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Should securities markets be transparent?

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Abstract

Market transparency lies at the heart of debate about floor versus automated trading systems, the informational advantages of market makers, and inter-market competition between trading systems. Since changes in transparency regimes are rare, analysis of each event becomes more crucial in our ability to evaluate prevailing theory accurately. We examine the natural experiment affected by the Toronto Stock Exchange when it publicly disseminated the limit order book on both the traditional floor and on its automated trading system. This change in transparency regime allows us to isolate the effects of increased transparency while controlling for stock-specific factors and for type (floor or automated) of trading system. We find that the increase in transparency reduces liquidity. In particular, execution costs and volatility increase after the limit order book is publicly displayed. We also show that the reduction in liquidity is associated with significant declines in stock prices.

JEL classification: G1; G14; G18

Keywords: Microstructure; Transparency; Limit order book

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1. Introduction[1]

Market transparency refers to the ability of market participants to observe information about the trading process. An especially important aspect of transparency concerns the effect of widely publicizing information about investors' latent demands present in the limit order book. This topic lies at the heart of debate about floor versus automated trading systems, the informational advantages of market makers, and inter-market competition between trading systems with different levels of transparency.

Previous theoretical research finds that transparency affects market quality, including liquidity, trading costs, and the speed of price discovery. Models by Pagano and Röell (1996), Chowdhry and Nanda (1991), Madhavan (1995, 1996), and Baruch (1997), among others, reach mixed conclusions regarding the effects of transparency. Even so, regulatory responses to transparency questions are often predicated on the belief that greater transparency will increase the efficiency and fairness of securities markets. For example, the United States Securities and Exchange Commission (SEC, 1994), the United Kingdom Office of Fair Trading (Carsberg, 1994), and the International Organization of Securities Commissions (2001) have called for increases in transparency to improve market quality. By contrast, the Securities Investment Board (SIB, 1994) opposes increases in transparency, fearing a reduction in liquidity if market makers publicly disclose information relating to their positions.

However, empirical evidence on transparency and its effects on liquidity and execution costs is sparse (O'Hara, 1999), primarily because of the lack of detailed data. Experimental (laboratory) studies where human subjects trade in artificial markets offer considerable promise for understanding transparency. The ability to frame controlled experiments also allows researchers to gather data on traders' estimates of value over time, their beliefs regarding the dispersion of "true" prices, and the trading profits of various classes of traders. Experimental studies such as Bloomfield and O'Hara (1999) and Flood et al. (1999) confirm that transparency matters and often in very complex ways. For example, Bloomfield and O'Hara find that while increased transparency results in increases in the informational efficiency of trade prices, it also results in a widening of spreads.

While experiments are valuable, their results typically reflect simplified trading protocols as opposed to real-world designs. True empirical analysis, however, requires an exogenous change in the information environment. Such events are rare and the few natural studies of transparency have generally focused on *post*-trade

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transparency.[2] This paper focuses on the change in pre-trade transparency when the Toronto Stock Exchange (TSE) instituted a computerized system to disseminate real-time detailed information on the limit order book to the public. This rule change applied to the stocks traded on the TSE's floor as well as the less actively traded stocks traded on the TSE's Computer Aided Trading System (CATS) and allows us to study the impact of a dramatic increase in pre-trade transparency on *the same stocks in the same market structure*. As such, our study provides a complement to other natural experiments recently examined in the literature.[3]

Beyond the rarity of such a change in transparency regime, the TSE's protocol change is of special interest for several reasons. First, the TSE's CATS is the blueprint for most automated trading systems in existence, suggesting that the TSE experience would have general implications for many existing markets world-wide. Second, the wide cross-section of stocks in our sample allows us to make inferences regarding the effects of changes in liquidity and execution costs on asset prices. Third, the protocol change allows us to isolate the effects of changes in disclosure across two systems *that already differ in the amount of transparency they offer*. Finally, the TSE's transaction data allows a detailed analysis of the effects of changes in transparency across "internal" dimensions, including an examination of RT (specialist) profits.

Our empirical results strongly support the view that transparency matters in the sense that it has an economic affect on trading costs and liquidity. We find that higher transparency does not improve market quality. In particular, our analysis shows that execution costs increase after the introduction of the rule change, even when controlling for other factors that may affect trading costs such as volume, volatility, and price. This finding is consistent with a decrease in liquidity under transparency because limit order traders are reluctant to offer free options to other traders. Cross-sectional evidence shows that the reduction in liquidity and increase in execution costs are associated with reductions in asset values, consistent with the predictions of Amihud and Mendelson (1986) and Brennan and Subrahmanyam (1996).

[2]Pre-trade transparency refers to the dissemination of current bid and ask quotations, depths, and information about limit orders away from the best prices. Post-trade transparency refers to the public and timely transmission of information on past trades, including execution time, volume, and price. Naik et al. (1994), Gemmill (1994), Board and Sutcliffe (1995), and Saporta et al. (1999) analyze the effects of delayed trade reporting on the London Stock Exchange. Porter and Weaver (1998) examine delayed reporting on the Nasdaq Stock Market. Simaan et al. (2002) examine the impact of anonymity on quoting behavior.

[3]Hendershott and Jones (2003) examine the effects when, responding to regulatory enforcement, the Island ECN stopped displaying its limit order book in the three most active exchange-traded funds. They find that Island's share of trading activity and price discovery falls while effective and realized spreads increase. Boehmer et al. (2003) examine the NYSE's OpenBook, which enables off-exchange traders to observe limit order book depth. They find that limit order cancel rates increase, time-to-cancellation falls, and limit order size diminishes, consistent with the "free option" arguments in the literature.

2. Institutions and data

2.1. The Toronto Stock Exchange

The TSE is the largest and most active stock exchange in Canada. During our study period, the TSE used two different trading systems, each with its own set of order priority rules and transparency. The first system, the CATS, debuted in 1977 and is the blueprint for most automated trading systems in existence, including major markets such as the Paris Bourse (CAC) system. The second system, the TSE's Floor, operates much like the NYSE.[4]

On April 12, 1990, the TSE instituted a computerized system called Market by Price (MBP), dramatically increasing the level of pre-trade transparency. Under the MBP system, the TSE began real-time public dissemination of the depth (bid sizes and ask sizes) and quotes for the current inside market as well as the depth and limit order prices for up to four price levels above and below the current market. The system also required that all depth be automatically displayed.[5]

The MBP rule change applied to both the stocks traded on the TSE's floor and to the less actively traded stocks traded on CATS. The protocol change allows us to isolate the effects of changes in disclosure across two systems that already differ considerably in the amount of transparency they offer. In particular, the TSE floor resembled the New York Stock Exchange (NYSE) floor in that *only* the Registered Trader (RT)–the TSE's equivalent of the NYSE specialist—observed the limit order book. By contrast, CATS already offered a high degree of transparency to all members, but not to the general public.

2.2. Data sources and procedures

The data in this study are drawn from the TSE equity history files for the months of February through June, 1990 and contain every trade and quote, with associated prices, volumes, and bid and ask sizes, as well as information for determining the stock's trading system (CATS or Floor-traded). The data are time stamped to the nearest second. Some of our data (March and May 1990), contain trader identifications and also indicate whether the trader is acting as an agent or trading for their own account.[6] In addition, we use data from the Institute for the Study of Securities Markets (ISSM) for US quotes on 36 TSE stocks cross-listed in the US to create a control sample for testing whether any observed spread width changes are part of a general trend across markets.

[4]CATS had strict price–time priority so that a new order at a given price goes to the end of the queue. By contrast, the Floor had sharing priority rules which allocated incoming marketable orders among all members with orders on the book. During 1998 the TSE closed their trading floor, by transferring all stocks to the CATS. The priority rules on CATS became a variation on the old floor rules.

[5]Prior to the introduction of MBP, RTs were allowed to quote "representative" depth for floor stocks. MBP changed representative floor depth to actual depth.

[6]The TSE has two sets of data—one has confidential markers not available on the other. We were not able to obtain the confidential version for the entire period.

Since Floor and CATS stocks have different priority rules and transparency, we first separate the sample according to the trading system. We restrict the sample to common stocks with prices above $1.00 during the sample period. We also exclude stocks that trade fewer than 6 times a day (on average). In addition, we include a number of filters to screen data errors arising from dropped or missing digits. For the few stocks with multiple share classes, we select only the most active class for analysis to avoid problems with interdependent observations. The resulting sample includes 60 CATS and 150 Floor stocks. Most of our tests focus on changes in market quality metrics surrounding the introduction of the MBP system on April 12, 1990. To guard against possible biases from proximity to the event date, we define the pre-period as February 1 to March 30, 1990 and the post period as May 1 to June 30, 1990.

3. Hypotheses

The "free option" properties of limit orders have been recognized since Copeland and Galai (1983) and are further analyzed in models by Easley and O'Hara (1991), Seppi (1997), and Foucault (1999). These models demonstrate that when limit order traders submit trades at a specified price, they are effectively writing options at a specified strike price. Without the constant monitoring of submitted orders, limit order traders risk being "picked off" by market order traders when share values move with the release of new information. Since an increase in pre-trade transparency effectively increases order placement efficiency by market order traders, it also effectively raises monitoring costs for limit order traders. It follows that liquidity providers will be less willing to provide free options to the market in the form of limit orders, thus decreasing liquidity, widening spreads and increasing price volatility.

A similar result can be generated using adverse selection costs. For example, if transparency increases informed traders' expected profits by allowing them to tap the liquidity offered by the limit order book more efficiently than in a non-transparent system, then uninformed traders may be less willing to provide liquidity, thereby widening spreads and increasing price volatility. It is possible that this increase in volatility is associated with greater price efficiency because informed traders trade more accurately in a transparent system, speeding up the process of price discovery. In other words, although prices may exhibit more volatility, the rate of convergence to full information values can be faster, depending on the dynamics of the trading model.

Chowdhry and Nanda (1991) provide the opposing argument in which informed traders prefer markets with less transparency to avoid revealing their private information. If more transparent markets have reduced adverse selection costs, spreads may be narrower, depth larger and price volatility lower.

Madhavan (1995) develops a model in which large uninformed traders prefer less transparent markets since trades can be broken up without attracting attention. Increases in transparency may result in traders moving to other markets (including off-exchange and after-hours trading) resulting in reduced liquidity. Madhavan (1996) develops a model in which price volatility will be lower under transparency if the market is sufficiently large and where volatility and market depth are inversely related. If the market is not sufficiently large, however, Madhavan (1996) also shows that volatility may be directly related to the level of transparency. Since the predictions of these models are inconsistent but focus on similar variables, we test the following hypotheses:

H1:. *Transparency increases have no effect on spread width.*

H2:. *Transparency increases have no effect on the asymmetric component of the spread.*

H3:. *Transparency increases have no effect on market depth.*

H4:. *Transparency increases have no effect on volatility.*

Amihud and Mendelson (1986), Brennan and Subrahmanyam (1996), Amihud (2002), Jones (2002), and Pastor and Stambaugh (2003) show that liquidity and stock prices are related. If transparency changes affect transaction costs, transparency may also affect stock prices. Therefore, we include the following hypothesis:

H5:. *Transparency increases have no effect on stock prices.*

Glosten and Milgrom (1985), Madhavan and Smidt (1991), George et al. (1994), and Seppi (1997) develop models of specialist behavior. These models imply that the specialist will supply liquidity when the limit order book has gaps that allow profitable trade and will manage quotes to minimize adverse selection exposure (Kavajecz, 1999). If the specialist's expected profits are positive when the specialist has an informational advantage over off-floor traders, then in a transparent system where the limit order book is freely observed, competition will force expected profits toward zero and specialist profits may be lower. Therefore, we test the following hypothesis:

H6:. *Transparency increases have no effect on specialist profits.*

This hypothesis contains a duality since finding no change in profits after the limit order book is made public may imply that changes in transparency have no affect on specialist's profits or that specialists have no informational advantage over off-floor traders.

Finally, if free options exist, then for a given change in transparency, we expect traders to rapidly seek to maximize profits. The wealth transfer from limit order traders to market order traders should be immediate. Thus, if two systems increase transparency to the same level, we expect the system that changes from no transparency to have larger changes in market quality than the system that changes from partial transparency. Since only the RT (specialist) routinely observed the limit order book on the TSE's Floor but CATS already offered a high degree of transparency to all members but not to the general public, we expect that following the change in transparency, CATS stocks would exhibit less dramatic changes in market quality than Floor stocks. Therefore, we propose the following hypothesis:

H7:. *The observable effects resulting from a transparency change are proportional to the size of the transparency change.*

We test these hypotheses in the following sections.

4. Empirical findings

4.1. Descriptive statistics

Table 1 contains descriptive statistics for the CATS and Floor stock portfolios. The table reports the average price, volatility (average standard deviation of daily returns), average daily share volume (in thousands), and the number of stocks in our sample for all stocks and for three volume partitioned portfolios. Portfolios are formed by ranking stocks by average daily volume for the period February 1 to March 30, 1990. Stocks are then separated according to trading system. Panel A contains statistics for stocks traded in the CATS system, while Panel B contains stocks traded in the TSE floor system. Examining the stocks in each portfolio shows that CATS stocks tend to have lower volumes than Floor stocks. It is a common misconception that the CATS system is abandoned by stocks as they increase in price

Table 1
Descriptive statistics of Toronto Stock Exchange Stocks. This table reports the mean price, volatility (mean standard deviation of daily returns), mean daily share volume (in thousands), and the number of stocks in our sample for all stocks and for volume portfolios. Numbers reported below are for the ranking period February 1–March 30, 1990. Groups are formed by ranking stocks by mean daily volume during the ranking period. Stocks are then separated according to trading system. Panel A (B) contains statistics for stocks traded in the CATS (Floor) system. Overall averages are also provided.

	Dollar volume portfolio			
	All firms	1 (Lowest)	2	3 (Highest)
A: *CATS stocks*				
Mean price	$14.17	$15.88	$13.31	$11.69
Volatility	0.018	0.018	0.021	0.015
Share volume	29.36	7.73	28.67	85.84
Number of stocks	60	27	22	11
B: *Floor stocks*				
Mean price	$16.09	$15.02	$14.14	$18.47
Volatility	0.019	0.018	0.021	0.017
Share volume	72.21	9.02	28.41	153.89
Number of stocks	150	43	48	59

or volume. In reality, TSE rules generally do not allow stocks to switch trading systems.

4.2. Changes in spread width: H1

4.2.1. Unconditional changes in quoted and effective bid-ask spreads

We begin by examining quoted dollar bid-ask spreads which we compute using averages across all observed quote revisions for each stock and then average across stocks. While dollar quoted spreads represent posted or firm prices, not all trades occur at the quoted prices. For example, upstairs trades are often negotiated by off-floor brokers and may occur inside the quoted spread. Other trades, whose size exceeds the current depth of the market, may incur execution costs larger than the quoted spread. Accordingly, we also examine effective spreads, which we compute as the absolute dollar deviation between the transaction price in stock i at time t and the prevailing midquote.[7] Effective spreads are trade-weighted over all transactions for stock i and then across stocks.

Table 2 shows the mean quoted and trade-weighted effective spreads for all firms and the three volume partitioned portfolios for the pre- (February 1–March 30) and post-periods (May 1–June 31) surrounding the event date of April 12, 1990. The results are also separated according to trading system: CATS and Floor. Panels A through C (percentage quoted spreads, dollar quoted spreads and percentage effective spreads, respectively) show statistically significant increases in spread width in the post period for all firms on both Floor and CATS stocks. Panel D shows Floor stocks also have a significant increase in dollar effective spreads. Comparing the magnitude of spread changes, Table 2 shows that overall, CATS stocks exhibit smaller spread width increases and the differences (post-pre MBP) have lower levels of statistical significance than Floor stocks.

Based on these results, we reject the null hypothesis that transparency increases have no effect on spread width. These results also provide preliminary evidence consistent with the hypothesis that the observable effects from a transparency change are proportional to the size of the transparency change. Since CATS stocks displayed a high level of transparency before MBP, spread widths on CATS stocks should be less affected by the increase in transparency than Floor stocks.

4.2.2. Multivariate tests

Observed changes in spread width may not be solely due to the changes in transparency. Previous research shows that spreads are a function of price, volume, and variance of return. Dollar spreads are known to increase with price and return volatility and decrease with volume consistent with the predictions of both

[7] Lee and Ready (1991) suggest a five second lag for identifying prevailing quotes. Blume and Goldstein (1997) suggest a 16 s lag for NYSE stocks and a range of from 3 to 34 s for regional market data. An analysis of our data suggests that a shorter lag (5 s) is appropriate for the electronic updating of CATS stocks, while a longer lag (20 s) is appropriate for the manual (specialist) updating of Floor stocks. These lags are used to determine prevailing quotes for the estimation of effective spreads.

Table 2
Quoted and effective spreads. This table shows the mean quoted spreads for Toronto Stock Exchange stocks during the periods February 1–March 30, 1990 (pre-period) and May 1–June 30, 1990 (post-period) which surround the increase in pre-trade transparency on April 12, 1990. Portfolios are formed by ranking stocks by mean daily volume during the pre-period. Stocks are then separated according to trading system. Panels A and B list the mean quoted percentage and dollar spreads, respectively, in the pre- and post-periods for quartiles of dollar trading volume. Panels C and D list trade-weighted effective percentage and dollar spreads, respectively. Within each panel, stocks are grouped by trading system: CATS and Floor. Tests for significant differences between pre- and post-period spreads using a paired *t*-test are indicated as follows: * denotes significance at the 5% level while ** denotes significance at the 1% level.

	Dollar volume portfolio			
	All firms	1 (Lowest)	2	3 (Highest)
Panel A: *quoted spread* (*in percentage*)				
A.1: CATS				
Pre-period	1.839	2.135	1.745	1.304
Post-period	2.222**	2.575**	2.168*	1.461
A.2: Floor				
Pre-period	1.672	2.008	1.969	1.185
Post-period	2.019**	2.407**	2.455**	1.389**
Panel B: *quoted spread* (*in dollars*)				
B.1: CATS				
Pre-period	0.201	0.235	0.192	0.134
Post-period	0.214**	0.248	0.209*	0.141
B.2: Floor				
Pre-period	0.181	0.216	0.184	0.153
Post-period	0.203**	0.245**	0.218**	0.161**
Panel C: *effective spread* (*in percentage*)				
C.1: CATS				
Pre-period	1.522	1.725	1.424	1.225
Post-period	1.773**	1.988	1.804	1.183
C.2: Floor				
Pre-period	1.266	1.550	1.488	0.878
Post-period	1.509**	1.708	1.902*	1.105**
Panel D: *effective spread* (*in dollars*)				
D.1: CATS				
Pre-period	0.167	0.194	0.157	0.121
Post-period	0.168	0.189	0.162	0.117
D.2: Floor				
Pre-period	0.136	0.165	0.136	0.114
Post-period	0.149*	0.180	0.163	0.115

asymmetric information and inventory control models of dealer behavior. Our results could be biased if these factors are not constant over our study period. Accordingly, we run the following regression:

$$\overline{S_{i,t}} = \beta_0 + \beta_1 \overline{Volume_{i,t}} + \beta_2 \sigma_{i,t} + \beta_3 Dummy_{i,t}, \quad (1)$$

Table 3
Regression models for execution costs. This table reports the results of regressions of the form:

$$\overline{S_{i,t}} = \beta_0 + \beta_1 \overline{Volume_{i,t}} + \beta_2 \sigma_{i,t} + \beta_3 Dummy_{i,t},$$

where $\overline{S_{i,t}}$ is the mean percentage spread (quoted or effective) for firm i in period t (pre or post); $\overline{Volume_{i,t}}$ is the mean daily dollar volume for firm i during period t; $\sigma_{i,t}$ is the standard deviation of daily return for firm i during period t; $Dummy_{i,t}$ is a dummy variable assigned the value of 1 if the observation is from the post-period and zero otherwise. Panel A (B) contains the results for the CATS (Floor) trading system, with t-statistics in parentheses: * denotes significance at the 5% level while ** denotes significance at the 1% level.

	Dependent variable				
	Intercept	Volume	Volatility	Dummy	F-statistic $\{R^2\}$
Panel A: *CATS*					
Quoted spread (%)	0.636	−0.000	0.799	0.213	61.23
	(3.54)**	(−4.15)**	(11.34)**	(1.48)	{0.613}
Effective spread (%)	0.508	−0.000	0.649	0.113	42.39
	(3.01)**	(−2.87)**	(9.81)**	(0.84)	{0.511}
Panel B: *Floor*					
Quoted spread (%)	0.262	−0.000	0.843	0.242	188.97
	(2.51)*	(−7.58)**	(20.00)**	(2.93)**	{0.653}
Effective spread (%)	0.292	−0.000	0.591	0.170	90.17
	(2.70)**	(−5.80)**	(13.50)**	(1.98)*	{0.472}

where $\overline{S_{i,t}}$ is the average quoted or effective (percentage) spread for firm i in period t (pre or post reduction); $\overline{Volume_{i,t}}$ is the (log) average daily share volume for firm i during period t; $\sigma_{i,t}$ is the standard deviation of daily return for firm i during period t; and $Dummy_{i,t}$ is a dummy variable assigned the value of 1 if the period is post, otherwise zero.[8] If increases in transparency are associated with changes in spread width, we would expect to find β_3 significantly different from zero.

Panel A of Table 3 contains the regression results for CATS stocks and Panel B for Floor stocks. Overall, the coefficients on the controlling variables (volume and volatility) are significant and of the expected sign. Focusing on β_3, the dummy variable for pre- and post-introduction of the MBP system, both the quoted and effective percentage spreads show significant increases for Floor stocks after controlling for changes in volume and return variance. The coefficient estimates on the dummy variable for quoted spreads are 0.213 and 0.242 for CATS and Floor systems, respectively, consistent with the findings of Table 2 above. However, the coefficient on the dummy is not significant for CATS stocks using either quoted or effective spreads, providing further evidence that transparency effects are most immediate for Floor-traded stocks. In summary, these multivariate tests imply that

[8]This regression specification implies spread width is a function of volume. Since volume is also a function of spread width, the regression could alternatively be specified where volume is jointly determined with the spread.

our previous inferences for Floor stocks do not result from changes in volume and/or return variance.

4.2.3. Evidence from cross-listed stocks

The wider spreads we document following the introduction of MBP may be a function of general spread increases across all stocks. To test this hypothesis, we create a control sample of TSE stocks cross-listed in the US during the study period. This control sample is particularly valuable since it contains the same stocks traded on markets with no change in transparency during the study period. There are 37 TSE stocks from our original sample of 210 that are actively traded in both Canadian and US markets. All but one is a Floor stock; therefore, we exclude the one CATS stock from the control sample. Of the 36 remaining securities, 21 are cross-listed on the NYSE, 11 are cross-listed on AMEX, and 4 on Nasdaq. Only quotes from the exchange that cross-listed the TSE stock are used to estimate the US spreads. We examine the average quoted spreads expressed in dollar terms and defined as $A_{i,t}-B_{i,t}$, where $A_{i,t}$ and $B_{i,t}$ are the inside ask and bid quotes for firm i at time t. Percentage spreads are not examined, due to the possible impact of exchange rate changes on prices in the two markets. We analyze changes in overall spread widths and partition by the three US exchanges. If the wider spreads observed on the TSE are due to a general trend, we would expect similar increases in spreads on cross-listed stocks.

Table 4 shows that, although average quoted spreads for the 36 securities widened in all four markets (TSE, NYSE, AMEX, Nasdaq), only the TSE spread changes are significant. When examining only TSE spreads, stocks cross-listed on either the

Table 4
Change in quoted spreads for cross-listed stocks. This table shows the mean quoted spreads for Toronto Stock Exchange stocks cross-listed in the US during the periods February 1–March 30, 1990 (pre-period) and May 1–June 30, 1990 (post-period). These periods surround the increase in pre-trade transparency which occurred on April 12, 1990. The sample contains 37 TSE stocks, from our original sample of 210, that are actively traded in the US during the period of our study. All but one are Floor stocks, therefore we exclude the one CATS stock from our sample. Listed are the results for dollar quoted spreads defined as $A_{i,t} - B_{i,t}$, where $A_{i,t}$ and $B_{i,t}$ are the inside ask and bid quotes for firm i at time t. We report the pre and post average dollar quoted spreads for the TSE as well as the three US exchanges. Only quotes from the appropriate exchange(s) are used to estimate spreads (TSE quotes for TSE spreads, NYSE quotes for NYSE spreads, etc.). Tests for significant differences between pre- and post-period spreads using a paired t-test are indicated as follows: * denotes significance at the 5% level while ** denotes significance at the 1% level.

	Stock exchange							
	Overall		NYSE cross-listed		AMEX cross-listed		Nasdaq cross-listed	
	TSE	US	TSE	NYSE	TSE	AMEX	TSE	Nasdaq
Pre-period	0.177	0.201	0.173	0.178	0.189	0.239	0.167	0.219
Post-period	0.192**	0.206	0.184*	0.183	0.212*	0.245	0.184	0.224
No. of stocks	36		21		11		4	

NYSE or AMEX as well as the overall sample show statistically significant increases in spread width. In contrast, when examining only NYSE, AMEX and Nasdaq spreads, the same securities transacting on US markets did not have statistically significant increases in spread width. These findings imply that observed changes in TSE spread widths, following the increase in pre-trade transparency, are not associated with a general widening of spreads across markets.

4.3. Changes in asymmetric information: H2

Finding spread width increases following the opening of the limit order book suggests that the adverse selection component of the spread may have increased as well. To investigate changes in adverse selection, we use the model developed in Madhavan et al. (1997):

$$
\begin{aligned}
P_t - P_{t-1} = {} & \phi(x_t - x_{t-1}) + \Delta\phi D(x_t - x_{t-1}) + \theta(x_t - \rho x_{t-1}) \\
& + \Delta\theta D(x_t - \rho x_{t-1}), \qquad (2)
\end{aligned}
$$

where P is the trade price of a security at time t or $t-1$; x is the sign indicator of the trade; ρ is the autocorrelation of the order flow; ϕ is the cost of supplying liquidity; θ is the asymmetric information parameter; and D is a dummy variable given the value 1 if the observation is from the post change period and zero otherwise. Δ indicates the change in either the liquidity or asymmetric parameters in the post period. For the purpose of determining its sign, a trade is assumed to be a buy if the trade price is equal to or greater than the mid point of the prevailing spread at the time of the trade. In the original MRR model, the autocorrelation term was introduced to capture order correlation arising from various institutional features of the NYSE. These features are largely absent on the TSE and therefore we estimate a more robust form of the model where this coefficient is set to zero. Regressions are performed for each stock in our sample and then averaged across portfolios or trading systems.[9]

Table 5 shows that overall, the adverse selection component increased significantly following the introduction of MBP for both CATS and Floor stocks. When partitioning by volume portfolios, the increase in the adverse selection component is significant for all three Floor volume portfolios but only the medium CATS volume portfolio. These findings result in our rejecting the hypothesis that transparency increases have no effect on the asymmetric component of the spread.

4.4. Changes in quoted depth: H3

We define market depth as the number of shares offered at the inside quote. Prior to the introduction of MBP, RTs were not required to reveal all existing depth for Floor stocks when quotes were revised, but instead were allowed to state

[9]Consistent with our effective spread analysis, a lag of five (twenty) s for CATS (Floor) stocks is used to determine the appropriate quote for calculating the sign indicator.

Table 5
Asymmetric information component of spread. This table lists the change in the asymmetric information component of the spread for Toronto Stock Exchange stocks from the pre-period (February 1–March 30, 1990) to the post-period (May 1–June 30, 1990) surrounding the increase in pre-trade transparency on April 12, 1990. Panel A (B) contains the results for the CATS (Floor) trading system. Portfolios are formed by ranking stocks by mean daily volume during the pre-period. The Madhavan et al. (1997) model is used to estimate the asymmetric information component:

$$P_t - P_{t-1} = \phi(x_t - x_{t-1}) + \Delta\phi D(x_t - x_{t-1}) + \theta(x_t - \rho x_{t-1}) + \Delta\theta D(x_t - \rho x_{t-1}),$$

where $P =$ the trade price of a security at time t or $t-1$; x is the sign indicator of the trade; ρ is the autocorrelation of the order flow; ϕ is the cost of supplying liquidity; θ is the asymmetric information parameter; and D is a dummy variable assigned the value 1 if the observation is from the post-period and zero otherwise. Δ indicates the change in either the liquidity or asymmetric parameters in the post-period. For the purpose of determining its sign, a trade is assumed a buy if the trade price is equal to or greater than the mid point of the prevailing spread at the time of the trade. Further, the autocorrelation of the order flow is assumed to be zero. Regressions are performed for each stock in our sample. The average asymmetric parameter is reported for the pre-period as well as its change in the post-period. Tests for significant differences between the pre- and post-period parameters using paired t-tests are indicated as follows: * denotes significance at the 5% level while ** denotes significance at the 1% level.

	Dollar volume portfolio			
	All firms	1 (Lowest)	2	3 (Highest)
A. CATS stocks				
Asymmetric information component pre-period	0.007	0.009	0.007	0.002
Change in asymmetric information component from pre- to post-period	0.002^{*}	0.001	0.003^{*}	0.0004
B. Floor stocks				
Asymmetric information component pre-period	0.005	0.006	0.006	0.003
Change in asymmetric information component from pre- to post-period	0.002^{**}	0.003^{**}	0.003^{**}	0.001^{**}

"representative" depth. After the introduction of MBP, all existing depth was reported electronically along with the revised quote. Therefore, for Floor stocks, any observed increases in depth in the post period may simply reflect the exposure of previously hidden liquidity and are hence not meaningful. Discussions with the TSE led to the conclusion that there is no direct way to determine the percentage of depth actually reported by the RTs prior to the MBP system. Therefore, accurate comparative measurement of quoted depth for Floor stocks over the periods is problematic.

However, the RTs never had discretion over the display of depth in CATS stocks since the system automatically displays all exposed depth at each price. Consequently, changes in market depth for CATS stocks are meaningful. Accordingly, we compute average inside depth (bid size plus ask size) for each CATS stock over the sample periods (pre and post) and then average across stocks.

We find that depth increases by 3.5% following the increase in transparency but the change is not significant at normal levels. When partitioning by volume

Table 6
Change in volatility following the increase in pre-trade transparency. This table shows mean volatility measures for Toronto Stock Exchange stocks during the periods February 1–March 30, 1990 (pre-period) and May 1–June 30, 1990 (post-period) surrounding the increase in pre-trade transparency on April 12, 1990. Also reported is the mean change between the two periods. Groups are formed by ranking stocks by mean daily volume during the pre-period. Stocks are then separated according to trading system. Panel A (B) contains the results for the CATS (Floor) trading system. Volatility is defined as the average squared 15 min return based on quote midpoints. Tests for significant differences between pre- and post-period volatility using a paired *t*-test are indicated as follows: * denotes significance at the 5% level while ** denotes significance at the 1% level.

	Dollar volume portfolio			
	All firms	1 (Lowest)	2	3 (Highest)
Panel A: *CATS*				
Pre-period	0.35%	0.35%	0.39%	0.28%
Post-period	0.39*	0.38	0.45**	0.28
N	60	27	22	11
Panel B: *Floor*				
Pre-period	0.33%	0.33%	0.36%	0.29%
Post-period	0.37**	0.36*	0.41*	0.34**
N	150	43	48	59

portfolios, we find the smallest and largest volume portfolios increase 6.2% and 9.1% respectively and the mid-range volume portfolio exhibits a decrease of 11% in depth.[10] None of the portfolios shows statistically significant increases at normal levels. Since CATS stocks exhibited a high degree of transparency before MBP, these statistically insignificant changes in depth provide additional evidence consistent with the hypothesis that small changes in transparency produce small changes in observable effects, but we are unable to reject the hypothesis that transparency changes have no effect on market depth.

It is possible that depth on prices away from the inside quote will also be impacted by increased transparency. Unfortunately, the TSE did not archive order data during 1990, so we cannot directly measure depth away from the inside quote. However, models such as Madhavan (1996) imply that decreases in depth may result in increased return volatility which we examine next.

4.5. Changes in volatility: H4

Table 6 displays estimates of return volatility, using the average squared, 15 min return based on quote midpoints during the pre- and post-rule change periods. Both Panels, A for CATS stocks and B for Floor stocks, show a significant increase in volatility over the time horizon. In particular, CATS volatility rose from 0.35% to 0.39% while Floor volatility increased from 0.33% to 0.37%. Thus, the change in

[10]Complete results are available from the authors.

transparency is associated with greater volatility in both systems resulting in our rejecting the hypothesis that transparency increases have no effect on returns volatility. When examining the analysis by portfolio, only one of the three CATS dollar volume portfolios exhibits a statistically significant increase in volatility, while all three of the Floor portfolios have statistically significant increases. Therefore, although the magnitude of the changes is similar across CATS and Floor stocks, the insignificant changes in the CATS volume portfolios are more consistent with the hypothesis that observable effects resulting from a transparency change are proportional to the size of the transparency change.

The extant literature documents a positive relationship between price volatility and trading frequency, which in turn may result from exogenous events such as news announcements. To control for this relationship, we estimate the following regression model:

$$\sigma_{i,t} = \beta_0 + \beta_1 N\_Trades_{i,t} + \beta_2 Dummy_{i,t}, \tag{3}$$

where $\sigma_{i,t}$ is the standard deviation of returns for firm i in period t (pre or post,) $N\_Trades_{i,t}$ is the number of transactions for firm i in period t (pre or post,) and $Dummy_{i,t}$ is a dummy variable assigned the value of 1 if the period is post, otherwise zero. We find, consistent with our earlier results, that the dummy coefficient is positive for both CATS and Floor stocks; however, neither coefficient is significant at normal levels.

4.6. Changes in stock price: H5

The increases in risk and trading cost detailed above should reduce stock price levels as predicted by many microstructure models. Indeed, an examination of stock prices shows that overall price levels declined about 4% between February 1 and June 30. This is consistent with previous studies that have shown a link between liquidity and stock prices, but may also reflect exogenous factors as well.

To better isolate the impact of changes in transparency on asset values, we estimate the following cross-sectional regression:

$$R_i = \beta_0 + \beta_1(s_{1i} - s_{0i}) + \beta_2(s_{1i} - s_{0i})D_i + \beta_3 D_i, \tag{4}$$

where, for firm i, R_i is the percentage return over the sample period, s_{0i} is pre-period percentage effective spread, s_{1i} is post-period percentage effective spread, and D_i is a dummy variable taking the value 1 if the stock is a Floor stock, otherwise zero. The intercept captures the mean change in prices over the period; the coefficient on the change in percentage effective spreads reflects the impact of higher costs on value; the third term captures the interaction of the change in spreads for Floor stocks alone; and, the last term captures any stock-specific effects peculiar to Floor stocks. We hypothesize that $\beta_1 < 0$ because the reduction in value should be greatest in those stocks experiencing the largest change in execution costs. The remaining variables are included as controls because CATS and Floor stocks differ in attributes such as firm size, trading volume, age, etc. We have no a priori reason to assume that these coefficients are different from zero.

Table 7
Regression models for the relationship between returns and execution costs. This table reports the results of cross-sectional regressions of the form:

$$R_i = \beta_0 + \beta_1(s_{1i} - s_{0i}) + \beta_2(s_{1i} - s_{0i})D_i + \beta_3 D_i,$$

where, for firm i, R_i is the percentage return over the sample period, s_{0i} is pre-period percentage effective spread, s_{1i} is post-period percentage effective spread, and D_i is a dummy variable assigned the value 1 if the stock is a Floor stock and zero otherwise. We constrain $\beta_2 = 0$ in model 2. Figures in parentheses are t-statistics: ** denotes significance at the 1% level.

	Dependent variable				
	Intercept	Δ Effective spread	Interaction term	Floor dummy	F-statistic $\{R^2\}$
Model 1	−0.022 (−1.00)	−5.48 (−4.20)**		−0.001 (−0.03)	8.81 {0.069}
Model 2	−0.020 (−0.92)	−6.10 (−3.88)**	0.207 (0.71)	−0.004 (−0.16)	6.03 {0.067}

Table 7 reports regression results using the full model and when constraining $\beta_2 = 0$. In both regressions the coefficient β_1 is significantly negative which is consistent with the view that higher execution costs result in lower stock returns. The evidence on the remaining terms is less conclusive but is consistent with the view that larger stocks (which tended to be traded on the Floor) experienced less of a decline in price over the period.

Amihud et al. (1997) find that stock prices react quickly to changes in market microstructure. This suggests that prices will drop as soon as it becomes apparent that increased transparency is associated with decreased liquidity.[11] To test this model, we calculate the average daily closing price of stocks in our sample for each day in April, which surrounds the introduction of MBP. Fig. 1 shows that prices increase modestly on the trading day following the increase in transparency and then drop by about 6% over the following week. These results are consistent with the quick adjustment of prices documented in Amihud et al. (1997).

4.7. Specialist profits: H6

In the case of Floor stocks, the RTs (specialists) enjoy informational advantages very similar to those granted to NYSE specialists. Since the informational advantage to Floor specialists should produce positive expected profits, when the limit order book is freely observed after MBP we expect competition to force Floor specialist profits to be lower than under the more transparent system. A sub-set of our data (March and May 1990) is sufficiently detailed to allow direct computation of

[11]We thank the reviewer for suggesting this model.

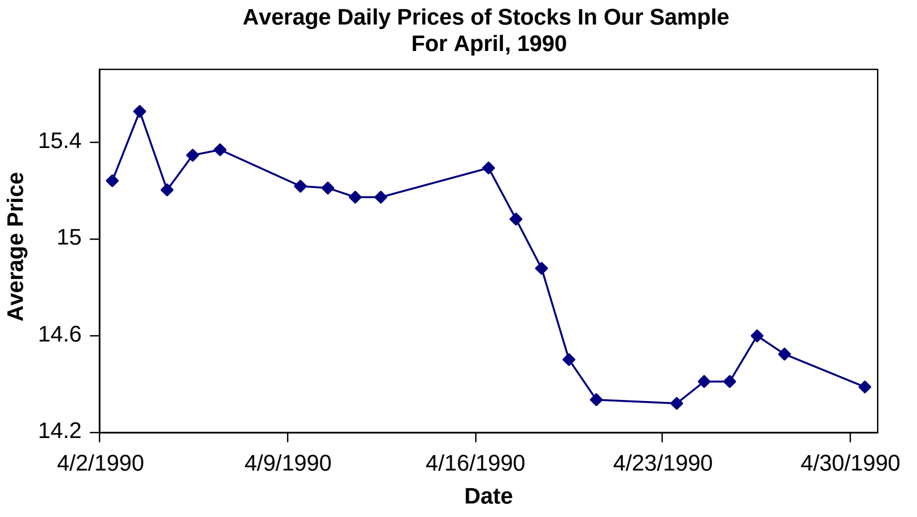

Fig. 1. This figure shows the average daily closing price for the Toronto Stock Exchange stocks in our sample for each trading day during April 1990. The increase in pre-trade transparency occurred on April 12, 1990.

specialist trading profits. This allows us to study the effects of disclosure on this important class of liquidity providers.

We define two measures of trading profits: (1) total (gross) profits, which captures the profits from all the specialist's trades, and (2) spread profits, which captures the profits from round-trip transactions at the bid-ask spread.

Total Profit is defined as

$$TP_i = \sum_{t=1}^{n} p_{it} x_{it} + m_{in} I_{in} - m_{i0} I_{i0}, \tag{5}$$

where: x_{it} is the signed volume representing specialist participation in stock i for transaction t (the sign is determined by the direction of the specialist's cash flow, positive for a sale, negative for a purchase); p_{it} is the price of stock i transaction t; $I_{in} = \sum_{t=1}^{n} x_{it}$, is the specialist's inventory in stock i at time n; and m_{in} is the quote midpoint for stock i at time n, when the specialist is assumed to liquidate his position. Initial inventory I_{i0} is not observed, and consistent with Hansch et al. (1999), we set this value to zero. Only stocks that involve specialist participation during both periods are included.

Table 8 shows that the high variance of trading profits induced by inventory holdings results in no significant change in average specialist profit per stock during the pre- and post-rule change. Although the findings are not significant, Panel A.2 shows the magnitude of specialist profits declines overall for Floor stocks, which implies that any value associated with the informational disparity between specialists and off-floor traders may be erased with the increase in transparency. Panel A.1

Table 8
Registered trader profit components—by stock. This table shows mean registered trader profits for Toronto Stock Exchange stocks during the periods March 1–March 30, 1990 (pre-period) and May 1–May 31, 1990 (post-period). Groups are formed by ranking stocks by mean daily volume during the period February 1 – March 30, 1990 and then separating according to trading system. Results are per stock and are partitioned by trading system: CATS or Floor. Panel A reports total profit:

$$TP_i = \sum_{t=1}^{n} p_{it}x_{it} + m_{in}I_{in} - m_{i0}I_{i0},$$

where, for stock i and transaction t, x_{it} is the specialist signed volume, p_{it} is price, I_{it} is the specialist's inventory, m_{it} is the quote midpoint, and $I_{in} = \sum_{t=1}^{n} x_{it}$. Only stocks that involved registered trader participation during both periods are included. Total profits consist of profits earned by capturing the spread (spread revenues) as well as trading profits. Panel B reports spread revenue:

$$SR_i = \sum_{t=1}^{n} (P_{it} - m_{it})x_{it}.$$

Standard deviations are in italics.

	Dollar volume portfolio			
	All firms	1 (Lowest)	2	3 (Highest)
Panel A: *total profits*				
A.1: CATS				
Pre-period	($2,141)	$288	($1,094)	($10,091)
	16,919	*1,732*	*10,139*	*37,113*
Post-period	1,224	2,471	1,609	(2,608)
	10,403	*11,601*	*8,982*	*9,922*
No. of stocks	60	27	22	11
A.2: Floor				
Pre-period	$1,207	$84	$3,307	$371
	21,165	*3,766*	*15,893*	*30,230*
Post-period	(2,803)	1,700	(309)	(7,922)
	52,086	*6,887*	*9,535*	*81,587*
No. of stocks	144	41	45	58
Panel B: *spread revenue*				
B.1: CATS				
Pre-period	$1,818	$2,985	$534	$1,521
	7,263	*9,882*	*1,269*	*6,825*
Post-period	378	437	898	(806)
	3,989	*728*	*3,092*	*8,385*
No. of stocks	60	27	36	11
B.2: Floor				
Pre-period	$1,853	$999	($401)	$4,208
	10,737	*2,535*	*16,955*	*7,252*
Post-period	2,086	503	257	4,626
	5,817	*2,315*	*1,635*	*8,250*
No. of stocks	144	41	45	58

shows an increase in specialist profit for CATS stocks, a result that is inconsistent with expectations and may result from aggregation of total profits.

Total profits consist of profits earned by capturing the spread (spread revenues) as well as trading profits; therefore, examining spread revenue separately may provide improved insight into specialist profits. Panel B in Table 8 lists the results for Spread Revenue which is based on the half spread:

$$SR_i = \sum_{t=1}^{n} (P_{it} - m_{it})x_{it}, \tag{6}$$

and shows an overall decrease from the pre- to the post-event period. These results suggest that the increase in spreads following MBP did not translate into higher spread revenue for specialists who overall found this portion of profits decreased after the change.

Since several specialists (RTs) work for each specialist (RT) firm, it may be more appropriate to examine changes in profits at the firm level. In our sample, 13 firms made markets in CATS stocks and 24 firms in Floor stocks. Table 9 contains specialist firm mean and median profits as well as the proportion of trades firms were party to as specialists. Panel A reveals a total profit decline similar to that reported on a per stock basis in Table 8 but the reduction in the post period for firms trading Floor stocks is statistically significant. All median measures decline in the post period, which is again consistent with the hypothesis that specialists earn less in a more transparent market.

Our findings for depth and volatility suggest a decline in public supplied liquidity. Given the affirmative obligations of Toronto specialists, we would expect them to be involved in more trades following the opening of the limit order book.[12] Panel C of Table 9 contains the average and median proportion of trades involving the firm as a specialist. Examining Panel C reveals that the average proportion of specialist trades increased in the post period for both CATS and Floor stocks. However, only the CATS increase is statistically significant. Given the economically small proportion of trades that specialists are involved in, this finding suggests that specialists did not make up for the loss of liquidity following the opening of the book.

4.8. *Observable effects are proportional to the size of the transparency change: H7*

The results specified in the preceding sections suggest that we cannot clearly reject the hypothesis that changes in transparency are proportional to the size of the transparency change. Although we find that spread widths are wider after MBP on Floor stocks than on CATS stocks, the difference is not statistically different at normal levels. When using a multivariate test to determine the cause of the spread width change, we find that the dummy variable measuring pre and post MBP is statistically significant for Floor stocks but not for CATS stocks. When examining

[12]The TSE has minimum guaranteed fill (MGF) amounts for public orders. The amount varies from stock to stock. TSE specialists are required to make up the shortfall if the amount on the book is less than the MGF.

Table 9
Registered trader profit components—by member firm. This table shows mean registered trader profits for Toronto Stock Exchange member firms during the periods March 1–March 30, 1990 (pre-period) and May 1–May 31, 1990 (post-period). Results are per member firm, and are partitioned by trading system: CATS or Floor. There are 13 (24) member firms trading CATS (Floor) stocks during our sample period. Panel A reports total profit:

$$TP_i = \sum_{t=1}^{n} p_{it}x_{it} + m_{in}I_{in} - m_{i0}I_{i0},$$

where, for stock i and transaction t, x_{it} is the specialist signed volume, p_{it} is price, I_{it} is the specialist's inventory, m_{it} is the quote midpoint, and $I_{in} = \sum_{t=1}^{n} x_{it}$. Total profits consist of profits earned by capturing the spread (spread revenues) as well as trading profits. Panel B reports spread revenue:

$$SR_i = \sum_{t=1}^{n} (P_{it} - m_{it})x_{it}.$$

Panel C lists the proportion of trades in which each member firm was involved in a registered trader capacity. Reported are the mean, standard deviation, and median for each measure. Tests for significant differences between pre- and post-period profits using a paired t-test are indicated as follows: * denotes significance at the 5% level.

	Mean	Median	Standard deviation
Panel A: total profits			
A.1: CATS			
Pre-period	($9,791)	$1,919	$47,189
Post-period	5,649	682	20,896
A.2: Floor			
Pre-period	$7,241	$8,398	$64,623
Post-period	(16,819)*	4,282	77,905
Panel B: spread revenue			
B.1: CATS			
Pre-period	$8,393	$2,593	$19,429
Post-period	1,746	437	9,741
B.2: Floor			
Pre-period	$11,123	$7,513	$29,613
Post-period	12,521	5,031	21,229
Panel C: proportion of trades involving RT			
C.1: CATS			
Pre-period	0.22%	0.25%	0.16%
Post-period	0.24%*	0.26%	0.16%
C.2: Floor			
Pre-period	0.52%	0.27%	0.67%
Post-period	0.59%	0.26%	0.89%

asymmetric information and volatility, we find significant increases in asymmetric information and volatility for both Floor and CATS stocks but when partitioning by volume portfolios, only one of the CATS portfolios shows significant increases while all the Floor portfolios have significant increases in both parameters. We are unable to test changes in depth for Floor stocks but CATS stocks show no significant changes in depth. Therefore, although some of the tests imply significant differences between Floor and CATS stocks, the differences are not consistent across all tests. One possible explanation for the inconsistency is that the change in transparency for CATS stocks is perceived as on the same order of magnitude with the change in transparency for Floor stocks. This conjecture would gain credence if opening the limit order book to the public is perceived as more important than simply opening the book to the floor of the exchange.

5. Discussion and conclusion

Transparency is a topic of considerable importance to investors, academics, and regulators. Previous theoretical research often presents contradictory views of transparency and there is little empirical evidence regarding *pre*-trade transparency. This study analyzes empirically the impact of an increase in pre-trade transparency, focusing on the highly topical issue of public display of the limit order book.

Several conclusions emerge from our analysis. Contrary to the common presumption among many policy makers and regulators, greater transparency need not increase market liquidity. In particular, we document economically significant increases in execution costs and volatility after the limit order book is displayed widely to the public, even when controlling for other factors that may affect liquidity. We also document a reduction in specialist profits which may be one of the reasons there is specialist opposition to increases in transparency.

Our findings are consistent with theoretical models in which traders adjust their trading strategies based on the level of transparency. Too much transparency increases the "free option" cost of limit-order providers, resulting in order withdrawal and a reduction in market depth. Thinner limit order books imply larger transitory price movements associated with order flows, increasing volatility and execution costs.

Greater transparency may affect market quality in other ways that we do not examine here. Fully transparent markets are susceptible to gaming and market manipulation. For example, the TSE offers a very high degree of transparency before open, displaying away orders and disseminating in real-time an indicated price (known as the calculated opening price) that would clear the market based on current system orders. Concern over possible manipulation has recently led the TSE to implement special procedures to discourage gaming of the opening price.

Full disclosure also creates incentives for large traders to seek alternative venues for their trading. For example, large institutional traders who are concerned about being front-run may seek to trade off-exchange, after-hours, abroad, or in "upstairs" markets, and this diversion of order flow can adversely affect liquidity in the primary market. The resulting changes in execution costs, volatility and liquidity are associated with price declines in the most affected stocks, consistent with theories (Amihud and Mendelson, 1986) where asset values increase with market liquidity.

In conclusion, our analysis shows that transparency *does* matter, affecting market quality and hence the value of traded securities. Thus, greater opaqueness may benefit markets that already offer a high degree of transparency. Whether this conclusion extends to other markets—such as the corporate junk bond market—that are far from transparent is a matter for future research.

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