Did Decimalization Benefit Members of the Toronto Stock Exchange?

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We examine the impact of adopting decimal price quotes on the welfare of members of the Toronto Stock Exchange (TSX) based on a multivariate analysis of seat prices. Consistent with existing studies, we find that decimalization leads to lower bid-ask spreads as well as lower quoted depths. To see if the combined effect of these changes benefited TSX members, we examine changes in the TSX's market share and total trading volume of interlisted stocks. In addition, we measure the wealth effect of decimalization on the TSX members using a multivariate analysis of seat prices. Our results suggest that TSX members anticipated positive benefits from decimalization, and that the switch to decimal prices had not adversely affected them.

Introduction

The decimalization of the North American market has attracted considerable research interest among academics, exchanges, and the regulatory body.[1] Large

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[1] There have been several changes in tick size in the North American markets. The NYSE converted to decimal pricing in January 2001, and Nasdaq followed in April 2001. In May and June of 1997, the NYSE, Nasdaq, and American Stock Exchange (ASE) reduced the tick size to \$1/16 from \$1/8. In April 1996, the TSX reduced the tick size for most of their stocks to \$0.05. In September 1992, the ASE reduced the tick size to \$1/16 for low priced stocks. There is an extensive literature related to the tick size change. See, for instance, Chung et al., (2004), Bessembinder (2003), Jones and Lipson (2001), Ronen and Weaver (2001), Goldstein and

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numbers of studies look into the effects of decimalization on the trading environments, such as bid-ask spreads, depth, trading volume, etc. These studies in general report reduced bid-ask spreads (quoted, effective, and realized), reduction in the quoted size, and lower return volatility. Although prior studies shed significant light on the effect of decimalization on trade costs, market quality, and inter-market comparison of trading cost, its effect on welfare of the exchange and market makers has received little attention. Yet the welfare of the exchange and its members is one of the key issues that policy makers had in mind, as indicated in the following press release of the Toronto Stock Exchange (TSX):

> We believe that trading in decimal increments will help secure our competitive advantage in the global marketplace. ..... This will benefit all investors in our market. The Exchange and its members will also benefit. (italics added)[2]

In this paper, we contribute to the literature by providing evidence on the effect of decimalization on the welfare of market makers. Using the first decimalization in the North American market, i.e., the TSX decimalization, we examine whether decimalization has delivered the intended benefits to TSX members. In particular, we examine changes in TSX seat prices and changes in the TSX's total trading volume and market share for stocks that are simultaneously interlisted on the TSX and a major U.S. market. A distinctive feature of our study is our focus on TSX seat prices in a multivariate framework to determine whether decimalization has increased the value of membership at the TSX. To the best of our knowledge, our work is unique in examining the effect of the decimalization on TSX members' welfare by looking at changes in seat prices.

We first document a significant reduction both in the bid-ask spread and the quoted depth following the switch to decimal quotes. These results are consistent with the predictions in Harris (1994, 1997, and 1999) and overlap with the evidence in several existing studies on TSX decimalization.[3] We present these results primarily to set the stage for our discussion on the main issues in this paper: analysis of the TSX trading volume, market share, and seat prices.

We then look at the impact of decimalization on trading volume and the TSX market share of total trading volume of interlisted stocks.[4] We find no significant

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Kavajecz (2000), Harris (1999, 1997, and 1994), Bacidore (1997), Ahn et al (1996, 1997), and Weaver and Porter (1997).

[2] This is a statement in 1996 by Rowland Fleming, then president of the TSX, in his summary of the rationale behind the decimal pricing.

[3] See, among others, Bacidore (1997), Ahn et al., (1996, 1997), and Weaver and Porter (1997).

[4] Such an analysis is interesting in view of the evidence in empirical work in the interlisting literature such as Foerster and Karolyi (1998) and theoretic predictions in market microstructure models such as Chowdhry and Nanda (1991). Using a sample of Canadian stocks

changes in both trading volume at the TSX and the TSX market share of the total interlisted trading volume following decimalization. We also do not find, on average, any significant changes in spreads and depths of the interlisted stocks traded on US markets.

The evidence of lower bid-ask spreads, no significant changes in trading volume, and TSX's market share appears to suggest that TSX members' profits may have suffered as a result of decimalization. In order to determine whether decimalization has increased or decreased the welfare of the TSX members, we examine prices from seat sales at the TSX.

If interlisted order flow or domestic trading volume increases or both order flow and trading volume increase, then TSX members are expected to benefit from increased market making and agency revenues. On the other hand, a reduction in the tick size can result in a transfer of wealth from TSX market makers to traders, leaving the net impact on TSX membership an unsettled issue.

The effect of decimalization on market makers' welfare is an unsettled issue in the literature. Existing studies of the TSX decimalization (Ahn, Cao, and Choe, 1997; Bacidore, 1997; and Weaver and Porter, 1997[5]) report a significant decrease in the quoted spreads of 17 to 27 percent and in the quoted depth of 27 to 52 percent, and no statistically significant increase in trading volume.[6] Bacidore's (1997) interpretation of the evidence is that "liquidity providers were adversely affected by the move because the decline in per-share profits was not offset by an increase in trading volume." In contrast, Weaver and Porter (1997) report that the members' trading profits are not adversely affected, and revenue derived from brokerage commissions appears to increase.

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interlisted in the US between 1981 and 1990, Forester and Karolyi (1996) find that the TSX losers, defined as firms that lost as least 30 percent market share to the US market, experienced significant reduction in the post-listing trading costs, while TSX winners, defined as firms that maintained at least 70 percent market share, did not experience significant reduction in trading costs. The authors attribute the result to the TSX market makers' response to the rising competition from the US market. Chowdhry and Nanda (1991), in an extension of Kyle (1985) and Admati and Pfleiderer (1988), predict that a market with lowest trading cost will capture most orders from both liquidity traders and informed traders. Liquidity traders would flow to the market because they prefer trading in a lowest cost market, and informed traders would also flow to the same market, as the informed traders prefer to camouflage their trades in a market with heavy liquidity trading. Hence the market with lowest trading cost emerges as the dominant market, according to this winner-takes-most hypothesis.

[5] Bacidore (1997) focuses on non US-Canada interlisted stocks, and examines the effect of decimalization on the market quality of TSX, while Ahn et al (1997) focus on a sample of U.S.-Canada interlisted stocks, and report no significant migration of order flows to TSX from U.S. Weaver and Porter (1997) use a proprietary dataset to examine the effect of decimalization on the market quality and market makers' profits.

[6] Many studies in the literature referenced in footnote 1 report similar findings, although on a different magnitude depending on samples and study periods.

Concerning Bacidore's interpretation, it is not clear that a simultaneous decline in quoted spreads and depth necessarily had a negative impact on member welfare because a reduction in depth gives the member an ability to change prices more frequently. In addition, a decline in depth reduces the amount of capital the member has at risk at a point in time. Hence, even if the revenue stream is lower, its reduced risk may compensate for the lower revenue. Because seat price is based on capitalized value of the expected profit streams, we believe that it provides an appropriate market-based estimate of the combined effects on discounted future profit streams.

In their analysis of TSX members' trading profit, Weaver and Porter did not control for other factors that are known to affect the members' trading profits, such as aggregate stock price and aggregate trading volume. In contrast, our model of seat price controls for such factors unrelated to decimalization but known to affect members' profits.

The seat prices provide useful information about the net benefit of decimalization on the welfare of TSX members because they impound expectations. If member profits had been expected to rise, but remained constant, seat prices would fall because they are the capitalized value of the expected profit stream. Simply looking at profits would not allow us to judge whether or not members had gained or lost. Examining changes in TSX member profits alone in the absence of a model of expected profits, as in Weaver and Porter (1997), is not sufficient to measure the welfare impact of decimalization. Changes in seat prices incorporate unexpected changes in member profits and indicate the welfare impact of decimalization. The use of seat prices is our main contribution and is the distinct feature of our analysis.

Our analysis of seat prices at the TSX is based on Schwert's (1978) study of the impact of SEC regulation on NYSE and American Stock Exchange (ASE) seat prices. Following Schwert, we relate changes in seat prices at the TSX to innovations in trading volume, price levels, and the announcement of decimalization. Our multivariate regression of seat prices shows that TSX members anticipated some benefits at the time the TSX decided to switch to decimal quotes. Moreover, we do not find any reversal of the abnormal seat price changes following the decimalization in April 1996, which we interpret as evidence that the switch to decimal quote did not adversely affect TSX members.

Data Description

Time-stamped bid and ask quotes, as well as transaction prices, are obtained from the Quotes and Trades files of the TSX transaction records. TSX distributes these tapes on a monthly basis, and our data span February 1996 through September 1996. The Quotes files contain quoted bid and ask prices by dealers on the TSX and the number of shares that are offered at these quotes. The Trades files contain time-stamped records of every trade involving TSX-listed stocks, providing the price, size, and time (to the nearest second) of the transaction.

We obtain monthly trading volume and market share data for interlisted stocks from the TSX Monthly Review. A history of seat sale prices from December 1991 to April 1997 was obtained from TSX. Volume and market share data span February 1995 through September 1996. We only focus on stocks that are interlisted on the TSX and one of the following U.S. venues: the NYSE, the ASE, and Nasdaq. Additionally, we require stocks in our sample to have prices greater than $3.00 because the move to decimal prices only affects such stocks.[7] We find 154 interlisted stocks with prices above $3.00 and for which trade and quotes data are available on the TSX data files.

The Effect of Decimal Prices on Bid-Ask Spreads, Quoted Depth and Order Flow

On April 15, 1996, TSX reduced the minimum price variation (the tick) from $0.125 to $0.05 for stocks priced above $5 and from $0.05 to $0.01 for stocks priced between $3 and $4.99. TSX, along with other Canadian exchanges, is the first among major exchanges in Canada and the US to adopt decimal pricing for all stocks listed on the exchange. In this section, we examine the effect of decimal pricing on bid-ask spreads, depth, and trading volume.

As the effect of decimal pricing would depend on the level of stock price, we first report in Table 1 the cross-sectional distribution of stock prices for 154 stocks in our sample. As another variable to consider is the listing exchange, we report our results for all stocks and for two subgroups. The first subgroup contains stocks listed on the NYSE/ASE, and the second subgroup contains stocks listed on Nasdaq. Overall, results for all stocks are in line with those for two subgroups.

As presented in Panel A of Table 1, cross-sectional average stock price is $18.50 with a median price of $12.93 for all stocks. As reported in Bacidore (1997) and Weaver and Porter (1997), the effect of decimalization on low price stocks tends to be minimal. Roughly 10 percent of our samples have an average price below $5, and there appears to be a fairly even distribution of prices among samples.[8] Table 1 also shows distribution of stock prices for NYSE/ASE stocks in Panel B, and Nasdaq stocks in Panel C. NYSE/ASE stocks have on average higher prices than Nasdaq stocks: the average price for NYSE/ASE stocks is $22.94, and $14.60 for Nasdaq stocks.

[7] Stocks priced below $3.00 are not included in our sample because the April 15 change to decimal quotes did not affect the minimum tick size for these stocks (these were already trading on a tick of $0.01).

[8] Consistent with results in the literature, decimalization has little effect on low-priced stocks in our sample. For stocks with average price higher than $5, the results are in line with results for all stocks. The results by price subgroup are available upon request.

Table 1—Distribution of Average Share Prices

This table reports the cross-sectional distribution of average share price of 154 Toronto Stock Exchange (TSX) stocks with prices over $3.00 and interlisted on major U.S. markets. For each stock, we first calculate the daily mean value of quote midpoints and then calculate the time series mean of the daily mean value of quote midpoints during our study period of March-September, 1996. We report the cross-sectional distribution of the time-series average prices. Panel A contains results for all stocks, Panel B for NYSE/ASE stocks, and Panel C for Nasdaq stocks

		Standard	Percentile						
	Mean	Deviation	5	10	25	50	75	90	95
Panel A: All Stocks N=154									
Share Price ($)	18.5	15.3	3.94	4.93	7.31	12.93	25.48	39.78	48.26
Panel B: NYSE/ASE Stocks N=72									
Share Price ($)	22.94	17.5	5.47	6.54	9.90	18.94	31.57	44.30	56.03
Panel C: Nasdaq Stocks N=82									
Share Price ($)	14.6	11.87	3.94	4.56	6.36	10.18	18.26	31.54	40.78

Our results here support similar findings in the literature. We present these results primarily to set the stage for discussion of seat prices, which is our main issue of the paper.

Bid-Ask Spread Changes on TSX Following Decimalization

Table 2 presents changes in quoted, effective, and average quoted depth for the 154 sample stocks around the introduction of decimalization. The results for all stocks are in Panel A, NYSE/ASE stocks in Panel B, and Nasdaq stocks in Panel C. The numbers from March and early April reflect the trading environment before the introduction of decimal quotes on April 15, 1996. The numbers from late April through September reflect the trading environment after the introduction of decimal quotes. Early and late April comprise the first ten and last ten trading days in April 1996. Other months comprise all trading days in the month. For each period we calculate the average spread and depth for each stock over all the quotes and transactions in the period. We then calculate the changes in these variables for each security from the pre to post-decimalization period. We report the medians of these changes. The significance of median changes is measured using the Wilcoxon sign-rank test statistic.

The median quoted bid-ask spread in March and early April is a little over $0.18. Following the introduction of decimal pricing, the quoted spread declined. The median change in quoted spread from early April to late April is -$0.064 (significant at the 1 percent level). Eighty percent of interlisted firms experienced a reduction in their quoted spreads during this period. A possible concern with using the period immediately following the decimalization is that it may not represent the equilibrium quoting strategy for registered traders (market-makers on TSX). Longer-

term changes following decimalization are likely to provide more stable evidence on changes in bid-ask spreads quoted by market makers on TSX.

Table 2—Changes in Quoted and Effective Bid-Ask Spreads and Quoted Depths around the Introduction of Decimal Pricing on the TSX

Depth refers to the number of round lots quoted by the dealer. Sample of 154 TSX stocks with prices over $3.00 and interlisted on major U.S. markets. Differences in medians are reported along with the p-value (in parentheses) of the sign-rank test of the null hypothesis that the change is zero. Results for all stocks are in Panel A, the NYSE/ASE stocks in Panel B, and Nasdaq stocks in Panel C

	Late April vs. Early April	May vs. March	June vs. March	July vs. March	August vs. March	September vs. March
Panel A: All Stocks N=154						
Quoted Spread ($)	-0.064	-0.047	-0.038	-0.022	-0.046	-0.042
	(0.001)	(0.001)	(0.001)	(0.376)	(0.001)	(0.001)
Effective Spread ($)	-0.047	-0.040	-0.034	-0.020	-0.037	-0.032
	(0.001)	(0.001)	(0.001)	(0.051)	(0.001)	(0.001)
Quoted Depth	-7.5	-11.0	-12.0	-16.8	-16.8	-13.2
(1,000 Shares)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Panel B: NYSE/ASE Stocks N=72						
Quoted Spread ($)	-0.068	-0.058	-0.050	-0.032	-0.060	-0.051
	(0.001)	(0.001)	(0.001)	(0.038)	(0.001)	(0.001)
Effective Spread ($)	-0.052	-0.046	-0.043	-0.032	-0.047	-0.041
	(0.001)	(0.001)	(0.001)	(0.033)	(0.001)	(0.001)
Quoted Depth	-18.5	-16.9	-23.4	-28.7	-26.2	-25.6
(1,000 Shares)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Panel C: NASDAQ Stocks N=82						
Quoted Spread ($)	-0.058	-0.036	-0.025	-0.003	-0.036	-0.029
	(0.001)	(0.001)	(0.092)	(0.545)	(0.001)	(0.001)
Effective Spread ($)	-0.038	-0.025	-0.023	-0.008	-0.031	-0.025
	(0.001)	(0.002)	(0.013)	(0.555)	(0.001)	(0.001)
Quoted Depth	-2.5	-5.1	-7.0	-12.1	-8.7	-6.0
(1,000 Shares)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)

To examine whether the reduction in the quoted spread is permanent, we use March as an anchoring month and examine spreads from May to September relative to March spreads. The median reduction in quoted spreads is between $0.04 and $0.05 (significant at the 1 percent level) for all months except July. The March to July reduction is $0.022. While the July reduction is smaller, it is not significant at the 10 percent level. About three of four interlisted stocks (73.4 percent) have spread reductions from March to May. The reductions appear to be permanent. Seventy-one percent of the interlisted stocks have lower spreads in September than in March.

Changes in the quoted spread may not be the best measure of the change in spreads faced by investors on TSX because not all trades on TSX are executed at the posted quotes. Following Christie and Huang (1994) and Lee, Mucklow, and Ready (1993), we estimate the effective dollar spread as twice the difference between the

transaction price and the midpoint of the bid and ask quotes outstanding at the time of the trade. The median effective spread prior to decimalization is $0.14. This is lower than the $0.18 quoted spread, indicating that not all trades are executed at the quotes. The effective spread in late April is $0.113. The median reduction in effective spread from early April to late April is $0.05 (significant at the 1 percent level). A similar pattern is observed for longer-term changes in effective spreads: large, significant reductions (from $0.03 to $0.04) for all months except July. The July reduction is $0.02 (insignificant at the 10 percent level).

The results for NYSE/ASE stocks in Panel B are in general consistent with results for all stocks in Panel A: quoted and effective spreads all declined. Spreads for Nasdaq stocks also declined but in a lesser degree than those for NYSE/ASE. This probably reflects the fact that Nasdaq stocks tend to be smaller stocks with lower average prices, as reported in Table 1.

Depth Changes on the TSX

Prior to the introduction of decimal prices the median displayed size was 41.5 round lots at the quoted bid and ask prices. Following decimalization the median displayed size shrunk to 32 round lots in May and to 40 round lots in June. The quoted depth in July, August, and September is 28, 29, and 31 round lots, respectively. Table 2 presents the median change in quoted depth around the introduction of decimal prices. The reduction in depth across all time intervals is statistically significant at the 1 percent level.

The reduction in spreads is an improvement in the trading environment for traders; however, it comes at the cost of reduced depth. For small traders the reduction in depth is not a problem. For large trades, the reduction in depth may lead to higher trading costs despite the reduction in quoted spreads because these trades now will have greater price impact. An analysis of trades in July, August, and September reveals that only 16 percent of TSX trades would not have exhausted the quoted depth. The remaining 84 percent of trades were greater than the quoted depth. In these cases the registered trader (RT) would have the opportunity to change the quoted bid or ask price. This effectively would raise the transaction costs of the investor, potentially leaving the registered trader's revenues unaffected. Subgroups results for depth in Panels B and C are qualitatively similar as those subgroup results for spread changes presented earlier.

In the next section, we examine whether trading volume has changed following decimalization. We examine the total trading volume of interlisted stocks as well as the TSX's market share of interlisted trading to see if decimalization has benefited TSX members. The reduction in the bid-ask spread measures could lead to an increase in the total trading activity because it represents a reduction in the cost of trading. Additionally, we would expect the lower spreads to draw market share away from U.S. markets.

Change in Trading Volume

To examine the change in trading volume, we measure the total number of shares traded for each interlisted stock in the months from March to August 1996. We compare these monthly trading volumes in 1996 to each stock's trading volume from the corresponding month in 1995. A similar procedure is followed to examine changes in market share.

Panel A1 of Table 3 shows that there is no significant change in total trading volume for all interlisted stocks from 1995 to 1996. Post-decimalization trading in May is no higher than pre-decimalization trading in May. It appears that the lower spreads associated with decimalization did not increase trading in TSX interlisted stocks. This result is consistent across all the months examined. Results for NYSE/ASE stocks in Panel B1, and Nasdaq stocks in Panel C1 show similar patterns to the results for all stocks.

We also compare actual post-decimalization trading volume with the predicted trading volume based on a univariate time-series model. Specifically, we model percentage changes in trading volume as an autoregressive process of order 1.[9] Our results, not reported in the tables, show no significant difference between the actual and predicted trading volume during the months of May and June 1996. For May the actual percentage change in trading volume is 1.78 percent, while the predicted increase is 8.65 percent. The difference of -6.87 percent is not statistically significant, with a p-value of 0.45. For June, the actual percentage change in trading volume is -16.1 percent, while the predicted change is -1.54 percent. The difference of -14.6 percent, while large, is not statistically significant, with a p-value of 0.2.

Change in TSX's Share of Interlisted Order Flow

Panel A2 of Table 3 shows that decimalization is not associated with an increase in the TSX market share of all interlisted trading. In May 1995 the TSX captured 53 percent of interlisted trading. In May 1996 the TSX market share was 54.9 percent. This 1.9 percent increase is not statistically significant. None of the other measured changes in market share is significantly different from zero either. Subgroup results in Panel B2 and C2 show a similar pattern as those for all stocks (in Panel A2).

The reaction of specialists/market makers in U.S. markets to decimalization is a possible explanation for the inability of the TSX to gain trading volume and market share. If U.S. market makers reacted to decimalization by reducing spreads and/or increasing depth, the competitive advantage of decimalization could have been countered. In reality, market makers in U.S. markets did not reduce spreads or increase depth following decimalization on the TSX. The inability of the TSX to

[9] The AR(1) coefficient is negative and statistically significant. The null hypothesis of an AR(1) model for trading volume is not rejected based on the Box-Ljung statistic for lags of the residual autocorrelation function.

draw increased market share from its lowered spreads can not be explained by a competitive response by U.S. market makers that reduced TSX's comparative advantage.

Table 3—Changes in Trading Volume (in thousand shares) and TSX Market Share (in percentage) for TSX Stocks over $3.00 and Interlisted on a Major U.S. Exchange

Comparison of 1995 and 1996 trading volume and market share for interlisted stocks. Test statistics are based on paired differences. Results for all stocks are in Panel A, the NYSE/ASE stocks in Panel B, and NASDAQ stocks in Panel C.

	March	April	May	June	July	August
Panel A: All Stocks						
A1: Volume						
1995	8,101	6,324	6,884	6,971	6,206	6,138
1996	6,858	7,544	7,036	6,677	6,288	5,291
Change	-1,243	1,220	152	-294	82	-847
(p-value)	(0.11)	(0.07)	(0.81)	(0.61)	(0.90)	(0.12)
A2: Market Share (%)						
1995	50.1	52.8	53.0	52.0	53.4	50.0
1996	52.7	51.2	54.9	51.8	52.5	50.3
Change	2.6	-1.6	1.9	-0.2	-0.9	0.3
(p-value)	(0.21)	(0.40)	(0.37)	(0.93)	(0.62)	(0.88)
N	112	113	115	119	127	124
Panel B: NYSE/ASE Stocks						
B1: Volume						
1995	10,478	8,921	9,574	9,391	8,598	7,933
1996	9,713	9,882	8,420	8,976	8,881	7,650
Change	-765	961	-1,154	-415	283	-283
(p-value)	(0.33)	(0.38)	(0.19)	(0.66)	(0.79)	(0.68)
B2: Market Share (%)						
1995	53.7	55.3	53.9	53.6	53.5	52.2
1996	56.0	53.3	61.5	55.1	57.2	53.8
Change	2.3	-2.0	7.6	1.5	3.7	1.6
(p-value)	(0.43)	(0.48)	(0.02)	(0.53)	(0.11)	(0.57)
N	60	61	61	61	64	62
Panel C: NASDAQ Stocks						
C1: Volume						
1995	5,358	3,278	3,846	4,426	3,776	4,343
1996	3,563	4,803	5,474	4,260	3,655	2,932
Change	-1,795	1,525	1,628	-166	-121	-1,411
(p-value)	(0.21)	(0.04)	(0.09)	(0.81)	(0.87)	(0.09)
C2: Market Share (%)						
1995	45.9	49.8	52.0	50.3	53.3	47.8
1996	48.9	48.7	47.5	48.4	47.7	46.8
Change	3.0	-1.1	-4.5	-1.9	-5.6	-1.0
(p-value)	(0.33)	(0.65)	(0.11)	(0.44)	(0.07)	(0.71)
N	52	52	54	58	63	62

Seat Prices on the TSX

In this section we examine the behavior of TSX seat prices around the time TSX announced it was moving to decimal prices. We use seat sale prices from December 1991 through April 1997. There were 22 seat sales ranging from C$45,000 to C$65,000 over this period.

Schwert (1977, 1978) documents that NYSE seat prices over the period from 1926-72 are positively related to unexpected changes in the volume of shares traded on the exchange. If the move to decimalization was expected to benefit TSX members, seat prices should increase at the time of the announcement.

In the previous section we document that the reduction in the tick from $0.125 to $0.05 is associated with a reduction in bid-ask spreads and no significant change in trading activity. Ceteris paribus, the reduction in spreads should result in savings for traders. Bacidore (1996) contends that the reduction in tick size has caused a wealth transfer from brokers to small traders. In contrast, Weaver and Porter (1997) present evidence that TSX member profits do not change following decimalization. In this section we analyze the value of TSX membership, which will allow us to infer the magnitude of any wealth gains or losses of TSX members.

Our analysis of seat prices follows Schwert (1978). Before presenting our analysis of seat prices, we provide some institutional details about TSX membership. There were 136 authorized seats held by 101 member-owners. The market for seats is private, although the exchange has to approve all transfers. Other than approval of transfers, the TSX role is limited to recordkeeping. Seat holders trade at reduced costs. They participate on the exchange in any or all of the following capacities: (1) *Order traders* handle the equity trades for non-members or their own accounts; (2) *Option traders* handle option trades for non-members or their own accounts; (3) *Registered traders (RTs)* are akin to specialists on the NYSE and provide market-making services for designated stocks.

TSX membership allows a seat holder to profit from any or all of these activities. The decline in bid-ask spread has direct effects on profits from market making of the registered traders. On the one hand, the decline in spreads in combination with a decrease or no change in volume will reduce, *ceteris paribus,* the value of market making activities and lower the value of a membership. On the other hand, an increase in trading activity and stock price levels should have a positive impact on seat prices because both broker commissions and registered trader revenues increase as a function of trading activity and price levels. Because options traded on the TSX are not affected by the move to nickel ticks, the value of the seat that is related to profits from these activities is not expected to change.

Following Schwert (1978), we model unexpected changes in seat prices as a function of the unexpected change in the level of prices of TSX-listed stocks and the unexpected change in trading volume. Our model of seat prices controls for changes in seat price that are not related to decimalization. The model allows us to analyze

abnormal seat price changes around the announcement of the decision to switch to decimal quotations.

To estimate the model, we use the TSX seat prices, the aggregate TSX trading volume, and the level of the TSX Price Index, spanning a period from December 1991 to April 1997. We obtained seat prices from the transaction record provided by TSX and trading volume and index values from TSX monthly reviews. We calculate percentage changes in these series and decompose the changes into expected and unexpected components using a time series analysis of the univariate series.

The first panel in Figure 1 shows the monthly percentage changes in seat prices over this period. We note that TSX seats are infrequently traded—only 22 of the 65 months examined have seat sale transactions. The infrequent trading poses difficulties in using monthly returns because non-trading months appear to show a zero-return even when factors that affect the value of TSX membership show non-zero changes. This can cause current changes in seat prices to be related to lagged values of prediction errors. To address this, we model an autoregressive error process in our seat prices.

The second panel in Figure 1 shows the unexpected percentage changes in monthly trading volume on the TSX. Percentage changes in volume $\{q_t\}$ are decomposed into expected components $\{\hat{q}_t\}$ and unexpected components $\{\hat{u}_t\}$ using a time series model. The percentage changes are found to follow an MA(4) process.[10] The expected percentage change in trading volume is given by

$$\hat{q}_t = 0.013 + 0.519 * \hat{u}_{t-1} - 0.080\hat{u}_{t-2} - 0.193\hat{u}_{t-3} + 0.273\hat{u}_{t-4}$$

The unexpected percentage change in trading volume is then calculated as

$$\hat{u}_t = q_t - \hat{q}_t$$

The time series of unexpected changes in trading volume supports our earlier evidence of no increase in trading volume following the decimalization. Specifically, if the move to decimal pricing caused changes in trading volume, there would be noticeable spikes in the time series of the unexpected changes in trading volume. We do not find any such shifts, indicating that the reduction in the tick did not result in increased trading volume.

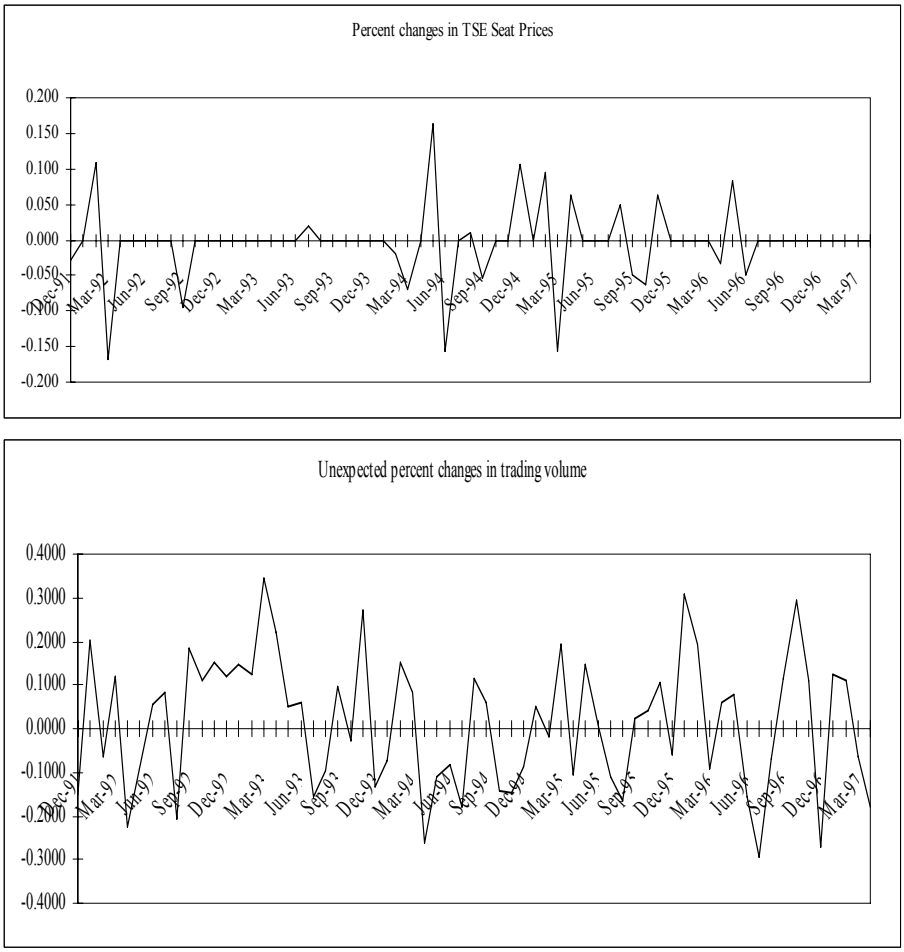
We estimate the relation between changes in seat prices and unexpected changes in the TSX price index value and trading volume using the following regression model:

$$r_t = \alpha + [\gamma_0 + \gamma_1 L]\hat{u}_t + [\beta_0 + \beta_1 L]r_{mt} + \left[1 - \sum_{\tau=1}^{6} \theta_\tau L^\tau\right]\varepsilon_t$$

[10] Schwert (1977) finds that an MA(4) model describes the percentage changes in NYSE and ASE trading volume.

Figure 1–Time Series Characteristics of Percent Changes in TSX Seat Prices and Unexpected Percentage Changes in Trading Volume

Unexpected trading volume is derived from an MA(4) model of the percentage changes in TSX monthly trading volume



r_t = Monthly percentage change in TSX seat price

$\hat{u}_t$ = Monthly unexpected percentage change in trading volume.

r_{mt} = Monthly percentage change in TSX price index

L^τ = Lag operator. $L^\tau X_t = X_{t-\tau}$

Lagged values of changes in the TSX price index, the unanticipated trading volume, and the error terms are included in the model to help alleviate problems associated with the thin trading of TSX seats. The results from estimating the model are presented in Table 4. The model explains 42 percent of the variation in seat prices. Aside from the high R^2 of the model, we note the following additional points.

Table 4—Estimation of the Relation between Changes in TSX Seat Prices and Unanticipated Changes in Trading Volume and Price Levels

The relation below is estimated using seat prices from 22 transactions occurring between December of 1991 and April of 1997. In months where there is no seat transaction, a zero return is assumed.

$$r_t = \alpha + [\gamma_0 + \gamma_1 L]\hat{u} + [\beta_0 + \beta_1 L]r_{mt} + \left[1 - \sum_{\tau=1}^{6} \theta_\tau L^\tau\right]\varepsilon_t$$

r_t is the monthly percentage change in TSX seat price, $\hat{u}_t$ is the monthly unexpected percentage change in trading volume, r_{mt}: monthly percentage change in TSX Price Index and L^τ: lag operator. $L^\tau X_t = X_{t-\tau}$

	Estimate	t-statistic	Approximate p-value
$\hat{\alpha}$	-0.006	-2.58	0.01
$\hat{\gamma}_0$	-0.0668	-1.73	0.09
$\hat{\gamma}_1$	0.0141	0.364	0.72
$\hat{\beta}_0$	0.599	3.22	0.00
$\hat{\beta}_1$	-0.047	-0.24	0.81
$\hat{\theta}_1$	0.555	3.96	0.00
$\hat{\theta}_2$	0.366	2.39	0.02
$\hat{\theta}_3$	0.266	1.69	0.10
$\hat{\theta}_4$	0.315	2.03	0.05
$\hat{\theta}_5$	0.344	2.23	0.03
$\hat{\theta}_6$	0.030	0.21	0.83
R^2	0.419		

First, the estimated relation between unexpected trading volume and changes in seat prices is negative. The coefficient on $\hat{u}_t$ is -0.067 (p-value = 0.09). The negative coefficient is contrary to expectations, but could result from the infrequency of TSX seat transactions. For example, Schwert (1977) finds no significant relation between changes in American Stock Exchange seat prices and contemporaneous unexpected changes in trading volume over the period from 1946 to 1972. This time period is characterized by relatively infrequent seat transactions on the American Stock Exchange. Our data prevent us from investigating this issue more thoroughly. We do estimate the regression model with the volume variable omitted, however, and find similar results.

Second, we note that changes in the TSX price index have a significant positive effect on TSX seat prices. The estimated coefficient on the percentage change in the price index is 0.60 (p-value < 0.01), indicating that TSX seats are more valuable when stock prices are high. This result is consistent with a model of seat prices where members' revenues are a function of price-based commissions and with the results in Schwert (1977).

To examine whether decimalization has affected seat prices, we analyze the residuals from the model of seat prices estimated above around the time that the intent to switch to decimal prices became known to TSX members. We use the TSX press releases related to decimalization to fix the time when members become aware of the impending switch to nickel ticks. In addition, we spoke with several TSX officials and confirmed the legitimacy of our event windows. The press release dates are presented below.

Date	Press Release
May, 1994	The TSX is in a position to switch to decimal quotes.
July, 1995	The TSX will trade in decimals rather than eighths. Suggests trading increments smaller than $0.125. Sets Fall of 1995 as period for announcing actual details of the plan.
October, 1995	Announces new tick schedule

Discussions with exchange officials indicated that the exchange members anticipated the May 1994 announcement. So although the announcement was made at the end of May, we believe that the May seat transaction reflected this information. The May 1994 announcement made TSX members aware of the possibility of decimal quotes and started discussion of the switch in the exchange community. As such, the July 1995 announcement was anticipated. A TSX official estimates that members had knowledge of the information in the July 1995 announcement as early as December 1994. The October 1995 announcement probably was anticipated by the members of the exchange as it only provided specific details of the previously announced plan to decimalize price quotations at TSX.

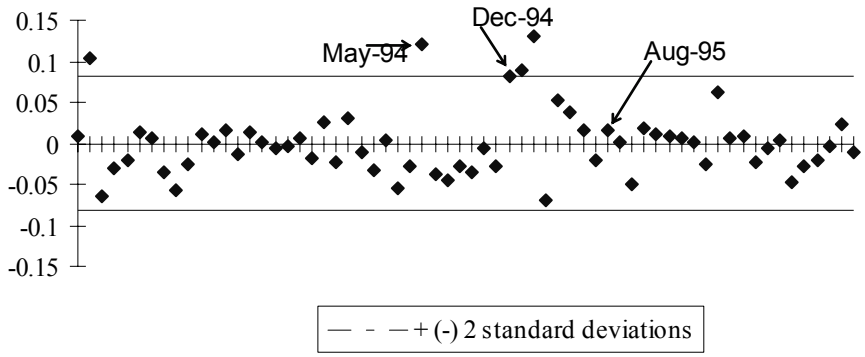
The discussion above leads to our choice of event dates. News about decimalization, and therefore changes in expected cash flows from membership occurred in May of 1994 and over the period from December 1994 to July 1995. Figure 2 plots the residuals from the model of seat price changes. It details the unexpected changes in seat prices over these information arrival intervals. The unexplained change in seat price for May 1994 is +12.3 percent and is statistically significant at the 5 percent level. The next significant unexpected changes in seat prices occur in December 1994 and in January and February 1995. These months span the beginning of the period over which TSX members became aware of the impending switch to decimal quotes. All of these abnormal changes in seat prices are positive and significant at the 5 percent level, indicating that TSX members *expected* to benefit from decimalization.

Figure 2—Residuals from the Model of Changes in TSX Seat Prices

The relation below is estimated using seat prices from 22 transactions occurring between December of 1991 and April of 1997. In months where there is no seat transaction, a zero return is assumed.

$$r_t = \alpha + [\gamma_0 + \gamma_1 L]\hat{u} + [\beta_0 + \beta_1 L]r_{mt} + \left[1 - \sum_{\tau=1}^{6} \theta_\tau L^\tau\right]\varepsilon_t$$

r_t is the monthly percentage change in TSX seat price, $\hat{u}_t$ is the monthly unexpected percentage change in trading volume, r_{mt} : monthly percentage change in TSX Price Index and L^τ : lag operator, i.e., $L^\tau X_t = X_{t-\tau}$



Since it is difficult to pin down the exact month that TSX members became aware of the October 1995 announcement, we also estimate the monthly unexpected change in seat prices over the period December 1994 to August 1995 using an indicator variable approach. Specifically, we include the following variables in our model of seat price changes:

$$d_{1t} = \begin{cases} 1 \text{ if } t = \text{May}, 1994 \\ 0 \text{ else} \end{cases}$$

$$d_{2t} = \begin{cases} 1 \text{ if December}, 1994 \le t \le \text{August}, 1995 \\ 0 \text{ else} \end{cases}$$

As an alternative, we omit d_{1t} and redefine d_{2t} over the entire May 1994 through August 1995 window as:

$$d_{2t} = \begin{cases} 1 \text{ if May}, 1994 \le t \le \text{August}, 1995 \\ 0 \text{ else} \end{cases}$$

These results are reported in Table 5. The estimated coefficient on the May 1994 indicator variable indicates that TSX seats experienced a significant abnormal return of +7.5 percent in that month. Clearly, at this time, TSX members believed that a switch to decimal prices would benefit them. This interpretation is supported by the coefficient on the December 1994 to August 1995 indicator variable. Over this

period members became aware of the impending switch. The average monthly abnormal change in seat price over this period is +1.5 percent (p-value = 0.03).

The second column presents the results using the alternative formulation of the indicator variable. In this regression the indicator variable isolates all seat price changes between the first announcement in May 1994 indicating the possibility of decimal trading to the final announcement of its eventuality in July 1995. The estimated average monthly abnormal return to seat holders is a significant +1.2 percent. Overall, the evidence supports the proposition that TSX members viewed the move to decimal quotes as beneficial.

The third and fourth columns re-estimate the relation omitting the unexpected changes in trading volume. We do this because of the anomalous estimated effect of unexpected trading volume on seat price changes. If unexpected volume is high during the event months, the model including it would predict low seat prices. This in turn would yield positive residuals if the estimated negative relation is incorrect. We find that omitting unexpected volume has no effect on the estimated information effects in the event months. The results in third and fourth column are consistent with those in columns one and two.

Table 5—Estimation of the Relation between Changes in TSX Seat Prices and Unanticipated Changes in Trading Volume and Price Levels

The relation below is estimated using seat prices from 22 transactions occurring between December of 1991 and April of 1997. In months with no seat sales, a zero return is assumed. The regression model is:

$$r_t = \alpha + \left[\gamma_0 + \gamma_1 L\right]\hat{u} + \left[\beta_0 + \beta_1 L\right]r_{mt} + \delta_1 d_{1t} + \delta_2 d_{2t} + \left[1 - \sum_{\tau=1}^{6}\theta_\tau L^\tau\right]\varepsilon_t$$

where r_t is the monthly percentage change in TSX seat price, $\hat{u}_t$ is the monthly unexpected percentage change in trading volume, r_{mt} is the monthly percentage change in TSX Price Index, d_{1t} and d_{2t} are dummy variables during information months and L^τ is the lag operator: $L^\tau X_t = X_{t-\tau}$. Estimates of the error process are not reported. P-values are in parentheses

	$d_{1t}: t = 5/94$		$d_{1t}: t = 5/94$	
	$d_{2t}: t = 12/94 - 8/95$	$d_{2t}: t = 5/94 - 8/95$	$d_{2t}: t = 12/94 - 8/95$	$d_{2t}: t = 5/94 - 8/95$
$\hat{\alpha}$	-0.011	-0.011	-0.012	-0.011
	(0.001)	(0.001)	(0.001)	(0.001)
$\hat{\gamma}_0$	-0.043	-0.045		
	(0.260)	(0.216)		
$\hat{\gamma}_1$	0.023	0.027		
	(0.530)	(0.465)		
$\hat{\beta}_0$	0.620	0.628	0.595	0.587
	(0.001)	(0.001)	(0.001)	(0.002)
$\hat{\beta}_1$	-0.001	-0.007	-0.003	0.012
	(0.998)	(0.968)	(0.987)	(0.947)
$\hat{\delta}_1$	0.075		0.087	
	(0.059)		(0.020)	
$\hat{\delta}_2$	0.015	0.012	0.016	0.013
	(0.027)	(0.014)	(0.013)	(0.003)
R^2	0.491	0.475	0.480	0.460

The evidence from the seat price change regressions indicates that TSX members believed that the move to decimal prices would benefit them. How does this reconcile with the effects of decimalization on trading volume and bid-ask spreads? Specifically, our finding of no significant increase in trading volume and a decrease in bid-ask spreads following decimalization raises questions about the ability of TSX members to benefit from decimalization. One possibility is that the TSX members were unjustifiably optimistic about decimalization, and the positive seat price changes prior to the implementation of decimalization were reversed after the true impact on order flow became known. We do not find evidence of a reversal in abnormal seat price changes following the implementation of decimal quotes in April 1996, however. (See Figure 2.) A second possibility is that the expected revenues lost from market-making activities are more than offset by increased expected revenues from order brokering. We cannot verify this conjecture because it requires separating TSX member revenues into agency and principal revenues; such data are not available to us at this time.

Moreover, it is not clear that a simultaneous decline in quoted spreads and depth necessarily had a negative impact on member welfare because a reduction in depth gives the registered traders an ability to change prices more frequently. A decline in depth reduces the amount of capital the registered trader has at risk at a point in time. Hence, even if the revenue stream is lower, its reduced risk may compensate.

Discussion and Conclusion

The switch to decimal price quotes at the Toronto Stock Exchange reduced the minimal allowable price change (the tick) from $1/8^{th}$ of a dollar to five cents for stocks priced above $5. In this study, we provide evidence on whether the adoption of decimal pricing system at the Toronto Stock Exchange has had a significant impact on the welfare of TSX members. Our main findings are that the lower tick associated with decimal quotes has resulted in lower bid-ask spreads accompanied by a corresponding decrease in quoted depth. Consistent with the evidence in existing studies, we find that these changes are not accompanied by an increase in trading volume or market share for TSX members.

Concerning the benefits of decimalization for TSX members, we do not see evidence of a negative impact of decimalization on the welfare of TSX members. Our analysis indicates that TSX members had anticipated positive gains from the decimalization (as evidenced by the positive coefficients of δ_1 and δ_2), and that this positive gain had not been reversed (as evidenced by no reversal of positive abnormal seat price changes in Figure 2) following decimalization. Overall, the evidence of positive abnormal changes in TSX seat prices associated with the move to decimal quotes is consistent with wealth-maximizing behavior on the part of TSX members. The results indicate that the switch to decimal quotes did not adversely affect TSX members.

References

1. Admati A, and P. Pfleiderer, "A Theory of Intraday Patterns: Volume and Price Variability," *Review of Financial Studies*, 1 (1988), pp. 3-40.

2. Ahn Heejoon, Charles Cao, and Hyuk Choe, "Tick Size, Spread, and Volume," *Journal of Financial Intermediation*, 5 (1996), pp. 2-22.

3. Ahn Heejoon, Charles Cao, and Hyuk Choe, "Decimalization and Competition among Exchanges: Evidence from the Toronto Stock Exchange Cross-listed Securities," *Journal of Financial Markets* 1 (1998), pp. 51-87.

4. Bacidore, Jeffrey, "The Impact of Decimalization on Market Quality: an Empirical Investigation of the Toronto Stock Exchange," *Journal of Financial Intermediation*, 6 (1997), pp. 92-120.

5. Bessembinder, H., "Trade Execution Costs and Market Quality after Decimalization," *Journal of Financial and Quantitative Analysis*, 38, no. 4 (2003), p. 498.

6. Christie, W., and R. Huang, "Market Structures and Liquidity: A Transaction Data Study of Exchange Listings," *Journal of Financial Inte*rmediation, 3 (1994), pp. 300-326.

7. Chung, K., B.F. Van Ness and R.A. Van Ness, "Trading Costs and Quote Clustering on the NYSE and Nasdaq after Decimalization," *Journal of Financial Research* (2004), pp. 309-328.

8. Chowdhry, Bhagwan, and Vikram Nanda, "Multimarket Trading and Market Liquidity," Review of Financial Studies, 3 (1991), pp. 483-511.

9. Foerster, S., and G.A. Karolyi, "Multimarket Trading and Liquidity: A Transactions Data Analysis of Canada-U.S. Interlistings," *Journal of International Financial Markets, Institutions and Money* 8 (1998), pp. 393-412.

10. Goldstein, M., and K. Kavajecz, "Eighths, Sixteenths, and Market Depth: Changes in Tick Size and Liquidity Provision on the NYSE," *Journal of Financial Economics*, 56 (NEED YEAR), pp. 125-149.

11. Harris, Lawrence, "Minimum Price Variations, Discrete Bid-Ask Spreads, and Quotation Sizes," *Review of Financial Studies*, 7 (1994), pp. 149-178.

12. Harris, Lawrence, "Decimalization: A Review of the Arguments and Evidence," working paper (1997), The University of Southern California, Los Angeles, CA.

13. Harris, Lawrence, "Trading in Pennies: A Survey of the Issues' Decimalization: A Review of the Arguments and Evidence," working paper (1999), University of Southern California.

14. Huang, R., and H. Stoll, "Dealer versus Auction Markets: A Paired Comparison of Execution Costs on Nasdaq and the NYSE," *Journal of Financial Economics*, 41 (1996), pp. 313-358.

15. Jones C.M., and M.L. Lipson, "Sixteenths: Direct Evidence on Institutional Execution Costs," *Journal of Financial Economics*, 59, no. 2 (2001), pp. 253-278.

16. Kyle, A., "Continuous Auctions and Insider Trading," *Econometrica*, 53 (1985), pp. 1315-1335

17. Lee, Charles, B. Mucklow, and Mark Ready, "Spreads, Depths, and the Impact of Earnings Information: An Intra-day Study," *Review of Financial Studies*, 6 (1993), pp. 345-374.

18. Ronnen, T., and D.G. Weaver, "Tennies' Anyone?" *Journal of Financial Markets*, 4, no. 3 (2001), pp. 231-260.

19. Schwert, G. William, "Stock Exchange Seats as Capital Assets," *Journal of Financial Economics*, 4 (1997), pp. 51-78.

20. Schwert, G. William, "Public Regulation of National Securities Exchanges: A Test of the Capture Hypothesis," *The Bell Journal of Economics* (1978), pp. 128-150.

21. Weaver, Daniel, and David Porter, "Tick Size and Market Quality," *Financial Management*, 26, no. 4 (1997), pp. 5-26