted spread	Effective spread	Proportional quoted spread	Proportional effective spread	Price	Daily dollar volume in 1,000's	Daily No. of trades	Daily share volume in 1,000's	Ask-size per quote in 100's	Bid-size per quote in 100's
Panel A. TSE stocks cross-listed on the NYSE/AMEX, but data are from trading on TSE ($N = 64$)										
Mean	21.76	15.86	1.28	0.96	25.15	7420.53	103.55	296.13	128.63	133.80
St. dev.	13.80	7.90	0.97	0.70	17.96	9550.80	106.59	316.37	132.38	138.73
Median	17.40	12.31	0.93	0.65	20.06	3800.07	71.06	148.71	75.16	74.08
Panel B. TSE stocks cross-listed on Nasdaq, but data are from trading on TSE only ($N = 65$)										
Mean	33.48	22.95	2.32	1.70	15.61	1263.95	52.84	93.70	56.11	54.52
St. dev.	41.42	23.24	1.19	0.82	13.52	1685.60	65.03	130.70	56.88	63.17
Median	21.77	15.62	2.18	1.56	10.23	414.32	24.90	43.54	35.00	30.90

Panel C. TSE stocks that are not cross-listed in the U.S. ($N = 384$)

Mean	27.92	21.66	2.22	1.71	15.94	1207.50	28.23	67.90	58.68	56.90
St. dev.	14.95	11.60	1.24	0.95	11.47	3598.67	57.60	130.38	78.80	75.60
Median	23.26	18.00	2.03	1.52	12.58	277.55	10.39	19.86	33.38	34.30

Panel D1. TSE stocks cross-listed on the NYSE/AMEX, but data are from trading on the NYSE/AMEX only ($N = 64$)

Mean	30.55	14.16	2.35	1.10	18.40	5256.92	77.72	209.74	70.00	69.38
St. dev.	14.61	4.76	1.71	0.64	13.12	10643.52	117.97	336.64	83.04	82.83
Median	25.38	12.30	2.10	0.96	14.63	752.64	26.80	67.31	38.75	33.22

Panel D2. Control sample from the NYSE/AMEX ($N = 64$)

Mean	32.79	14.94	2.54	1.14	18.54	5335.37	76.45	197.95	50.40	53.40
St. dev.	15.38	7.70	1.96	0.69	13.33	12238.33	119.94	369.25	75.40	79.20
Median	30.27	13.52	2.00	1.10	13.84	537.94	29.00	66.20	21.76	22.52

Panel E1. TSE stocks cross-listed on Nasdaq, but data are from trading on Nasdaq only ($N = 65$)

Mean	34.40	26.73	4.05	3.11	11.44	1592.81	51.34	89.30	NA	NA
St. dev.	20.06	14.70	2.77	2.07	9.92	5152.88	97.98	171.53		
Median	26.53	22.74	3.41	2.65	7.50	226.28	17.92	33.65		

Panel E2. Control sample from Nasdaq ($N = 65$)

Mean	46.81	37.31	5.56	4.46	11.38	1567.50	53.00	87.85	NA	NA
St. dev.	45.60	38.11	4.91	4.11	9.71	5123.46	101.29	166.14		
Median	33.00	25.92	3.90	3.07	7.83	226.93	17.78	34.00		

5.2. The impacts of the TSE decimalization on spreads

We first analyze the impacts of the TSE decimalization on bid–ask spreads. We use two spread measures. The first is the quoted spread, which is the difference between the ask and bid prices. The second measure is the effective spread, which we define as $2|p_t - q_t|$, where p_t is the transaction price at time t, and q_t is the midpoint of bid and ask quotes prevailing at time t. Since a significant portion of trades are executed at prices in between the bid and ask quotes, [13] the effective spread is a more reasonable measure of the transaction costs paid by investors. For the cross-listed stocks traded on the NYSE/AMEX or Nasdaq, we define the prevailing quote as the latest one among the quotes posted at least five seconds prior to the reported transaction time. We base this treatment on Lee and Ready (1991), who find that trades are often reported with a lag. They suggest comparing trades to the quote reported at least five seconds prior to the trade. Since late reporting is not an issue for stocks traded on the TSE, we do not make the adjustment when analyzing the quotes posted on the TSE.

5.2.1. Spreads on the TSE

Table 2 shows that, for all three samples, both the quoted and effective spreads on the TSE are significantly reduced after the TSE decimalization. All test statistics, from both the nonparametric Wilcoxon tests and the t-tests, strongly reject the null hypothesis that there is no change in the spread or the effective spread from the pre- to the post-event period.[14] We find all test statistics are significant at the 5% level. For TSE stocks cross-listed on the NYSE/AMEX, the reduction in the quoted (effective) spread is 27.4% (26.2%), or four (three) Canadian cents, from 21.8 (15.9) to 17.8 (12.9) Canadian cents on a per-share basis. For the stocks cross-listed on Nasdaq, the quoted (effective) spread decreases from 33.5 (23.0) to 29.7 (20.6) Canadian cents, a 16.3% (15.5%) reduction. TSE stocks that are not cross-listed on U.S. markets also exhibit a reduction in the quoted (effective) spread of 16.8% (15.3%). Results based on the proportional spread show slightly larger reductions. We conclude that the observed spread changes are both statistically and economically significant.

Harris (1994) documents that the impact of the tick-size reduction on the bid-ask spreads is not uniform across stocks. For this reason, we partition each

[13] For stocks traded on the NYSE or Nasdaq, about 20%–38% of the trades are executed at prices better than the bid or ask prices. See Huang and Stoll (1996), Lee and Ready (1991), and McInish and Wood (1995) among many others.

[14] To test whether the change in the spread is zero, we calculate t-statistics (the ratio of percentage change and standard error, both of which are reported in the table). Due to space limitations, we do not report t-statistics in the table.

Table 2
The quoted and effective spreads on the Toronto Stock Exchange (TSE) for cross-listed and non-cross-listed TSE stocks

This table presents the quoted (effective) spread in Canadian cents, the proportional quoted (effective) spread in percent, and percentage change in each of these variables on the TSE for the $2\frac{1}{2}$-month period before and after April 15, 1996. Summary statistics are reported for TSE stocks cross-listed on the NYSE/AMEX or Nasdaq, and for TSE stocks not cross-listed in the U.S. The intraday information is from the TSE database. The quoted spread is the difference between the ask and bid quotes. The effective spread is calculated as $2|p_t - q_t|$ where p_t is the price at time t and q_t is the midpoint of bid and ask quotes in effect at t. The proportional quoted (effective) spread is the quoted (effective) spread divided by quote midpoint. The cross-sectional means, standard errors (in parentheses), and medians are reported.

		TSE-NYA ($N = 64$) Cross-listed on the NYSE/AMEX			TSE-NAS ($N = 65$) Cross-listed on Nasdaq			TSE-pure ($N = 384$) Not cross-listed in the U.S.		
		Before	After	Change (%)	Before	After	Change (%)	Before	After	Change (%)
Quoted spread	Mean	21.76	17.80	− 27.38*	33.48	29.72	− 16.27*	27.92	24.55	− 16.80*
	(S.E.)	(1.72)	(2.18)	(3.46)	(5.13)	(5.00)	(3.20)	(0.76)	(0.92)	(1.43)
	Median	17.40	12.18	− 32.74	21.77	19.84	− 17.60	23.26	18.64	− 22.05
Effective spread	Mean	15.86	12.87	− 26.22*	22.95	20.60	− 15.51*	21.66	19.36	− 15.32*
	(S.E.)	(0.98)	(1.37)	(3.63)	(2.90)	(3.00)	(3.22)	(5.90)	(7.26)	(1.44)
	Median	12.31	8.47	− 32.40	15.62	13.94	− 20.09	18.00	15.02	− 20.24
Proportional quoted spread	Mean	1.28	0.86	− 32.56*	2.32	1.95	− 19.86*	2.22	1.82	− 20.27*
	(S.E.)	(0.12)	(0.09)	(2.64)	(0.15)	(0.16)	(3.40)	(0.06)	(0.06)	(1.30)
	Median	0.93	0.55	− 37.25	2.18	1.56	− 22.50	2.03	1.52	− 23.69
Proportional quoted spread	Mean	0.96	0.64	− 31.30*	1.70	1.40	− 19.41*	1.71	1.43	− 18.30*
	(S.E.)	(0.08)	(0.06)	(2.84)	(0.10)	(0.11)	(3.36)	(0.05)	(0.05)	(1.33)
	Median	0.65	0.42	− 36.02	1.56	1.17	− 23.55	1.52	1.22	− 22.04

* Indicates significance at the 5% level using nonparametric Wilcoxon test.

sample into three equal-sized subsamples based on daily average number of trades in which daily average number of trades proxies for trading activity. Since decimalization can affect trading characteristics of the stock, we use the average number of trades from the pre-decimalization period as the partitioning variable.[15] The results reported in Table 3 show that stocks with a greater trading frequency have a lower spread in the pre-event period. More importantly, stocks with a greater trading frequency experience a greater reduction in the spread. For TSE stocks cross-listed on the NYSE/AMEX, the reductions in the quoted (effective) spreads are 11.6% (8.9%), 28.8% (28.1%), and 41.1% (41.0%), respectively, for the three trading frequency subsamples. The other two samples (*TSE-NAS* and *TSE-pure*) exhibit a similar pattern.

We also examine the time-series behavior of the effective spread. The objective is to investigate whether the spread decreases suddenly after April 14, 1996, or has decreased slowly over time. We calculate the cross-sectional average of the effective spread on each day. Fig. 1 presents the time-series behavior of the cross-sectional average. The plot shows that the effective spread abruptly decreases within a few days after the event day. While this occurs for all three samples, the spread reduction is most clear-cut for TSE stocks cross-listed on the NYSE/AMEX. Clearly, the graph shows that the C $\$\frac{1}{8}$ tick size is a binding constraint in the pre-decimalization period.

Overall, these results suggest that investors could find it less expensive to trade cross-listed stocks on the TSE than on U.S. markets. Therefore, we analyze how U.S. market makers and dealers respond to such pressure from the TSE.

5.2.2. Spreads on U.S. markets for cross-listed TSE stocks

Table 4 reports the quoted and effective spreads for TSE stocks that are also traded on the NYSE/AMEX or Nasdaq (samples *NYA* and *NAS*) and for the stocks in control samples (*NYA-control* and *NAS-control*). For TSE stocks traded on the NYSE/AMEX, the quoted (effective) spreads are 30.6 (14.1) and 30.5 (14.2) cents for pre- and post-decimalization periods, respectively. Thus, there is no significant change in the spread. The control sample does not exhibit a change in the spread either.

Interestingly, TSE stocks traded on Nasdaq exhibit completely different results. For these stocks, there is a 7.8% (11.9%) reduction in the spread (the proportional spread) quoted on Nasdaq from pre- to post-decimalization periods. The reduction is about 4 cents on a per-share basis, which is economically significant. By contrast, for the control sample consisting of similar Nasdaq stocks, there is no significant change in the spread. Similarly, the effective spread (the proportional effective spread) on Nasdaq for the TSE stocks is significantly

[15] Trading frequency and share price are highly correlated. We also partition the sample into three equal-sized subsamples using share price as the partitioning variable. The results are similar and are available upon request.

reduced by 6.1% (12.7%), while the control sample does not experience any significant change in effective spread.

Collectively, the evidence from the TSE is consistent with the hypothesis that decimalization leads to a significant reduction in the spread on the TSE for cross-listed stocks. Due to the increased competition between the TSE and U.S. markets, the TSE decimalization also leads to a significant, although smaller, reduction in the spread on Nasdaq for TSE cross-listed stocks. However, the evidence strongly rejects the hypothesis that following the adoption of decimalization, the increased competition between the TSE and NYSE/AMEX should lead to a significant reduction in the spread on the NYSE/AMEX for TSE cross-listed stocks.

5.3. The impacts of the TSE decimalization on volumes and depths

Following the decimalization in Canada, investors who trade cross-listed TSE stocks on the TSE and Nasdaq can benefit because the effective spread is reduced by a significant amount. However, examining the change in the spread alone cannot tell us whether the change in the tick size will benefit or hurt market makers and specialists. Even though the spread narrowed after the decimalization, the market makers' profits might not have decreased if trading volume increased significantly to offset the impact of decreased per-share profit. We address this issue by examining the changes in trading volume and market depths.

5.3.1. Volumes and depths on the TSE

We use three measures to examine the impact of decimalization on trading volume: daily number of trades, share volume, and dollar volume. For each measure, we calculate the natural log of the ratio of pre-decimalization volume to post-decimalization volume to conduct statistical tests. This transformation is motivated by the fact that all three variables are highly skewed, as shown in Table 1. We use a similar logarithmic ratio for ask and bid sizes to test the change in market depths.

Table 5 presents trading volumes and market depths on the TSE for the three TSE samples. The result shows that share and dollar volumes for stocks cross-listed on the NYSE/AMEX decrease by 19.9% and 16.8%, respectively. Both decreases are significant at the 5% level. In the next subsection, we will show that, for TSE stocks cross-listed on the NYSE/AMEX, volumes on the NYSE/AMEX also decreased by similar percentages, and that there is no net increase in volume on the TSE following the decimalization. For stocks cross-listed on Nasdaq, share and dollar volumes have increased by 9.2% and 13.3%, respectively, and the associated standard deviations are 6.9% and 7.6%. However, these increases are insignificant at 5% level. TSE stocks not cross-listed on U.S. markets exhibit no significant change in share and dollar volumes.

Table 3
The quoted and effective spreads on the Toronto Stock Exchange (TSE) for cross-listed and non-cross-listed TSE stocks (sorted by trading frequency)

This table presents the quoted (effective) spread in Canadian cents and percentage change in the quoted (effective) spread on the TSE for the $2\frac{1}{2}$-month period before and after April 15, 1996. The intraday information is from the TSE database. Stocks in the sample are partitioned into three groups based on average daily number of trades in the pre-decimalization period. The quoted spread is the difference between the ask and bid quotes. The effective spread is calculated as $2|p_t - q_t|$ where p_t is the price at time t and q_t is the midpoint of bid and and ask quotes in effect at t. The cross-sectional means and standard errors (in parentheses) are reported.

Panel A: TSE stocks cross-listed on the NYSE/AMEX (TSE-NYA)

	Ntrade < 31.0 ($N = 21$)			$31.0 \leqslant N$trade < 110.0 ($N = 21$)			$110.0 \leqslant N$trade ($N = 22$)		
	Before	After	Change (%)	Before	After	Change (%)	Before	After	Change (%)
Quoted spread	29.28	27.48	− 11.57*	20.82	16.43	− 28.80*	15.48	9.84	− 41.12*
	(3.20)	(4.48)	(5.76)	(3.58)	(3.82)	(5.71)	(0.72)	(1.64)	(4.95)
Effective spread	20.57	19.69	− 8.85	14.86	11.58	− 28.14*	12.32	7.58	− 41.00*
	(1.95)	(2.83)	(5.92)	(1.90)	(2.23)	(5.81)	(0.32)	(1.05)	(5.34)

Panel B: TSE stocks cross-listed on Nasdaq (TSE-NAS)

	$N\text{trade} < 11.0$ ($N = 21$)			$11.0 \leqslant N\text{trade} < 46.0$ ($N = 22$)			$46.0 \leqslant N\text{trade}$ ($N = 22$)		
Quoted spread	59.93	57.17	− 1.25	24.15	19.79	− 19.90*	17.57	13.43	− 27.00*
	(14.17)	(13.51)	(6.36)	(2.21)	(2.18)	(3.88)	(1.45)	(1.73)	(4.87)
Effective spread	37.87	37.43	0.47	18.10	14.80	− 19.67*	13.57	10.31	− 26.60*
	(7.90)	(7.90)	(5.60)	(1.48)	(1.51)	(4.21)	(1.03)	(1.32)	(5.10)

Panel C: TSE stocks not cross-listed in the U.S. (TSE-pure)

	$N\text{trade} < 6.2$ ($N = 128$)			$6.2 \leqslant N\text{trade} < 17.0$ ($N = 128$)			$17.0 \leqslant N\text{trade}$ ($N = 128$)		
Quoted spread	38.21	35.72	− 7.38*	27.10	23.40	− 16.46*	18.42	14.51	− 26.57*
	(1.46)	(1.80)	(2.76)	(1.01)	(1.26)	(2.28)	(0.72)	(1.02)	(2.08)
Effective spread	29.42	28.20	− 5.17*	20.86	18.43	− 14.25*	14.70	11.44	− 26.45*
	(1.20)	(1.47)	(2.68)	(0.76)	(0.95)	(2.20)	(0.50)	(0.75)	(2.22)

* Indicates significance at the 5% level using nonparametric Wilcoxon test.

Table 4
The quoted and effective spreads on the NYSE/AMEX or Nasdaq for cross-listed TSE stocks

This table presents the quoted (effective) spread in cents, the proportional quoted (effective) spread in percent, and percentage change in each of these variables on the NYSE/AMEX or Nasdaq for the $2\frac{1}{2}$-month period before and after April 15, 1996. Summary statistics are reported for TSE stocks cross-listed on the NYSE/AMEX, or Nasdaq (primary samples). The control samples are constructed by selecting stocks from the same exchange (NYSE/AMEX or Nasdaq) that share similar characteristics as stocks in the primary samples. The intraday information is from the TAQ database. The quoted spread is the difference between the ask and bid quotes. The effective spread is calculated as $2|p_t - q_t|$ where p_t is the price at time t and q_t is the midpoint of bid and ask quotes in effect at t. The proportional quoted (effective) spread is the quoted (effective) spread divided by quote midpoint. The cross-sectional means, standard errors (in parentheses), and medians are reported.

Panel A: TSE stocks cross-listed on the NYSE/AMEX

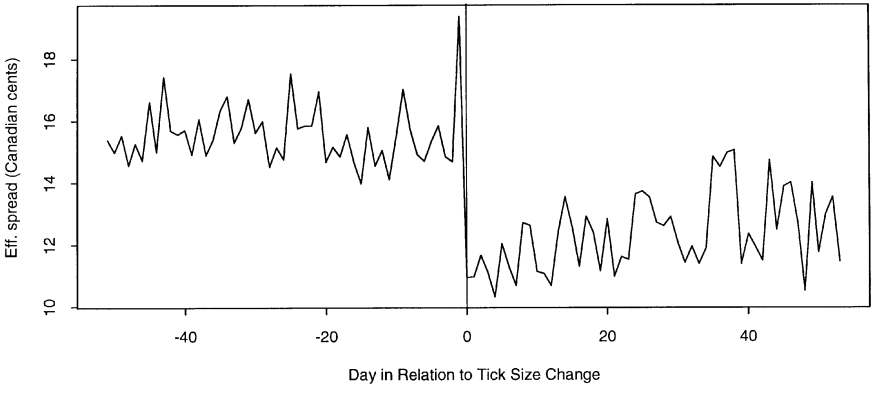
		NYA ($N = 64$) Cross-listed on the NYSE/AMEX			NYA-control ($N = 64$) Control sample from the NYSE/AMEX			Tests H_o: No difference in % spread change between NYA and NYA-control		
		Before	After	Change (%)	Before	After	Change (%)	Difference (%)	T-test {p-value}	Wilcoxon {p-value}
Quoted	*Mean*	30.55	30.54	1.04	32.79	33.11	1.25	− 0.21	{0.92}	{0.56}
spread	(S.E.)	(1.82)	(1.85)	(2.04)	(1.92)	(1.98)	(1.46)	(2.35)		
	Median	25.38	25.75	0.62	30.27	29.11	0.92	− 2.78		
Effective	Mean	14.16	14.22	0.92	14.94	14.72	0.66	0.26	{0.89}	{0.51}
spread	(S.E.)	(0.60)	(0.60)	(1.63)	(0.96)	(0.73)	(1.31)	(1.94)		
	Median	12.30	12.58	− 1.31	13.52	12.90	− 0.81	− 1.08		
Proporational	Mean	2.35	2.27	− 2.86	2.54	2.46	− 3.42	0.56	{0.83}	{0.96}
quoted	(S.E.)	(0.21)	(0.21)	(2.18)	(0.24)	(0.25)	(2.83)	(2.59)		
sprerad	Median	2.10	1.83	− 2.33	2.00	1.98	− 3.02	− 0.04		
Proporational	Mean	1.10	1.07	− 1.94	1.14	1.10	− 2.11	0.17	{0.91}	{0.55}
effective	(S.E)	(0.08)	(0.08)	(1.60)	(0.08)	(0.08)	(1.51)	(2.10)		
spread	Median	0.96	0.91	− 1.59	1.00	0.96	− 1.71	1.89		

Panel B: TSE stocks cross-listed on Nasdaq

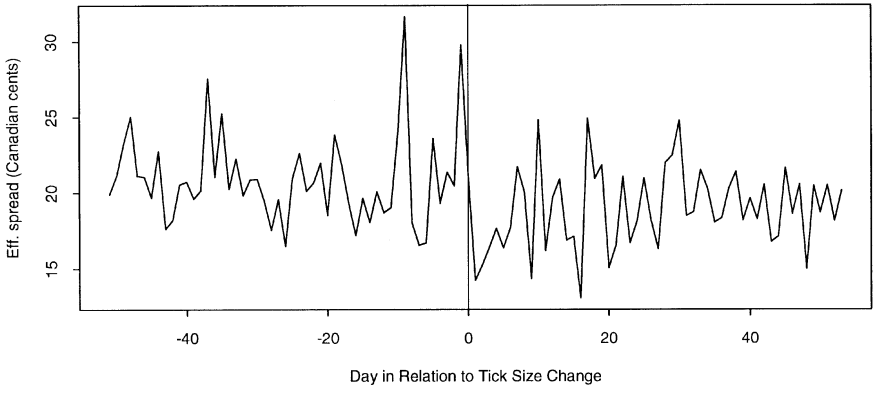
		NAS ($N = 65$) Cross-listed on Nasdaq			NAS-control ($N = 65$) Control sample from Nasdaq			Tests H_0: No difference in % spread change between NAS and NAS-control		
		Before	After	Change (%)	Before	After	Change (%)	Difference (%)	T-test {p-value}	Wilcoxon {p-value}
Quoted	*Mean*	34.40	30.37	− 7.80*	46.81	47.93	2.95	− 10.75	{0.00}	{0.00}
spread	(S.E.)	(2.48)	(1.95)	(2.11)	(5.65)	(5.44)	(2.35)	(3.30)		
	Median	26.53	26.28	− 8.13	33.00	33.70	2.22	− 9.61		
Effective	Mean	26.73	24.40	− 6.10*	37.31	37.82	4.11	− 10.21	{0.01}	{0.01}
spread	(S.E.)	(1.82)	(1.55)	(2.36)	(4.72)	(4.07)	(2.67)	(3.73)		
	Median	22.74	21.68	− 8.23	25.92	26.68	1.24	− 8.44		
Proportional	Mean	4.05	3.45	− 11.85*	5.56	5.42	− 2.47	− 9.38	{0.00}	{0.00}
quoted	(S.E.)	(0.34)	(0.28)	(2.66)	(0.60)	(0.50)	(2.50)	(3.66)		
spread	Median	3.41	2.68	− 12.47	3.90	3.77	− 2.93	− 9.02		
Proportional	Mean	3.11	2.73	− 12.68*	4.46	4.28	− 3.45	− 9.23	{0.02}	{0.02}
efffective	(S.E.)	(0.25)	(0.22)	(2.84)	(0.51)	(0.42)	(2.97)	(4.01)		
spread	Median	2.65)	2.33	− 12.60	3.07	2.97	− 3.20	− 8.76		

* Indicates significance at the 5% level using nonparametric Wilcoxon test.

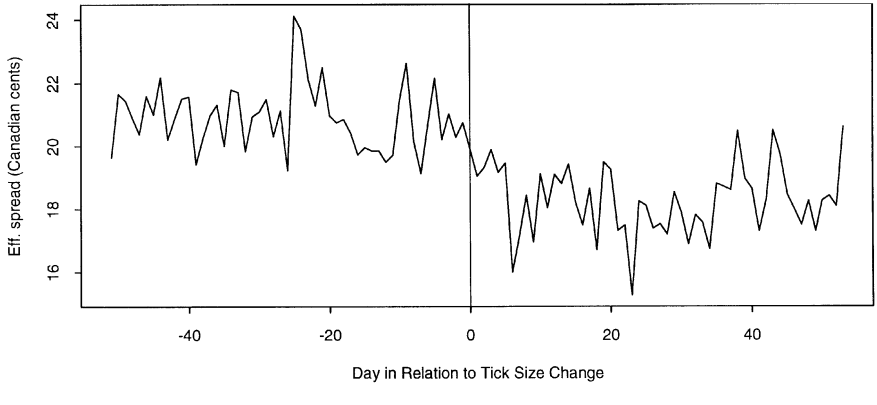
Panel A. TSE Stocks Cross-listed on the NYSE/AMEX



Panel B. TSE Stocks Cross-listed on NASDAQ



Panel C. TSE Stocks not Cross-listed in the U.S.



To better understand the impact of the decimalization on volume, we draw time-series plots of daily average dollar volumes in Fig. 2. These figures do not reveal any significant structural changes in dollar volume for all three samples surrounding the TSE decimalization. One noticeable observation is that trading volume is higher during the first month of the sample period (e.g., February, 1996) relative to those during other months for TSE stocks cross-listed on the NYSE/AMEX (Fig. 2, Panel A). This plot indicates that the decrease in average volume from pre- to post-decimalization period is due to high volume in February, but not due to any significant volume change surrounding TSE's decimalization.[16] For other two measures of volume, daily average share volume and daily average number of trades, the time series plots show similar pattern and are not reported. We provide a formal test, using sample stocks from U.S. markets in the following section.

Another measure of market liquidity, the ask size or bid size per quote, declines significantly for all three samples. The reduction in the ask size is 51% for TSE stocks cross-listed on the NYSE/AMEX, down from 12,863 to 6344 shares. For TSE stocks cross-listed on Nasdaq, the average ask sizes are 5611 and 3565 shares for the pre- and post-decimalization periods, approximately, an 27.7% decrease. TSE stocks not cross-listed in the U.S. show a similar reduction in ask sizes (25.7%). All reductions are economically and statistically significant. Bid sizes also show a similar pattern. The time-series plots in Figs. 3 and 4 confirm that the TSE decimalization has a significant impact on market depths.

5.3.2. Volumes and depths on U.S. markets for cross-listed TSE stocks

In this section, we analyze volumes and depths on the NYSE, AMEX and Nasdaq for cross-listed TSE stocks. As noted earlier, we use two samples, *NYA* and *NAS*, and the corresponding matched samples, *NYA-control* and *NAS-control*.

Table 6 presents a summary of the test results. Panel A shows that for the TSE cross-listed stocks traded on the NYSE/AMEX, there is a significant reduction in all three measures of volume. The reduction in the daily number of trades,

[16] According to official TSE statistics, the aggregated monthly dollar volumes for 300 component stocks of the TSE 300 index are 20,892, 20,628, 16,988, 19,378, 18,751, and 14,596 million Canadian dollars, respectively, for the first six months of 1996. These figures also show a declining pattern in volume for large stocks during the sample period.

Fig. 1. Daily average effective spreads on the TSE for cross-listed and non-cross-listed stocks.

Table 5
The impact of the decimalization on trading volume and market depth on the Toronto Stock Exchange (TSE) for cross-listed and non-cross-listed TSE stocks

This table presents daily number of trades, daily share volume, daily dollar volume, ask size, bid size per quote, and logarithmic change (Log diff. in %) in each of these variables on the TSE for the $2\frac{1}{2}$-month period before and after April 15, 1996. Summary statistics are reported for TSE stocks cross-listed on the NYSE/AMEX or Nasdaq, and for TSE stocks not cross-listed in the U.S. These figures are obtained from trading on the TSE only. The cross-sectional means, standard errors (in parentheses) and medians are reported.

		TSE-NYA ($N = 64$) Cross-listed on the NYSE/AMEX			TSE-NAS ($N = 65$) Cross-listed on Nasdaq			TSE-pure ($N = 384$) Not cross-listed in the U.S.		
		Before	After	Log diff. (%)	Before	After	Log diff. (%)	Before	After	Log diff. (%)
Ntrade	Mean	103.35	85.21	− 19.05*	52.84	50.34	− 0.60	28.23	24.47	− 9.42*
	(S.E.)	(13.32)	(12.75)	(4.30)	(8.06)	(8.08)	(6.26)	(2.94)	(3.16)	(2.58)
	Median	71.06	51.14	− 19.72	24.90	23.35	− 3.38	10.39	9.66	− 9.63
Share Volume in 1000's	Mean	296.13	235.87	− 19.86*	93.70	98.09	9.22	67.90	59.46	− 3.06
	(S.E.)	(39.54)	(30.91)	(6.13)	(16.21)	(16.67)	(6.90)	(6.64)	(5.70)	(4.16)
	Median	148.71	140.16	− 23.08	43.54	45.29	8.53	19.86	20.53	− 3.72
Dollar volume in C$1000's	Mean	7420.53	6177.02	− 16.81*	1263.95	1537.37	13.29	1207.50	1108.38	− 0.95
	(S.E.)	(1193.84)	(1028.67)	(6.34)	(209.07)	(284.45)	(7.64)	(183.40)	(152.46)	(4.19)
	Median	3800.07	3331.11	− 18.97	414.32	507.67	10.05	277.55	245.62	− 2.69
Ask size per quote in 100's	Mean	128.63	63.44	− 51.00*	56.11	35.65	− 27.70*	58.68	38.88	− 25.67*
	(S.E)	(16.54)	(6.42)	(5.21)	(7.05)	(3.35)	(6.53)	(4.00)	(2.64)	(2.72)
	Median	75.16	43.44	− 57.63	35.00	24.45	− 31.00	33.38	27.48	− 26.54
Bid size per quote in 100's	Mean	138.80	67.76	− 51.05*	54.52	36.91	− 24.60*	56.90	39.24	− 26.08*
	(S.E.)	(17.34)	(7.28)	(5.21)	(7.84)	(4.44)	(6.27)	(3.85)	(2.38)	(2.65)
	Median	74.08	47.62	− 50.27	30.90	24.80	− 27.10	34.30	26.90	− 29.00

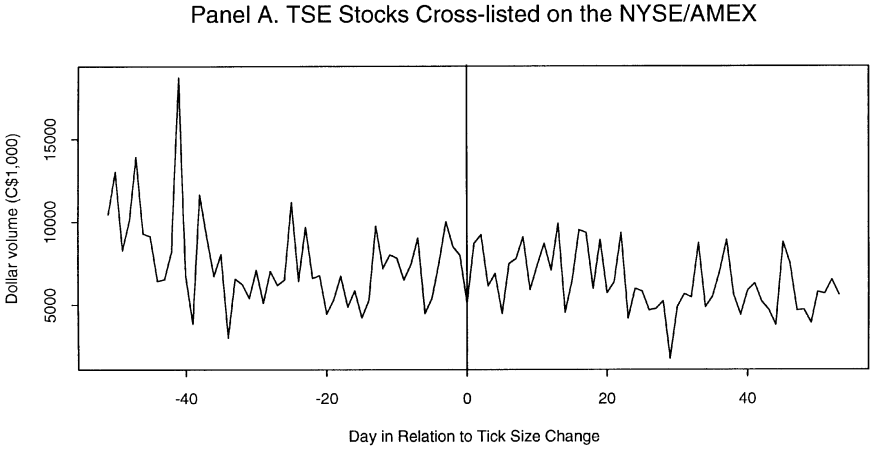
* Indicates significance at the 5% level using nonparametric Wilcoxon test.

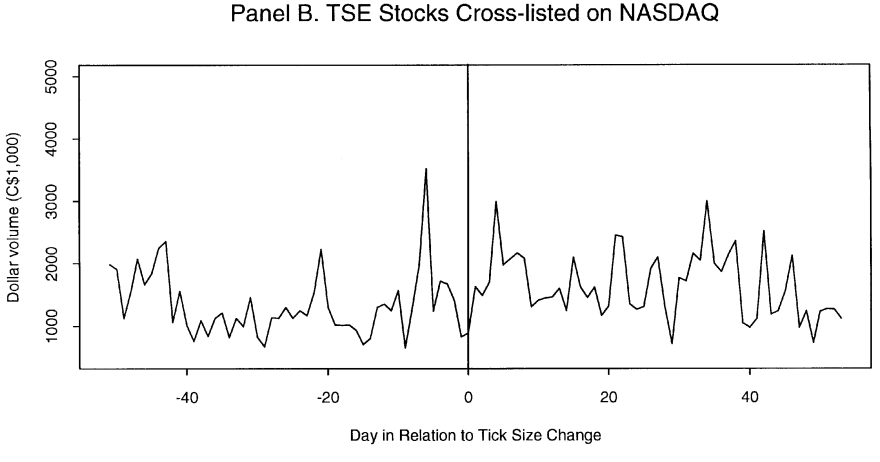
share volume, and dollar volume are 17.8%, 18.8%, and 14.8%, respectively. To further test whether the change in volume is due to the decimalization in Canada, we compare the change in volume for the cross-listed stocks traded on the NYSE/AMEX to stocks in our control sample. For stocks in the *NYA-control* sample, there is also a decrease in trading volume, although the decrease is insignificant. The decreases in number of trade, share volume, and dollar volume are 4.9%, 6.6%, and 1.5%, respectively. The difference in the change in share (or dollar) volume between the two samples, *NYA* and *NYA-control*, is not significant. For example, the difference is -12.3% (-13.3%) for share (dollar) volume, and the associated standard error is 8.3% (8.8%). Thus, after taking into account the reduction in volume of the control sample, the volume reduction on the NYSE/AMEX for TSE cross-listed stocks does not appear to be caused by the TSE decimalization.

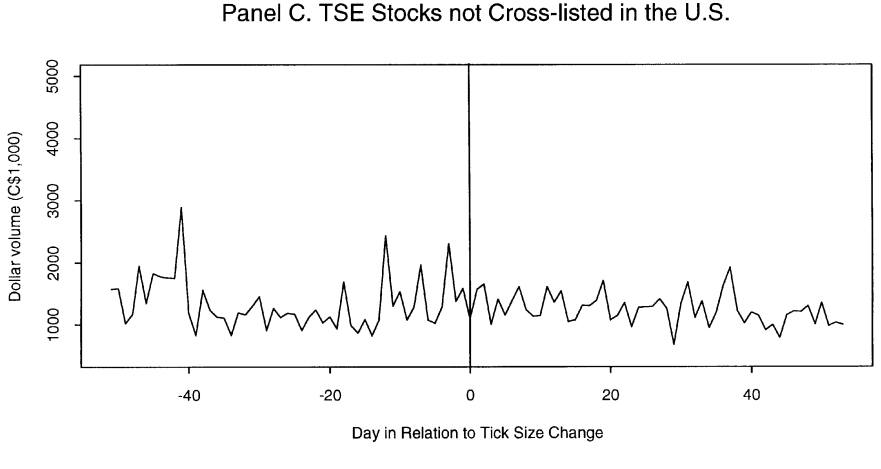
This result helps explain the volume reductions on the TSE for those stocks cross-listed on the NYSE/AMEX. In Table 5, we show that the reductions in the three volume measures on the TSE are 19.0%, 19.9%, and 16.8%, respectively. These numbers are similar to volume reductions on the NYSE/AMEX (i.e., 17.8%, 18.8%, and 14.8%, respectively, in Table 6). The difference in the change of each of these three volume measures is statistically insignificant between two samples, *TSE-NYA* and *NYA*. In other words, the volume reduction on the TSE is similar to that on the NYSE/AMEX in magnitude. This simultaneous reduction in volume is mainly due to high trading volume in the first two months of the year, and not related to TSE decimalization which was effective on April 15, 1996. Tables 5 and 6 together suggest that there is no *net* increase in trading volume on the TSE following the decimalization, and that order flows do not migrate from the NYSE/AMEX to the TSE in the post-decimalization period.

For both measures of market depth, the ask and bid sizes, there is no significant change for both samples of stocks, *NYA* and *NYA-control*. Therefore, the evidence strongly suggests that the significant reduction in ask and bid sizes on the TSE is indeed due to the TSE decimalization.

Panel B shows that trading volumes increase for TSE stocks cross-listed on Nasdaq. However, the rising volume appears to be a general phenomenon on Nasdaq because Nasdaq stocks in the control sample also experienced a significant increase in volume in the absence of spread reduction. For each of the three volume measures, the change from the pre- to the post-event period is insignificantly different between TSE stocks (*NAS*) and their matched sample stocks (*NAS-control*). For example, increases in dollar volume on Nasdaq are 29.3% and 19.1%, respectively, for cross-listed stocks and stocks in the control sample. The difference is 10.2% and the standard deviation is 12.4%. The evidence presented in Tables 5 and 6 together shows that there is no *net* increase in volume on the TSE and no order flow migration from Nasdaq to the TSE.


Panel A. TSE Stocks Cross-listed on the NYSE/AMEX
Dollar volume (C$1,000)
5000
10000
15000
-40
-20
0
20
40
Day in Relation to Tick Size Change


Panel B. TSE Stocks Cross-listed on NASDAQ
Dollar volume (C$1,000)
1000
2000
3000
4000
5000
-40
-20
0
20
40
Day in Relation to Tick Size Change

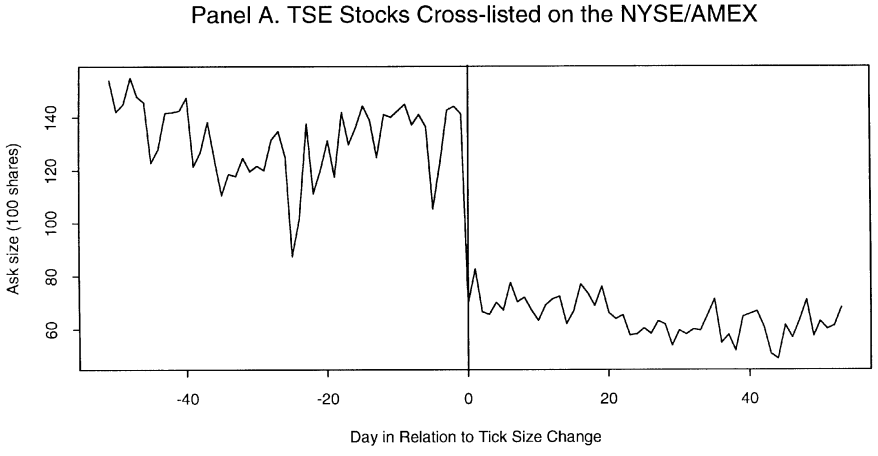

Panel C. TSE Stocks not Cross-listed in the U.S.
Dollar volume (C$1,000)
1000
2000
3000
4000
5000
-40
-20
0
20
40
Day in Relation to Tick Size Change

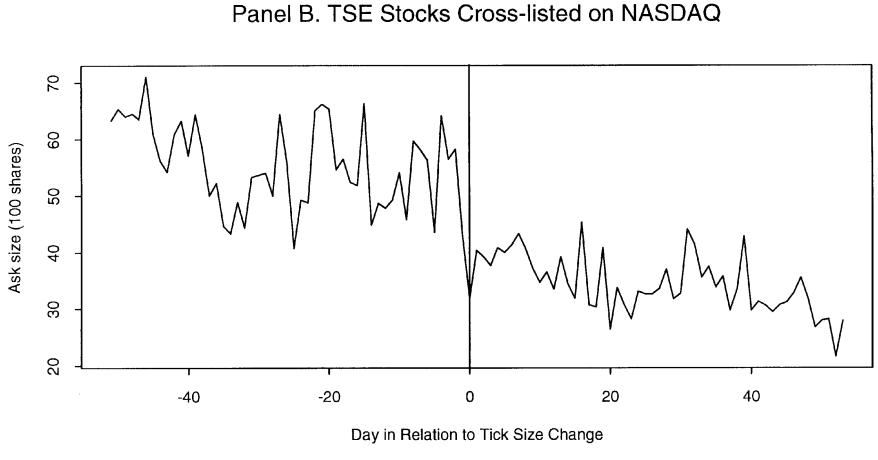
5.4. The net impact of the TSE decimalization on trading costs

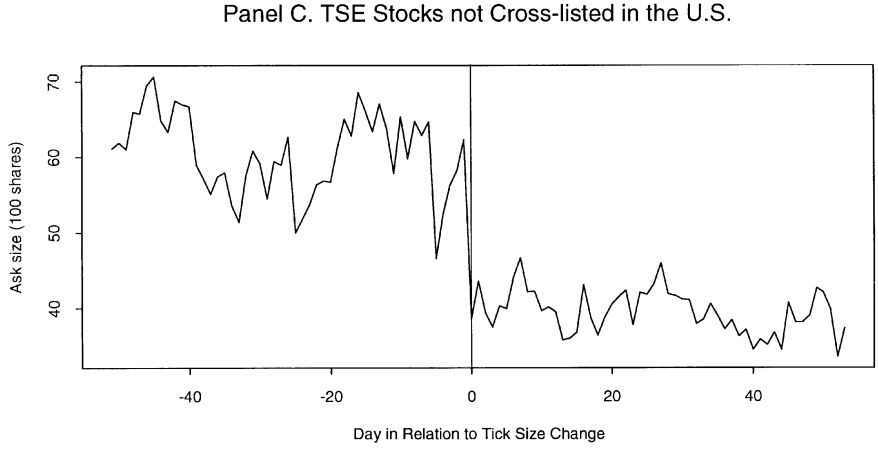
Until now, we have examined spreads and depths separately. The spread on the TSE decreases significantly. However, there is a simultaneous decrease in the depth on the TSE. Given that tighter spreads and smaller depths have opposite implications for market liquidity, a question that remains unanswered is 'What is the net impact of the TSE decimalization on trading costs?' Alternatively, 'Does it cost less to execute the same quantity of shares after the decimalization?' We address this issue in two ways. First, we examine the change in the depth-to-spread ratio, which measures the tradeoff between the spread and the depth. According to Harris (1997), the depth-to-spread ratio can be used to approximate the size of an order that would move prices one percent if the relationship between total size and price is linear. Intuitively, this ratio measures whether the decrease in depth is larger or smaller than the decrease in the spread. In calculating the depth-to-spread ratio for each quote, we use the sum of bid size and ask size divided by the quoted spread. Second, we examine the change in the effective spread on the TSE for each trade size category. This measure quantifies how much less (or more) it costs to execute a given number shares in the post-decimalization period. We partition trade size into five categories: 100–500; 600–1000; 1100–5000; 5100–10,000; and above 10,000 shares, and report the change in the effective spread on the TSE for each trade-size category.

The percentage change in the depth-to-spread ratio is reported in Panel A of Table 7. The increase in the depth-to-spread ratio for TSE stocks cross-listed on the NYSE/AMEX is 4.7%, for TSE stocks cross-listed on Nasdaq is 20.0%, and for TSE stocks not cross-listed in the U.S. is 16.1%. For the first sample, *TSE-NYA*, the depth-to-spread ratio increase is not significant. However, for the latter two samples, *TSE-NAS* and *TSE-pure*, the increases are significant at the 5% level. Panel B of Table 7 reports the percentage change in the effective spread on the TSE by trade size. For all three samples, *TSE-NYA*, *TSE-NAS*, and *TSE-pure*, across all trade size categories, there is a significant reduction in effective spreads. Take the *TSE-NYA* sample as an example, the reduction in the effective spread is 27.7% when the trade size is between 100 and 500 shares, and the reduction is 31.2% when the trade size is above 10,000 shares. The effective spread results suggest that, for any given trade size, execution costs are lower in the post-decimalization period. Overall, the increase in the depth-to-spread ratio and the decrease in effective spreads suggest that the TSE decimalization results in a net decrease in trading costs for TSE stocks.

Fig. 2. Daily average dollar volumes on the TSE for cross-listed and non-cross-listed stocks.


Panel A. TSE Stocks Cross-listed on the NYSE/AMEX
Ask size (100 shares)
60
80
100
120
140
-40
-20
0
20
40
Day in Relation to Tick Size Change


Panel B. TSE Stocks Cross-listed on NASDAQ
Ask size (100 shares)
20
30
40
50
60
70
-40
-20
0
20
40
Day in Relation to Tick Size Change


Panel C. TSE Stocks not Cross-listed in the U.S.
Ask size (100 shares)
40
50
60
70
-40
-20
0
20
40
Day in Relation to Tick Size Change

6. Discussion of results

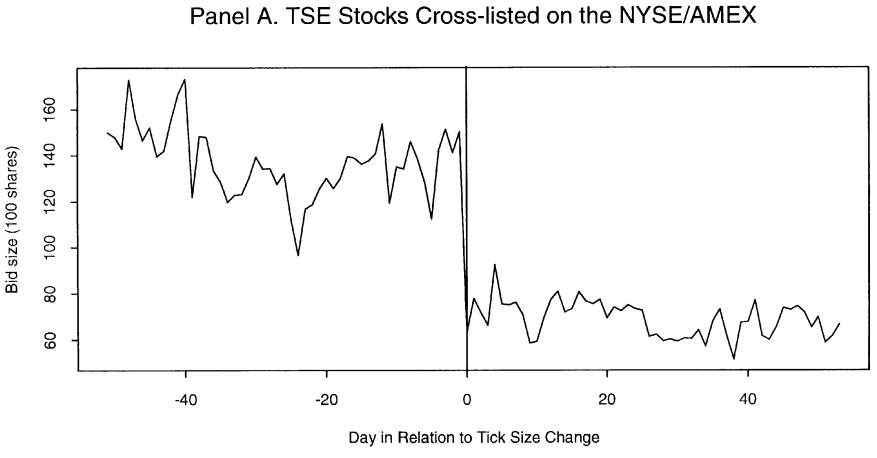
We have documented a significant reduction in both quoted and effective spreads on the TSE for cross-listed stocks following the tick-size change. For the same stocks traded in the U.S., spreads on the NYSE/AMEX do not change, while spreads on Nasdaq decline significantly. Intuitively, these results imply that trading volume should increase on the TSE for two reasons: First, a simple demand-supply theory (Harris, 1994) suggests that both domestic and foreign investors should trade more frequently than before, because the trading costs are lower on the TSE after the decimalization. Second, if there is more than one venue on which to trade the same stock, order flows should go to the market on which the trading costs are the lowest. Therefore, the evidence of no increase in order flows on the TSE and no decrease in order flows on the NYSE/AMEX and Nasdaq is puzzling, especially given the ease of cross-border arbitrage for cross-listed stocks. In this section, we provide several possible explanations for the apparent insensitivity of trading volume to the change in trading costs.

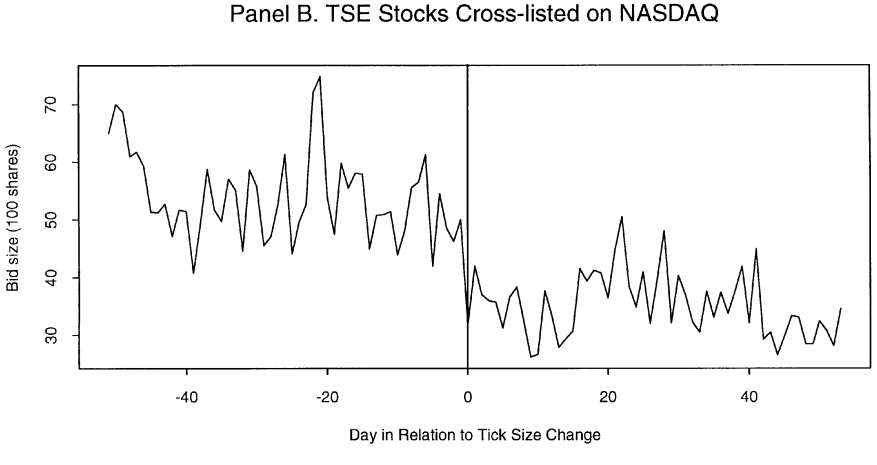
First, trading cost is only one of many considerations that investors use to determine whether to trade more. Other factors, such as tax consequences (e.g., realizing capital losses) and investment objectives, are also important in making trading decisions. For example, long-term investors are less sensitive to trading costs. Certain types of traders are more sensitive to trading costs, such as those who have private information. These traders might compare the value of the information and trading costs before they make a trading decision. If the majority of the investors are not sensitive to trading costs, decreases in trading costs will not affect trading volume significantly.

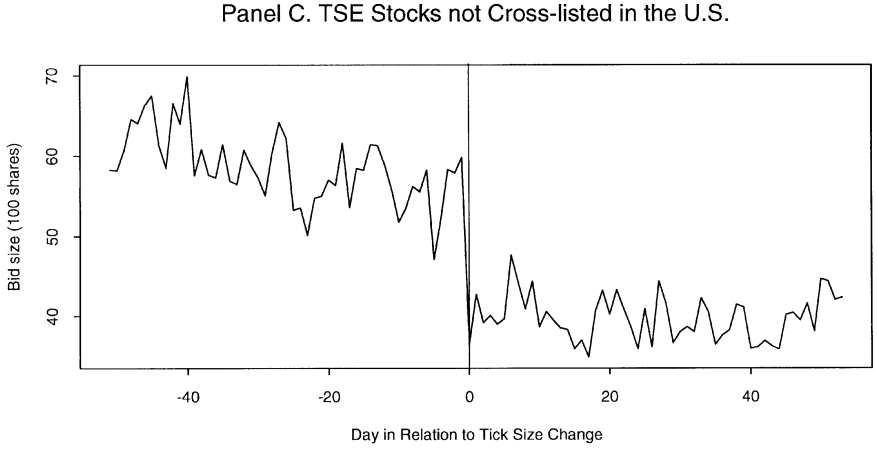
Second, stock exchanges compete with each other on many dimensions, where the bid–ask spread (or trading costs) is only one dimension. Despite evidence that the bid–ask spread is wider on U.S. markets, these markets, especially the NYSE, might provide better liquidity service than the TSE. For example, the NYSE offers block traders superior execution (LaPlante and Muscarella, 1997). Many market participants, including Canadian market makers, believe that it is easier overall to trade in the U.S. (*The Wall Street Journal*, April 15, 1996). If cost savings due to the decrease in the spread cannot offset the benefits of trading on U.S. markets, order flows will not migrate from the NYSE, AMEX, or Nasdaq to the TSE.

Third, there is an asymmetry in the practice of payment-for-order flow in Canada. This practice is prohibited between Canadian dealers and Canadian brokers. While Canadian brokers can not accept payments from Canadian dealers, they are allowed to accept payments from U.S. dealers. For Canadian

Fig. 3. Daily average ask sizes on the TSE for cross-listed and non-cross-listed stocks.


Panel A. TSE Stocks Cross-listed on the NYSE/AMEX
Bid size (100 shares)
60
80
100
120
140
160
-40
-20
0
20
40
Day in Relation to Tick Size Change


Panel B. TSE Stocks Cross-listed on NASDAQ
Bid size (100 shares)
30
40
50
60
70
-40
-20
0
20
40
Day in Relation to Tick Size Change


Panel C. TSE Stocks not Cross-listed in the U.S.
Bid size (100 shares)
40
50
60
70
-40
-20
0
20
40
Day in Relation to Tick Size Change

brokers, especially discount brokers, this practice reduces incentives to forward an order to the TSE rather than to Nasdaq. For U.S. brokers who are engaged in an order purchase agreement with Nasdaq dealers, there is no incentive to forward an order to the TSE. This could be another reason why the volume on the TSE does not increase even though the spread is much smaller on the TSE in post-decimalization period.

Fourth, according to the *TSE Official Trading Statistics* (1995), most NYSE specialist firms and Nasdaq member firms are not TSE member firms and do not have direct operations in Canada. Among large U.S. investment/brokerage firms, only Merrill Lynch, Inc. and Morgan Stanley, Inc. are registered as TSE member firms. This lack of both infrastructure and the logistics of trading operations could hinder U.S. brokerage firms from trading directly on the TSE.

Finally, the impact of the TSE decimalization on trading costs might not have been recognized by traders and investors over a short period of time. Our sample includes only a two and half month after the decimalization. It is plausible that the sample period is not long enough for traders and investors to adequately evaluate the change in trading costs and to adjust trading decisions. An important question is whether the TSE market share and order flow increase over a longer period of time. We leave this question for future research.

The results presented in this paper also provide an important implication for the debate on the efficiency of Nasdaq. We find that the TSE decimalization reduces the spread on Nasdaq by 8% (or 4 cents on a per share basis) for TSE stocks, but does not affect those comparable Nasdaq stocks. It implies that decimalization intensifies competition for order flow by putting pressure on Nasdaq dealers. In response, Nasdaq dealers quote smaller spreads and manage to maintain their market shares. Since the reduction in the spread on Nasdaq for cross-listed stocks occurs without a change in the tick size on Nasdaq, the spreads for the other Nasdaq stocks could be smaller if competitions among dealers were perfect. Hence, Nasdaq dealers do not seem to operate as efficiently as perfect competition warrants. Otherwise, we should not observe a significant reduction in the spread on Nasdaq for cross-listed stocks. Our empirical results support the recent conclusion by SEC that 'Nasdaq market has not always operated in an open and freely competitive manner' (SEC, 1996).

Fig. 4. Daily average bid sizes on the TSE for cross-listed and non-cross-listed stocks.

Table 6
The impact of the decimalization on trading volume and market depth on the NYSE/AMEX or Nasdaq for cross-listed TSE stocks

This table presents daily number of trades, daily share volume, daily dollar volume, ask size, bid size per quote, and logarithmic change (Log diff. in %) in each of these variables on the NYSE/AMEX or Nasdaq for the $2\frac{1}{2}$-month period before and after April 15, 1996. Summary statistics are reported for TSE stocks cross-listed on the NYSE/AMEX or Nasdaq (primary samples). The control samples are constructed by selecting stocks from the same exchange (NYSE/AMEX or Nasdaq) that share similar characteristics as stocks in the primary samples. These figures are obtained from U.S. trading only. The cross-sectional means, standard errors (in parentheses), and medians are reported.

Panel A: TSE stocks cross-listed on the NYSE/AMEX

		NYA ($N = 64$) Cross listed on the NYSE/AMEX			NYA control ($N = 64$) Control sample from the NYSE/AMEX			Tests H_o: No difference in % volume (or depth) change between NYA and NYA-control		
		Before	After	Log diff. (%)	Before	After	Log dif. (%)	Difference (%)	T-test {p-value}	Wilcoxon {p-value}
*N*trade	Mean	7.72	59.14	− 17.76*	76.45	69.10	− 4.85	− 12.91	{0.04}	{0.02}
	(S.E.)	(14.74)	(10.60)	(4.77)	(15.00)	(12.74)	(4.23)	(6.11)		
	Median	26.80	23.80	− 21.12	29.00)	26.44	− 5.50	− 19.46		
Share volume in 1,000's	Mean	209.74	165.73	− 18.82*	197.95	180.43	− 6.56	− 12.26	{0.15}	{0.18}
	(S.E.)	(42.08)	(31.40)	(5.90)	(46.15)	(37.85)	(5.88)	(8.33)		
	Median	67.31	58.28	− 19.72	66.20	73.34	− 8.12	− 10.57		
Dollar volume in U.S.$1,000's	Mean	5256.92	4303.70	− 14.78*	5335.37	5144.33	− 1.48	− 13.30	{0.20}	{0.21}
	(S.E.)	(1330.43)	(1058.46)	(6.32)	(1529.80)	(1407.26)	(6.01)	(8.80)		
	Median	825.54	797.10	− 14.06	537.94	898.50	− 9.62	− 13.34		
Ask size per quote in 100's	Mean	70.00	69.59	− 1.04	50.40	54.86	7.56	− 8.60	{0.35}	{0.60}
	(S.E.)	(10.38)	(9.80)	(6.07)	(9.42)	(12.92)	(8.02)	(9.24)		
	Median	38.75	35.20	2.52	21.76	24.82	8.53	0.90		
Bid size per quote in 100's	Mean	69.38	73.52	3.61	53.40	55.87	43.8	− 0.76	{0.91}	{0.92}
	(S.E.)	(10.35)	(10.15)	(6.30)	(9.90)	(12.42)	(6.35)	(7.41)		
	Median	33.22	36.18	5.81	22.52	25.67	8.37	2.87		

Panel B: TSE stocks cross-listed and traded on Nasdaq

		NAS ($N = 65$) Cross listed on Nasdaq			NAS-control ($N = 65$) Control sample from Nasdaq			Tests H_0: No difference in % volume or (depth) change between NAS and NAS-control		
		Before	After	Change (%)	Before	After	Change (%)	Difference (%)	T-test {p-value}	Wilcoxon {p-value}
Ntrade	Mean	51.34	62.35	20.31*	53.00	62.40	16.09*	4.22	{0.67}	{0.80}
	(S.E.)	(12.15)	(14.64)	(7.44)	(12.56)	(12.94)	(6.33)	(10.03)		
	Median	17.92	25.96	7.50	17.78	19.18	7.80	3.64		
Share volume in 1,000's	Mean	89.30	112.65	24.51*	87.85	97.71	8.90	15.62	{0.19}	{0.38}
	(S.E.)	(21.27)	(24.67)	(9.44)	(20.60)	(20.72)	(6.53)	(11.80)		
	Median	33.65	43.37	8.56	34.00	26.56	12.37	1.13		
Dollar volume in US$1,000's	Mean	1592.81	1860.16	29.37*	1567.50	1660.34	19.15*	10.21	{0.41}	{0.67}
	(S.E.)	(639.14)	(566.67)	(10.15)	(635.48)	(561.62)	(7.40)	(12.40)		
	Median	226.28	325.00	10.48	226.93	304.20	13.75	− 8.07		
Ask size per quote in 100's	Mean	NA								
	(S.E.)									
	Median									
Bid size per quote in 100's	Mean	NA								
	(S.E.)									
	Median									

* Indicates significance at the 5% level using nonparametric Wilcoxon test.

Table 7
The net impact of the TSE decimalization on trading costs

Panel A reports the percentage change in the depth-to-spread ratio on the TSE for the $2\frac{1}{2}$-month period before and after April 15, 1996. Panel B presents, for each trade size category, the percentage change in the effective spread on the TSE for the $2\frac{1}{2}$-month period before and after April 15, 1996. For each quote, the depth-to-spread ratio is calculated as (ask size + bid size)/(quoted spread). The effective spread is calculated as $2|p_t - q_t|$ where p_t is the price at time t and q_t is the midpoint of bid and ask quotes in effect at t. Summary statistics are reported for TSE stocks cross-listed on the NYSE/AMEX or Nasdaq, and for TSE stocks not cross-listed in the U.S.

		TSE-NYA Cross-listed on the NYSE/AMEX Change (%)	TSE-NAS Cross-listed on Nasdaq Change (%)	TSE-pure Not cross-listed in the U.S. Change (%)
Panel A: The percentage change in the depth-to-spread ratio on the TSE				
Depth-to-spread ratio	Mean	4.75	20.05*	16.18*
	(S.E.)	(5.50)	(7.52)	(3.20)
Panel B: The percentage change in the effective spread on the TSE				
Trade size in shares				
100–500	Mean	− 27.70*	− 14.86*	− 13.15*
	(S.E.)	(4.06)	(3.87)	(1.85)
600–1000	Mean	− 27.31*	− 18.00*	− 16.03*
	(S.E.)	(3.81)	(3.70)	(2.09)
1100–5000	Mean	− 22.75*	− 10.61*	− 15.83*
	(S.E.)	(4.23)	(3.75)	(2.62)
5100–10000	Mean	− 42.21*	− 30.07*	− 33.66*
	(S.E.)	(3.38)	(11.88)	(4.83)
Above 10,000	Mean	− 31.23*	− 26.63*	− 31.26*
	(S.E.)	(6.70)	(9.32)	(4.18)

* Indicates significance at the 5% level using nonparametric Wilcoxon test.

7. Conclusions

Focusing on TSE stocks cross-listed on the NYSE, AMEX or Nasdaq, this paper examines the impact of decimalization in Canada on transaction costs, market liquidity, and trading activity in both Canada and the U.S. We find a significant reduction in the spread and quotation depth on the TSE and a significant reduction in the spread on Nasdaq for TSE stocks. However, the decimalization does not affect the spread on the NYSE and AMEX for TSE cross-listed stocks. The most important finding is that despite an economically significant reduction in the spread on the TSE, orders for the cross-listed stocks do not migrate from U.S. markets to the TSE. This result contrasts with the TSE's objective to attract order flows from the U.S. markets and to increase the

market share of the TSE in cross-listed stocks. Our results are consistent with the view that the savings in transaction costs on the TSE are not sufficient to offset the benefits of trading on the NYSE and AMEX, and that Nasdaq dealers might not operate as efficiently as perfect competition warrants.

Our results have several implications. First, competition among exchanges exists in many dimensions; the bid–ask spread is only one of them. Other factors, including the quality of liquidity service, are also important. Second, our finding that the quoted spread on Nasdaq declines by 4 cents on a per share basis for cross-listed stocks but does not change for other comparable Nasdaq stocks suggests that Nasdaq dealers could quote narrower spreads without any rule change on Nasdaq. The total excess cost per year is estimated to be $8.5 million for investors who trade 65 cross-listed TSE stocks on Nasdaq. This estimate is based on the reduction in the effective half-spread after the decimalization and the average daily share volume in the pre-decimalization period.[17] If a similar reduction in the effective spread were applied to other Nasdaq stocks, the estimated excess costs would be much larger. Finally, the practice of payments for order flow goes beyond borders. This practice has existed between Canadian brokers and U.S. dealers for years. Given the restriction that a Canadian broker cannot accept payments for the purchased order from a Canadian dealer but can accept payments from a U.S. dealer, there is little incentive to direct the order to the TSE for execution, even though the TSE offers lower trading costs. Existing studies of market quality and execution costs focus exclusively on the practice of payments for order flow within the U.S. Given that an increasing number of foreign stocks have been cross-listed on the U.S. markets, and that U.S. markets intend to attract more foreign issues, the consequence of this practice for both foreign and domestic investors deserves the attention of both academics and policy makers.

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[17] 1.165 cents × 89,300 shares/day × 252 days × 65 stocks × 50% = $8,520,425, assuming 50% of reported Nasdaq volume is due to the dealer effect on reported volume.

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