Spreads, Depths, and the Impact of Earnings Information: An Intraday Analysis

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For a sample of NYSE firms, we show that wide spreads are accompanied by low depths, and that spreads widen and depths fall in response to higher volume. Spreads widen and depths fall in anticipation of earnings announcements; these effects are more pronounced for announcements with larger subsequent price changes. Spreads are also wider following earnings announcements, but this effect dissipates quickly after controlling for volume. Collectively, our results suggest liquidity providers are sensitive to changes in information asymmetry risk and use both spreads and depths to actively manage this risk.

Since Stigler (1964), Demsetz (1968), and Bagehot (1971), numerous studies have examined the impact of information asymmetry on the bid–ask spread. The

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typical information asymmetry model [e.g., Copeland and Galai (1983) and Glosten and Milgrom (1985)] assumes two types of traders: "informed" traders and "liquidity" traders. Informed traders trade because they have private information not currently reflected in prices, while liquidity traders trade for reasons other than superior information. Specialists sustain losses from trading with informed traders, and they recover these losses through the bid–ask spread. These models predict that greater information asymmetry between informed and liquidity traders will lead to wider spreads.[1]

Throughout this literature, the focus has been on the size of the bid–ask spread. However, as noted by Harris (1990), the spread is only one dimension of market liquidity.[2] On the New York Stock Exchange (NYSE), a complete quote includes the best price available for both purchases (the ask) and sales (the bid), as well as the number of shares available at each price (the depth). If the specialist believes the probability that some traders possess superior information has increased, he may respond by increasing the bid–ask spread.[3] Alternatively, the specialist could protect himself by quoting less depth (offering to trade less at each quoted price).

Since market liquidity has both a price dimension (the spread) and a quantity dimension (the depth), it is surprising that much of the literature focuses only on the spread. Many of the existing models of market making under asymmetric information ignore depth by requiring all trades (and therefore quotes) to be the same size [e.g., Copeland and Galai (1983), Glosten and Milgrom (1985), and Easley and O'Hara (1992)]. Models that allow for differing trade sizes, such as Kyle (1985) and Rock (1989), typically assume that the specialist quotes a complete pricing schedule. In these latter models, information about both price and quantity is needed to evaluate the liquidity implicit in the pricing schedule. However, much of the empirical work to date has focused exclusively on the spread as a proxy for market liquidity.

In this article, we contend that when trades can differ in size, it is theoretically impossible to make inferences about overall liquidity

[1] In Glosten and Milgrom (1985), an increase in asymmetric information can occur with an increase either in the proportion of informed traders or in the precision of their information.

[2] Harris (1990, p. 3) defines liquidity as follows: "A market is liquid if traders can buy or sell large numbers of shares when they want and at low transaction costs. Liquidity is the willingness of some traders (often but not necessarily dealers) to take the opposite side of a trade that is initiated by someone else, at low cost."

[3] On the NYSE, the specialist's quote reflects the aggregate supply of liquidity from limit orders (the book) and standing orders (the crowd), as well as the specialist's own willingness to trade [see Cohen et al. (1979), Rock (1989), Harris (1990), and Lee and Ready (1991)]. Thus, throughout this article, the specialist's behavior represents that of all liquidity suppliers.

shifts on the basis of either quoted spreads or quoted depths alone. However, we show that the combination of wider (narrower) spreads and lower (higher) depths is sufficient to infer a decrease (increase) in quoted liquidity.[4] Using this criterion, we show quoted liquidity decreases both after periods of high trading volume and immediately before the release of earnings news. The preannouncement drop in liquidity is more pronounced for earnings announcements with a greater subsequent price effect. Collectively, our findings suggest that liquidity providers are sensitive to changes in information asymmetry risk and actively manage this risk by using both spreads and depths.

Our research strategy employs two different sets of intraday tests. In the first set of tests, we examine the general relation between spreads, depths, and volume without conditioning on a particular information event. Using observations at half-hour frequencies, we document a cross-sectional relation between spreads and depths: wide spreads are accompanied by low depths and narrow spreads are accompanied by high depths. Although both spreads and depths display pronounced intraday patterns, the association of wide (narrow) spreads and low (high) depths holds even after controlling for this intraday effect. This result is consistent with institutional constraints that may induce specialists to use *both* spread.and depth to convey the liquidity inherent in their quotes.

We also use time-series regressions to investigate the effect of volume on quoted liquidity. We find spreads widen and depths decrease in response to abnormally high trading volume. The combination of spread and depth changes suggests that, on average, quoted liquidity decreases in response to volume shocks. This finding is consistent with Easley and O'Hara's (1992) model, in which specialists use trading volume to infer the presence of informed traders. However, it is inconsistent with the alternative hypothesis, suggested by Harris and Raviv (1993), that increased volume primarily reflects increased liquidity trading and, therefore, higher overall market liquidity.

Our second set of tests uses event study methods to investigate liquidity shifts in the four-day period surrounding earnings announcements. We focus on earnings announcements because they are anticipated events with significant price impacts. If liquidity providers anticipate the timing of earnings releases, quoted liquidity should be lower in the period immediately before these announcements. Prior

[4] Not all trades take place at quoted bid or ask prices [e.g., see Lee and Ready (1991)]. Therefore, it is useful to distinguish between the ex ante liquidity in quotes and the ex post liquidity implicit in trade prices. Our emphasis is on the former, but we also include in our tests a measure of ex post liquidity called the *effective spread*, defined as twice the absolute difference between the trade price and the midpoint of the prevailing bid and ask prices at the time of the trade. Unqualified references to spreads, depths, and liquidity in this article pertain to the ex ante, or quoted, variables.

studies have used daily data to examine information asymmetry costs around earnings announcements, but report mixed findings.[5] We argue that the use of intraday data and precise (to the nearest minute) announcement times, the inclusion of depth, and the adjustment for contemporaneous volume are important design improvements. Incorporating these features, we find an increase in spreads and a decrease in depths beginning at least one full trading day prior to the announcement.[6] Further, we document a more pronounced drop in liquidity for the subsample of announcements with a larger subsequent price impact. These results suggest liquidity providers anticipate the timing of earnings news and are able to discern, ex ante, the more important announcements.

Our results show that spreads increase dramatically in the half hour containing the announcement, and remain wider than during nonannouncement periods for up to one day.[7] The quoted depths, however, return to nonannouncement levels after three hours. These findings are consistent with Kim and Verrecchia (1991b), who predict that information asymmetry will be higher after the earnings announcement, because the announcement is a noisy signal and certain traders have a superior ability to process the earnings information. However, the postannouncement liquidity effects should be interpreted with caution, because this period is characterized by extremely high trading volume. In the Kim and Verrecchia model, the source of the increased information asymmetry risk is the public disclosure of the earnings, not the accompanying volume. Thus, their model predicts a drop in postannouncement liquidity that is independent of the general relation between volume and liquidity. We show that after controlling for the volume increase, the drop in postannouncement liquidity is insignificant except for the half hour containing the earnings release. This result suggests that the information advantage from a superior ability to process earnings news, as formalized by Kim and Verrecchia, may be a short-lived phenomenon.

The picture that emerges from these results is that of a surprisingly dynamic market for the supply of liquidity. Specialists, and other suppliers of liquidity, appear to react quickly to changes in information asymmetry risk by adjusting both spreads and depths. In par-

[5] Information asymmetry around earnings announcements has been examined by using daily quoted spreads [Morse and Ushman (1983), Venkatesh and Chiang (1986), Skinner (1991)] and block trades [Daley, Hughes, and Rayburn (1991), Barclay and Dunbar (1991), and Seppi (1992)]. Several other empirical studies [Stoll (1989), Glosten and Harris (1988), George, Kaul, and Nimalendran (1991), and Hasbrouck (1988)] have estimated the relative magnitude of the different components of the bid-ask spread without focusing on particular events.

[6] Effective spreads also increase significantly in advance of earnings announcements.

[7] Patel (1991) also reports an increase in the spread after earnings announcements. He does not examine depth or preannouncement spread effects.

ticular, we show that liquidity suppliers respond quickly to incoming trades, anticipate earnings announcements, distinguish the more important news releases, and adjust quickly to the information asymmetry problem after the announcement. Our analyses also highlight the importance of including the quantity dimension (depth) in assessing overall market liquidity.

The remainder of the article is organized as follows. In Section 1, we develop the theoretical basis for our unconditional tests of the relation between spreads, depths, and volume. In Section 2, we provide the background and motivation for our tests of liquidity shifts around earnings announcements. In Section 3, we describe the data and sample selection procedures. The results of the unconditional tests are presented in Section 4, and the earnings announcement results are presented in Section 5. In Section 6, we summarize key results and discuss implications for future research.

1. The Theoretical Relation among Spread, Depth, and Volume

In this section, we first argue that, in the context of extant theory, directional inferences about market liquidity are impossible using only quoted spread or depth. Second, we suggest that institutional constraints compel the specialist to use both spread and depth to manage liquidity risk, so that movements in these two measures should be empirically related. Finally, we introduce volume and discuss the likely effect of this variable on spreads and depths.

2.1 The relation between spread and depth

The theoretical relation between quoted spread and quoted depth has not been explicitly modeled. Some models of market-maker pricing under asymmetric information effectively ignore depth by assuming a unit size for all trades [for example, Copeland and Galai (1983), Glosten and Milgrom (1985), and Easley and O'Hara (1992)]. Other models capture the depth implicitly by having the specialist quote complete pricing functions rather than individual bid and ask prices [see Kyle (1985) and Rock (1989)]. The latter models feature an inextricable association between the price dimension (spread) and quantity dimension (depth) of market liquidity. However, very little work has focused on how these dimensions interact, particularly in response to changes in the information environment.

In both Kyle (1985) and Rock (1989), specialists quote full pricing functions, so potential traders observe the full schedule of prices for each quantity demanded. We can interpret the actual NYSE quotes by treating the ordered pairs (ask price, depth at ask) and (bid price, depth at bid), as two points on the pricing function. However, current

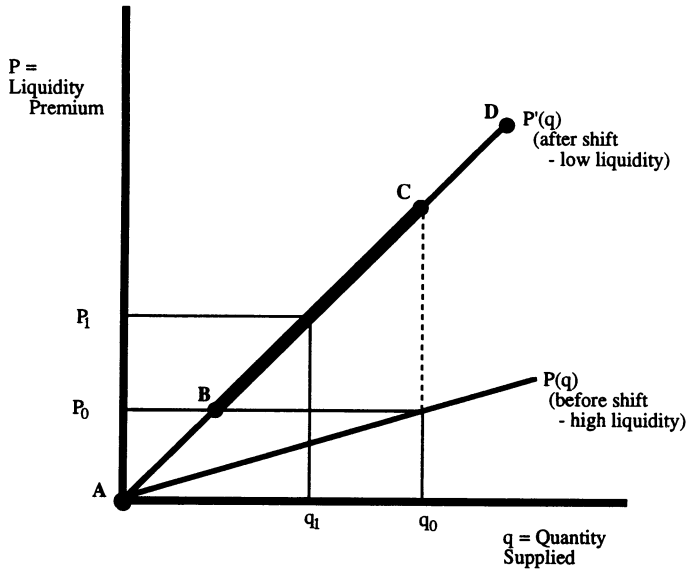

Figure 1
The specialist's pricing function before and after a decrease in market liquidity
A specialist currently quoting (P_0, q_0) on the pricing schedule $P(q)$ may effect a decrease in liquidity by quoting any point on the new price schedule $P'(q)$. Only when the new quote is on segment *BC* is the direction of the liquidity shift unambiguously determined by using either spread or depth in isolation.

theory does not suggest which point on a given pricing function the specialist will choose. Given appropriate matching depths, a quote with a ¼ spread might well come from the same pricing function as a quote with a ⅛ spread.

To illustrate, in Figure 1 we compare two pricing functions (the ask side of the market) with different amounts of liquidity.[8] Suppose a specialist currently quoting (P_0, q_0) becomes less willing to trade and changes his pricing function from $P(q)$ to $P'(q)$.[9] This shift may be effected by selecting any ordered pair on the new schedule. If the specialist chooses a point on the open segment *AB*, then both the spread and depth decrease. Conversely, if he chooses any point on the open segment *CD*, then both the spread and depth increase. In either case, the market liquidity decreases.

We can see from Figure 1 that the examination of either spread or

[8] The pricing functions are drawn to be linear as in Kyle (1985), but the discussion applies for any increasing function. Note that if the bid side of the market is the mirror image of the ask side, then P_0 represents one-half of the quoted spread.

[9] A specialist's willingness to trade may change for various reasons, including, but not limited to, a change in the perceived level of asymmetric information, the need to manage his inventory level, or a change in his ability to extract monopoly rents.

depth, in isolation, does not allow us to make inferences about market liquidity. The risk of examining only spread lies with moves to a point on segment *AB*. Points on this segment represent a decrease in quoted spread, but such a shift would be mistaken for an *increase* in overall liquidity. Similarly, examining depth alone results in erroneous inferences when the move is to a point on *CD*. In fact, the inference is correct only along segment *BC*, when we observe a spread increase and a *simultaneous* depth decrease.

Another illustration provides further insight into the interdependence of spreads and depths. Consider observing just two quotes: the first is (P_0, q_0) and the second is some point along $P'(q)$. How do we know if the new quote reflects a movement along the same pricing schedule or a shift to a new pricing schedule? If the new quote is anywhere *except* on segment *BC*, we cannot be sure. However, if the new quote is along *BC*, we can reasonably infer that a shift in market liquidity has taken place. That is, the specialist is now quoting from a new pricing schedule. This inference is reasonable because a pricing schedule that can accommodate both quotes would have to be *downward* sloping. Again, the liquidity inference is unambiguous only when the changes in both the price and quantity dimensions reinforce each other.

1.2. The effect of institutional constraints

The discussion thus far abstracts from two important institutional considerations. First, quoted spread and quoted depth are subject to practical size constraints. The NYSE specialist has an affirmative obligation to keep a fair and orderly market, which includes quoting tight spreads with reasonable depths. The average spreads and depths are part of the monthly statistics reported on each specialist, and affect his performance evaluation. Excessive spreads or inadequate depths are generally regarded as indicators of poor performance, since they suggest liquidity is either costly or relatively thin.

If the specialist is averse to quoting extremes in either dimension, he is likely to use both spreads and depths in managing liquidity risk. Returning to Figure 1, we see that a specialist quoting (P_0, q_0) can shift to the new pricing schedule $P'(q)$ by choosing many combinations of spread and depth changes. However, if the specialist changes only the spread (which corresponds to a strictly vertical shift on the graph to point *C*), the new quote will reflect a more extreme spread than necessary. Similarly, if only the depth is changed (a move to point *D*), the decrease in depth is more extreme than necessary. Consequently, the specialist is more likely to choose a quote on segment *BC* over a quote along either *CD* or *BC*. Since the specialist will attempt to strike a "balance" between spread and depth, lower (higher) spreads should generally be accompanied by higher (lower) depths.

A second institutional consideration is the effect of price discreteness. The models of Kyle (1985) and Rock (1989) assume continuous prices and volume. In these models, a specialist can quote arbitrarily close to the new liquidity schedule by changing either spread or depth. In practice, stock prices usually trade in ⅛ths and trading volume is usually denominated in 100 shares. Although discreteness affects both spreads and depths, the discreteness of spreads is the greater concern, since a ⅛th move in spread is proportionally much greater than a 100 share change in depth. The coarseness of spread changes suggests shifts in liquidity might be more readily detected in depths, rather than spreads. This observation reinforces our assertion that depth is an important empirical proxy for market liquidity.[10]

1.3 The effect of volume

Most earlier theoretical models ignore the effect of trading volume on quoted spreads. Models that discuss the relation generally do so in a cross-sectional context, concluding that markets with greater trading activity will feature tighter spreads [e.g., Copeland and Galai (1983)]. Prior empirical research is largely consistent with this prediction, as firms with tighter spreads are generally characterized by higher volume and a greater number of trades [see McInish and Wood (1992) for a synopsis]. However, these analyses are based on cross-sectional differences in volume and spreads. The relation between volume and quoted liquidity in a time-series framework has been largely ignored.

Recently, Easley and O'Hara (1992) present a model in which volume plays an important role in establishing spreads. In their model, the specialist uses trading volume as a signal that an information event has occurred. The specialist sets the initial spread based on the ex ante probability of informed traders, and widens the spread in response to an unusually high number of trades. Since the model assumes a unit trade size, it does not incorporate depth. However, a logical extension of the model is that depth should decrease with higher volume. This model therefore predicts a negative relation between volume and market liquidity in a time-series context.

While the Easley and O'Hara framework is appealing, mitigating factors may reduce or negate the predicted empirical relation. For

[10] Price discreteness also affects the normality assumptions that underpin many parametric tests. The quoted spread, in particular, is essentially a categorical variable that most frequently assumes the values ⅛, ¼, ⅜, or ½. We address this issue by using primarily nonparametric statistics in our empirical design. We also augment our ordinary least squares (OLS) regressions of quoted spreads with a parallel ordered probit design.

example, if volume shocks reflect mainly a lack of consensus among market participants, as suggested by Harris and Raviv (1993), periods of higher volume may correspond to the arrival of public limit orders on both sides of the bid–ask spread. Thus, an alternative hypothesis is that higher volume is associated with increased depths and tighter spreads. In addition, the specialist may be able to discern that a volume shock is due to a change in the demands of liquidity traders (for example, index arbitrage, mutual fund redemptions, or certain block trades). In cases where increased volume is due to identifiable liquidity trading, specialists would not be expected to decrease liquidity. Given these factors, the relation of volume and liquidity in a time-series context is an open empirical question. In this article, we provide insights on this question by documenting the relation between volume during a given half-hour interval and the spread and depth at the end of this interval.[11]

2. Earnings Announcements and Liquidity Effects

Earnings announcements offer a particularly interesting opportunity to examine the effect of changes in information asymmetry for two reasons—their timing is largely predictable, and they convey price relevant information.[12] Thus, if the specialist and other liquidity providers anticipate a greater probability of facing an informed trader in advance of earnings releases, the models of Copeland and Galai (1983) and Glosten and Milgrom (1985) predict the spread should widen.

Any probability of information leakage prior to the earnings announcement increases information asymmetry. In fact, evidence suggests the buy–sell direction of both block trades [Seppi (1992)] and trades by corporate insiders [Seyhun (1992)] anticipates the upcoming earnings news. However, even in the absence of leakage, information asymmetry risk may increase before earnings releases for two reasons. First, the specialist faces the risk that other traders may receive and trade on the public news before he has a chance to revise his quotes. Although the specialist's information may in general be quite timely, his obligation to provide tradable quotes exposes him

[11] In related research, Hasbrouck (1988), Lee and Ready (1991), and Petersen and Umlauf (1991) show that the direction of incoming order flow has an effect on the subsequent quote revision: an upward (downward) shift in the midspread is likely to be preceded by a trade at the ask (bid). However, these studies do not examine the effect of volume on the spread and and depth of the specialist's quote.

[12] Using prior release dates, Kross and Schroeder (1984) show that over 80 percent of earnings announcements are within three days of the date predicted. Anecdotal evidence from discussions with market participants suggests some traders may have even more precise information about the timing of the releases. Numerous studies document the price and volume reactions associated with earnings announcements; two of the earliest works are Beaver (1968) and Morse (1981).

to potential losses if any trader has even a few seconds of advance notice. Another risk is suggested by Kim and Verrecchia (1991a) and Daley, Hughes, and Rayburn (1991). Specifically, the expectation of imminent earnings news may stimulate some traders to search for information immediately prior to the announcement. In either case, the specialist is at greater risk prior to earnings releases. Thus, we hypothesize that specialists will anticipate upcoming earnings news by widening spreads and lowering depths.

Three other empirical studies have investigated the effect of accounting earnings releases on quoted spreads, with mixed results [Morse and Ushman (1983), Venkatesh and Chiang (1986), and Skinner (1991)]. Using a limited sample of 25 National Association of Securities Dealer (NASD) firms, Morse and Ushman (1983) found no change in the quoted spread. Skinner (1991) finds some evidence of an increase in spreads *after* earnings announcements that convey large earnings surprises. Venkatesh and Chiang (1986) find significant changes only when no other announcement is made in the 30 days prior to the earnings announcements.

The above studies suggest earnings news may have some effect on market liquidity. However, the scope and interpretability of these results are limited, for several reasons. First, the analyses were all performed at the daily level, using closing bid–ask prices.[13] Since most of the price reaction to a news event occurs within minutes after the announcement, closing quotes may not reflect the announcement effect.[14] Similarly, any anticipatory effect on the quoted spread may be lost in the coarseness of the daily data. Second, these studies examine changes in quoted, rather than effective, spreads. Lee and Ready (1991) show that around 30% of trades occur inside the spread, so quoted spreads may not capture the abnormal reaction. Third, these analyses do not incorporate the depth of the quote, so inferences about market liquidity may be difficult. Finally, the studies do not control for contemporaneous volume, making the interpretation of the postannouncement liquidity effects [e.g., Skinner (1991)] difficult. We overcome these limitations by using intraday quote and trade data to examine not only effective and quoted spreads but also depths. The use of precise intraday announcement times (accurate to the nearest minute) from the Dow Jones News Service, or "Broad Tape," further enhances our statistical power.

[13] The use of closing bid–ask quotes is a limitation, because these quotes are "indications" and do not represent firm offers to trade.

[14] Patell and Wolfson (1984) show that profitable trading opportunities cease within minutes of an earnings announcement. We use the same sample of announcements as Lee (1992), in which the mean price adjustment was found to be undetectable after the first hour of postannouncement trading.

In related work, Barclay and Dunbar (1991) and Daley, Hughes, and Rayburn (1991) use an alternative approach to investigate changes in market liquidity around earnings announcements. Specifically, they examine the permanent and temporary price effects of block trades around earnings announcements. Barclay and Dunbar find no evidence of changes in market liquidity around earnings announcements. Conversely, Daley, Hughes, and Rayburn find some evidence that information asymmetry decreases after the announcement. However, these studies exclude the day before and the day of the announcement, because of concerns over the accuracy of the announcement date.[15] Yet these are the periods where we expect (and find) the most pronounced effects. In addition, both studies use transaction prices to infer the effective spread, a technique necessitated by the absence of quote data. In our study, the quoted and effective spread are measured using intraday trades and quotes.

Although most extant models would predict an increase in information asymmetry in advance of an earnings announcement, the predictions for the postannouncement period are less clear. One hypothesis is that the earnings news reduces the information advantage of the informed trader, so spreads (depths) should decrease (increase) during this time. Alternatively, Kim and Verrecchia (1991b) suggest that, because the announcement is a noisy signal and certain traders have a superior ability to process the earnings news, information asymmetry should be higher after the earnings announcement. We investigate these competing hypotheses by examining the intraday behavior of both spreads and depths immediately after the Broad Tape news release.

In the Kim and Verrecchia (1991b) model, all market participants know that some traders have superior ability to process the information contained in the announcement. This knowledge implies that the liquidity drop following an announcement should be independent of changes in liquidity due to trading volume. To test this prediction, our investigation includes an evaluation of the postannouncement liquidity effect after controlling for the volume reaction.

3. Data and Sample Selection

The transaction data used for this study were obtained from the Institute for the Study of Security Markets (ISSM). The ISSM tape is an amalgamation of several data sources. The primary components—

[15] Both studies use COMPUSTAT announcement dates, which have been shown to be less precise than the Broad Tape dates used in our study [see Brown, Clinch, and Foster (1991)]. Daley, Hughes, and Rayburn (1991) define the preannouncement period as days −2 to −6 and the postannouncement period as days +1 to +5.

trades and quotes—come from the Securities Industry Automation Corporation (SIAC). Although only NYSE firms were selected for this study, the tape provides a detailed time-stamped chronology of each trade and quote for each firm whose primary exchange is the NYSE or AMEX. The quote data include the bid price, ask price, depth on both sides (measured in round lots of 100 shares), time of execution (to the nearest second), and a condition code that identifies special trading conditions, where applicable. Although NYSE-listed stocks are traded on regional exchanges, the NYSE quotes generally match or are inside the quotes from the regional exchanges. The ISSM tape also excludes about two-thirds of the quotes from the regional exchanges.[16] Accordingly, we examine only those quotes issued by the NYSE specialists, and we assume these are a reasonable proxy for the overall level of market liquidity.

This study covers the 12-month period from January 4, 1988, to December 30, 1988, or 253 trading days. The sample consists of 230 firms that were selected from the 1988 ISSM transaction tape. This sample was developed in Lee (1992) and has not been changed here due to cost considerations. In Table 1, we detail the selection criteria for the sample. Although some of the filters used are not ideally suited to our purposes, we do not feel that they cause any significant biases.[17] The firms in our sample are somewhat larger and more actively traded than the median NYSE firm. The median market capitalization for our firms at the beginning of 1988 is \$650 million, which is in the fourth highest decile of all NYSE firms. On average, our firms had 17,500 trades during 1988 (70 trades per day) and, collectively, accounted for one-sixth of total NYSE trades in the year.

We use the following four market metrics:

1. Quoted spread = ask price − bid price;
2. Quoted depth = depth at ask price + depth at bid price;
3. Effective spread $= \dfrac{2\,\Sigma_{i=1}^{n} |P_i - (\text{ASK}_i + \text{BID}_i)/2|\,Q_i}{\Sigma_{i=1}^{n} Q_i}$,

   where n is the number of trades in a half-hour interval, P_i is the price of the ith trade, Q_i is the number of shares transacted in the ith trade, and ASK_i and BID_i are the ask and bid prices, respectively, of the quote in effect when the ith trade was transacted;[18]

[16] Regional quotes that do not represent the best bid or offer at the time they are posted are excluded from the ISSM data. These quotes are primarily electronically generated (autoquotes) and have a minimum depth of 100 shares.

[17] The only filter that we feel may cause biases in our results is the omission of firms with trading halts. These companies may experience greater price volatility and have a greater percentage of informed traders. Therefore, their omission may bias against finding any results.

[18] Lee and Ready (1991) show that when a quote revision is time-stamped within five seconds before

Table 1
Sample selection

Total NYSE firms listed for the full year in 1988	1463
Change in shares outstanding >10%	332
Trading halts	266
Thinly traded stocks	216
Extremely high or low priced stocks	45
Total remaining firms	604
Firms in a 50% random sample	302
Less: firms in specialized or regulated industries	72
Total sample firms	230

Restrictions imposed on the sample firms, listed in the order in which they were applied:

- Change in shares outstanding: Since substantial changes in the total shares outstanding distort the volume statistics, we remove issues for which the total shares outstanding changed by more than 10 percent during the year.
- Trading halts: Trading on a security may be temporarily suspended for the dissemination of news or when a severe imbalance of buy–sell orders occurs. A few firms also had extremely large block trades (exceeding 3.3 million shares). These events are known to have a disproportionately large effect on intraday trading patterns.
- Thinly traded stocks: To provide sufficient observations for intraday inferences, firms that average less than 10 trades a day are removed from the sample.
- Extremely high or low priced stocks: Securities with extreme prices have a disproportionate effect on the relative spread measure.
- All firms with year end prices of less than $5 or greater than $100 are removed.

4. Volume = total number of shares traded per half-hour interval.

Quoted spread and quoted depth are measured at the end of each half-hour interval.[19] The NYSE was open from 9:30 A.M. to 4:00 P.M. EST during 1988, providing 13 half-hour observations per day. Some quotes are not eligible for inclusion in the National and NASD Best Bid and Offer calculations. These quotes are nontradable, since they do not represent firm commitments to trade by the specialist. Intervals ending with nontradable quotes are treated as missing observations. The effective spread measures the average spread paid on the shares transacted during an interval. This effective spread is volume-weighted. We also calculated a trade-weighted average, but the two measures yield substantially identical results. For some of the tests, the measures described earlier are expressed as a percentage deviation from the nonevent period average for the same firm and time of day. These

a trade, the quote is likely to have actually occurred after the trade. Consequently, in identifying the quote in effect for each trade, we ignore any quote that was time-stamped within five seconds before the trade.

[19] We chose end-of-interval liquidity rather than average quoted liquidity during the interval because the former provides a cleaner test of the *response* of liquidity providers to volume [e.g., as modeled by Easley and O'Hara (1992)]. We also calculated the time-weighted spreads and depths across each half-hour interval for our event study tests and found essentially the same results.

standardized measures allow for comparisons across firms and time periods with different "normal" spreads, depths, and volumes.[20]

For the tests in Section 5, the date and time of all announcements of dividend changes and quarterly earnings were identified by searching the Dow Jones News Service (DJNS) for the period from January 1, 1988, to December 31, 1988. Each announcement is time-stamped to the nearest minute.[21] The earnings announcement selected for analysis is the first announcement after each fiscal quarter that provided an actual earnings figure. Even if an announcement was later corrected, we use the earlier announcement time. Earnings announcements are excluded from the sample if they were made outside of trading hours or within two days of an announcement of a dividend change. After removing these confounding events, 209 of the 230 firms remain, with a total of 606 intraday announcements.

To create a nonannouncement control period for each firm, the 53 half-hour trading intervals (four full trading days) centered on each earnings announcement are excluded. When an earnings announcement was expected, but not found in the DJNS, it was located in the *Wall Street Journal* Index (WSJI). Since the exact times of such announcements are not known, they are excluded from the analysis. To ensure that these announcements do not affect the nonannouncement statistics, the three trading days around the WSJI announcement date are excluded from the nonannouncement control period. Similarly, days 0 to +2 relative to the Broad Tape release date of each dividend change announcement are removed.

Summary statistics for the nonevent distributions of the quoted spread, quoted depth, effective spread, and volume are reported in Table 2. The mean and median quoted spread are both $0.25. The mean and median effective spread are $0.18 and $0.14, respectively. Many trades occur within the bid–ask spread, so the mean and median effective spreads are less than the mean and median quoted spreads. The mean and median depths are 110 and 58 round lots, respectively. Thus, a "typical" quote would have a spread of ¼ and a depth of 29 round lots (2900 shares) on each side. The typical depth is approximately equal to the average half-hour volume for that firm, and the typical quoted spread is 1.1 percent of the stock price.

[20] All key results are unchanged when we standardize the quoted spreads and depths by the beginning of the year price and the average daily volume rather than their respective averages.

[21] The accuracy of the DJNS time stamp relative to the time stamps for ISSM trades is important, since we make a clear distinction between pre- and postannouncement periods. The relative precision of these time stamps is difficult to gauge. However, we show later that no significant increase in trading volume occurs until the half hour containing the announcement. This finding strongly suggests announcement times are accurate to within a half hour, which is the finest resolution used in this study.

Table 2
Summary statistics for spread and depth variables during nonevent periods

Statistic	Mean	Standard deviation	Median	Upper quartile	Lower quartile
Quoted spread	0.25	0.10	0.25	0.25	0.125
Quoted depth	110	200	58	114	23
Effective spread	0.18	0.08	0.14	0.24	0.12
Volume	94	305	15	76	2
Quoted depth as a percent of average half-hour volume for the firm	229	339	118	263	53
Quoted spread as a percent of beginning-of-year price	1.3	0.88	1.11	1.66	0.67

The quoted spread and quoted depth are actual statistics at the end of each half-hour interval during the trading day, averaged across all nonevent periods for all companies. Effective spread is the volume-weighted average of the effective spread paid on all trades during each half-hour interval in the nonevent period. Volume is the number of shares traded in a half-hour interval. Both the trading volume and the quoted depth are expressed in round lots of 100 shares.

4. Unconditional Tests

In this section, we report the results of tests that do not condition on earnings announcements. First, we examine the cross-sectional relation between spreads and depths. In Table 3, we show that spreads and depths are negatively related—wide spreads tend to be associated with low depths, and narrow spreads tend to be associated with high depths. To construct this table, the quote at the end of each half-hour interval is classified into one of nine categories. These classifications are based on how the quote's spread and depth compare to the median spread and depth for that firm. Values reported in the contingency table represent the number of quotes in each of the nine categories. The values in parentheses are the expected number of quotes in each category under the null hypothesis that spread and depth are uncorrelated.

The unexpectedly large number of observations in the upper right and lower left corner cells indicates that high (low) spreads tend to be associated with low (high) depths. The χ^2 statistic for this table strongly rejects the null hypothesis of independence in spread and depth levels. However, this statistic assumes independence in the individual cells. The independence assumption is violated because of serial correlation in the time series of both spreads and depths and because of the use of estimated medians to partition the data. This violation could inflate the *magnitude* of the statistic. Similarly, the magnitude of the χ^2 statistic at the individual firm level could also be inflated. However, the *sign* of each firm-level statistic should be negative with probability .5 under the null hypothesis of no correlation. We find spread and depth levels exhibit a negative relation

Table 3
The relation between spreads and depths

Relation of spreads to median firm spread	Relation of depths to median firm depth			
	Below	Equal	Above	Total
Below	72,023 (81,320)	6,337 (7,517)	92,770 (82,293)	171,130
Equal	186,414 (188,278)	17,291 (17,405)	192,507 (190,529)	396,212
Above	100,222 (89,061)	9,527 (8,233)	77,670 (90,125)	187,419
Total	358,659	33,155	362,947	754,761

This table reports the results of a nonparametric test of the relation between the level of quoted spreads and the level of quoted depths measured in half-hour intervals. Each half-hour interval for 230 firms and 253 trading days is classified into one of nine categories, based on whether the quoted spread and quoted depth at the end of the interval are higher, lower, or equal to their respective medians. A quoted spread (depth) is in the equal category if it is the same as the median spread (depth) for that firm. Table values represent the number of half-hour intervals in each category. Values in parentheses are the expected number in each category under the null hypothesis that spreads and depths are uncorrelated. At the firm level, this negative relation is observed for 217 out of 230 (94 percent) of the firms in our sample.

for 217 (94 percent) of the 230 firms in our sample. This result is significant at the 1 percent level in a Fisher sign test.

Much recent evidence shows that quoted spreads are higher at the beginning and at the end of the trading day.[22] This pattern has been interpreted as evidence of changing liquidity. However, as we note in Section 1, conclusions about market liquidity should not be made without examining both spreads and depths. The average levels of quoted spread, quoted depth, effective spread, and trading volume at each half-hour interval of the trading day are depicted in Figure 2. To facilitate comparison, all four statistics are expressed as percentage deviations from their respective full-day averages. This figure shows the familiar U-shaped pattern in quoted spreads and trading volume reported in previous studies, plus two new findings: effective spreads follow a similar U-pattern, and quoted depths follow a reverse U-pattern. The patterns in this graph indicate that market liquidity is indeed lower at both the beginning and end of the day.

Figure 2 suggests that the negative relation in Table 3 is partially attributable to the systematic intraday changes in liquidity. To explore this possibility, we recalculated Table 3, using separate medians for each time of day (results not shown). After controlling for intraday patterns, we found that the negative relation remains for 209 (91 percent) of the 230 firms in our sample, which suggests wider spreads

[22] Several studies document intraday patterns in spreads and volume [e.g., Brock and Kleidon (1992), Brown, Clinch, and Foster (1991), and McInish and Wood (1992)].

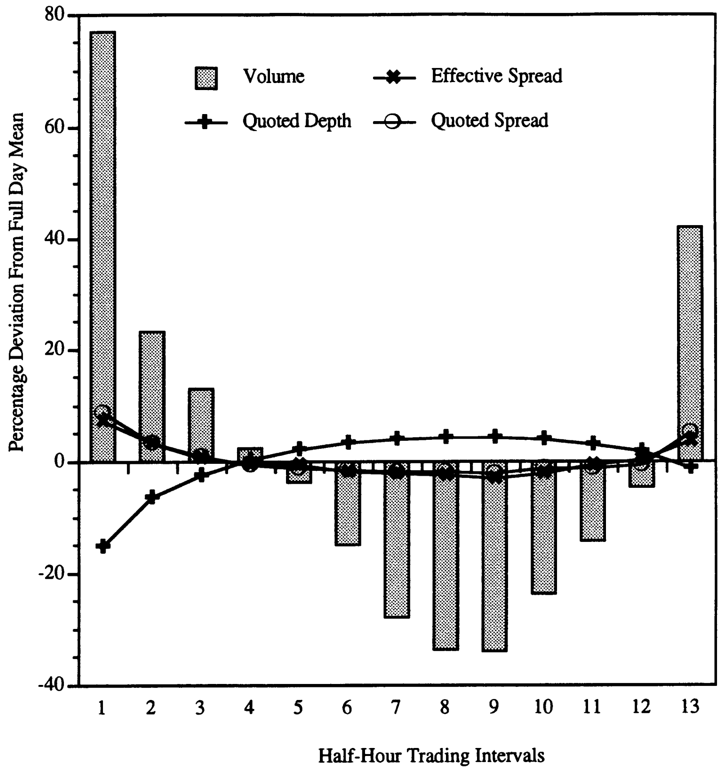

Figure 2
The intraday pattern in spreads, depths, and volume
This graph depicts the percentage deviation in the volume, spread, and depth statistics for each of the 13 half-hour trading intervals during the day (from 9:30 A.M. to 4:00 P.M.), relative to the mean for the full day. Time period 1 is 9:30–10:00 A.M.; period 2 is 10:00–10:30 A.M.; . . . and period 13 is 3:30–4:00 P.M.

are still associated with lower depths, even after accounting for intraday patterns.

The foregoing results do not consider the effect of trading volume. However, as discussed in Section 2, trading volume is expected to have a significant effect on spreads and depths. If the predictions of Easley and O'Hara (1992) hold true, higher volume during a given interval should be associated with wider spreads and lower depths at the end of the interval. Conversely, if volume shocks are associated with increased liquidity trading, intervals with higher volume may be characterized by narrower spreads and higher depths. To test these hypotheses, we regress our three measures of liquidity (quoted spread, quoted depth, and effective spread) on the trading volume during the interval.

In Table 4, we report the cross-sectional averages of the estimated

Table 4
The relation between volume and liquidity

	Intercept (α)	$\sqrt{\text{Volume}}$ (β)	AR(1) parameter (γ)
Quoted spread	−4.3	5.3	0.461
	(−22.5)	(27.9)	(40.2)
Quoted depth	2.6	−3.6	0.643
	(13.7)	(−16.0)	(71.1)
Effective spread	−3.7	4.1	0.169
	(−10.7)	(11.0)	(42.6)

For each firm, a time-series regression is estimated with the spread or depth as the dependent variable and volume as the independent variable. All variables are measured in half-hour intervals. Table values are the cross-sectional average across all firms in our sample ($n = 230$). The numbers in parentheses are the t-statistics under the null hypothesis that the cross-sectional mean of the coefficients equals zero. Specifically, each firm's data is fitted with the following model:

$$\text{LIQ}_t = \alpha + \beta\text{VOL}_t + \omega_t,$$

where

$$\text{LIQ}_t = \text{liquidity measure at the end of time interval } t$$
$$= (\text{Stat}_t/\text{AvgStat}_t - 1) \times 100,$$

Stat_t is the actual liquidity statistic at the end of time interval t (i.e., either quoted spread, quoted depth, or effective spread) and AvgStat_t is the mean of that statistic for that firm and time of day,

$$\text{VOL}_t = \text{normalized volume} = \sqrt{\text{SHR}_t/\text{AvgShr}_t},$$

SHR_t is the number of shares traded during the interval and AvgShr_t is the mean number of shares traded for that firm and time of day,

$$\omega_t = \text{error term} = \epsilon_t + \gamma\omega_{t-1},$$

where γ is the AR(1) parameter and ϵ_t is i.i.d. normal with mean zero and constant variance.

coefficients from three sets of time-series regressions for each of the 230 firms in our sample. To facilitate the interpretation of these cross-sectional averages, all dependent variables are expressed as percentage deviations from the mean value for that firm and time of day. The independent variable in each regression is the square root of the ratio of volume in the interval to the mean volume for that firm and time of day.[23] Since the residuals from simple OLS regressions were all highly autocorrelated (the Durbin–Watson statistics were nearly all less than unity), the regressions also include an autoregressive term.

In Table 4, we show a strong positive relation between volume and spreads (spreads tend to be wider after periods of higher volume) and a negative relation between volume and depths, even after con-

[23] To check the robustness of these results, we performed the same regressions using volume with no transformation and volume with log transformations and different additive constants. In all these alternative specifications, the relation between spread (depth) and volume remains significantly positive (negative).

trolling for time of day. For all three liquidity measures, our results are consistent with the Easley and O'Hara (1992) prediction that volume shocks are associated with higher information risk and lower market liquidity.[24] We use similar regressions in the next section to investigate the interaction between liquidity and volume around earnings announcements.

5. The Impact of Earnings Announcements

In this section, we use event study methods to test for changes in liquidity around earnings announcements. The theory developed in Section 2 predicts that the period immediately before an earnings release should be characterized by elevated information asymmetry risks.[25] Thus, we expect to observe higher spreads and/or lower depths in the preannouncement period. We also examine the period immediately following the announcement. However, the abnormally high trading volume in the postannouncement period makes interpretation of these results more difficult.

5.1 Statistical tests

We use both univariate and multivariate tests to examine the changes in spread, depth, and volume around earnings announcements. The univariate tests are based on a Monte Carlo resampling technique that compares the cross-sectional mean of a statistic during the announcement period with an empirical distribution of the corresponding statistic generated from the nonannouncement period.[26] Significance levels are inferred from nonparametric statistics and the research design controls for the composition of firms and the time of day of the announcements. The univariate approach provides an intraday profile of the variables of interest across the announcement period. However, these tests do not control for the contemporaneous relation between liquidity and volume. This relation is of particular concern in the postannouncement period, when volume is known to be abnormally high. To control for these interactions, we conduct a set of multivariate tests which add event-period dummy variables to the volume regressions introduced in Section 4.

For the univariate tests, we express our spread, depth, and volume

[24] Concerned about the discreteness of quoted spreads, we also ran an ordered probit specification with similar results: higher volume is associated with wider spread. We report the OLS results because the coefficients are more easily interpreted.

[25] We would not expect systematic inventory imbalances in advance of earnings announcements, because the trading volume is essentially unchanged from the nonevent period [see Brown, Clinch, and Foster (1991)].

[26] The procedure used here is similar to an approach described in Chapter 3 of Noreen (1989).

variables as percentage deviations from the mean for that firm and time of day. We examine each of 53 half-hour trading intervals around the announcement (26 in advance of the announcement, one including the announcement, 26 following the announcement). For each time interval, we compare the event-period average to an empirical distribution of the same statistic obtained by random sampling, with replacement, from the nonannouncement period (periods excluding all dividend and earnings announcements). This comparison yields a point estimate of the abnormal reaction as well as a significance test against the null hypothesis that the announcement observations represent random draws from the nonannouncement empirical distribution.

The actual procedure for computing the statistics and the reference distributions for the nonannouncement periods is given here. To avoid introducing complex notation, we describe only the procedure for the spread statistic for the half-hour trading interval immediately before the announcements; the procedure for each of the other 52 intervals (and each of the other measures) is identical.

For each announcement, the quoted spread at the end of the half-hour period immediately preceding the earnings announcement is deemed the "interval -1" spread.[27] For example, if Kellogg announces third-quarter results at 10:44 A.M., we deem Kellogg's quoted spread as of 10:30 A.M. to be the interval -1 spread. We then compute the equally weighted average of these spreads across all firms and all announcements for each firm. The result is the actual "event-period" spread for the half-hour before the announcement. For each announcement included in the event-period spread, we draw a random nonevent control observation with replacement from the nonevent distribution for the same firm and the same time of day. In Kellogg's case, a control observation is drawn randomly from the sample of all quoted spreads in effect at 10:30 A.M. for Kellogg on nonevent days. To create a reference distribution, we repeat this process 300 times, thus generating 300 nonevent control observations for each event-period observation.

We repeat this calculation process for the other 52 event periods and for each of the other statistics. In addition to the half-hour statistics, we examine averages over the two trading days immediately before and after the announcement. For these longer intervals, we also generate corresponding nonevent distributions. In the Kellogg example, the day -1 event period observation would be an equally weighted average of the 13 half-hour spreads from 11:00 A.M. of the

[27] For purposes of this example, the term *spread* refers to the percentage deviation from the mean quoted spread for that firm and time of day.

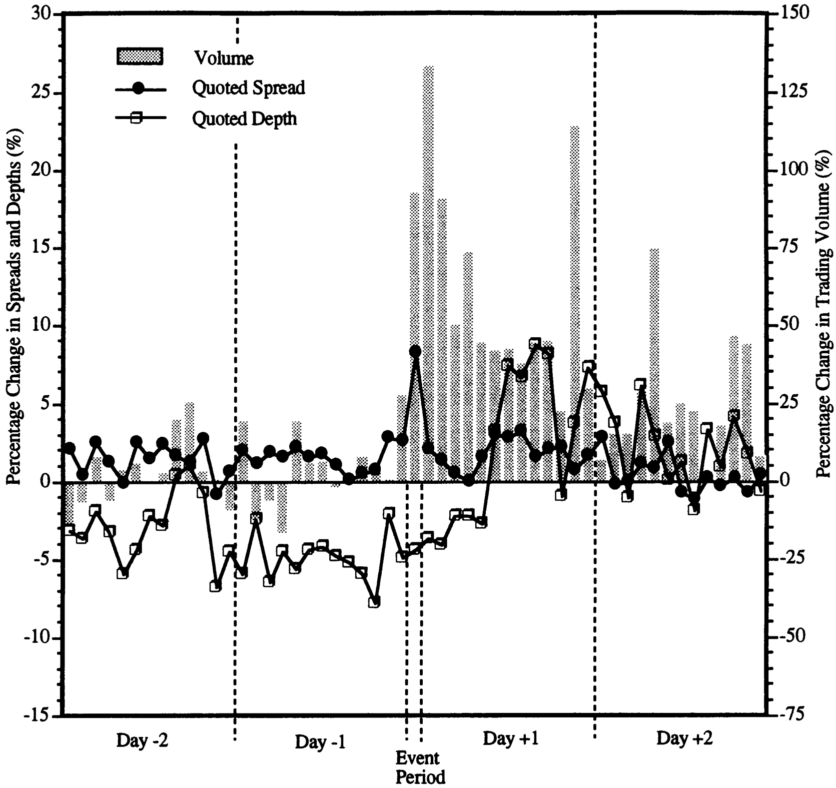

Figure 3
Changes in quoted spread, quoted depth, and trading volume around earnings announcements
This graph presents the mean percentage change in the quoted spread, quoted depth, and trading volume around earnings announcements. All variables are measured in half-hour intervals relative to the half-hour interval that contained the Broad Tape news announcement (event period). Based on randomly generated nonevent distributions, the 5 percent significance levels are attained for quoted spread, quoted depth, and volume when their mean percentage changes are 2, 5, and 18 percent, respectively.

day before the announcement to 10:30 A.M. on the day of the announcement, inclusively.

5.2 Univariate test results

In Figure 3, we show the abnormal reaction of the quoted spread, quoted depth, and volume (number of shares traded) in the half-hour intervals around the Broad Tape announcement of earnings. The graph values represent the average percentage deviation in each variable from its nonannouncement period mean. Based on the randomly generated nonevent distributions, the 5 percent significance levels are attained for quoted spread, quoted depth, and volume when their average percentage deviations are 2, 5, and 18 percent, respectively.[28] A comparison of these figures to their statistical cutoff levels shows that many of the preannouncement spread (depth) observations are individually significant, and almost all are above (below) the nonevent means.

These results show both a statistically significant increase in quoted spread and a statistically significant decrease in quoted depth prior to earnings announcements. As discussed earlier, the combination of an increase in spread and a decrease in depth demonstrates an unambiguous decrease in liquidity. The largest increase in the spread is observed during the half-hour interval containing the earnings announcement, and the largest decrease in depth occurs $1\frac{1}{2}$ hours before the announcement. Trading volume increases dramatically in the half-hour containing the announcement, but the volume in advance of the news release is not significantly higher. In the absence of advanced trading, the preannouncement drop in liquidity is unlikely to be caused by specialist inventory effects.

Note also that the increase in spread persists in the postannouncement period. The quoted spread remains above nonannouncement levels for a full trading day (13 half-hour intervals) after the Broad Tape announcement. The preannouncement depth is significantly lower than normal but recovers quickly and actually becomes higher than normal three hours after the announcement.

In Panel A of Table 5, we present results for one-day intervals immediately before and after the announcement as well as for the half-hour containing the earnings announcement. As described earlier, table values for days -2, -1, $+1$, and $+2$ represent the equally weighted average of the 13 half-hour observations in each of these intervals. The corresponding reference distributions are also adjusted to reflect this aggregation. This table shows that the average percentage increase in quoted spread on day -1 is 1.4 percent, while the average percentage decrease in depth is 5.3 percent. Thus, although the spread and depth are affected by the anticipated earnings news, the magnitude of the impact on depth is proportionally greater. Conversely, during the announcement period the spread experiences a greater absolute change (8 percent) than does the depth (4 percent).

Since a substantial percentage of trades occurs inside the quoted spread, this spread may not capture the effective spread paid by traders. To address this concern, we include in Table 5 the change in the effective spread around the earnings news release. In Panel A, we show that the effective spread results are even stronger than those

[28] The actual cutoff levels differ slightly for each of the 53 event intervals, but these differences are less than 0.1 percentage point.

Table 5
Analysis of changes in quoted spread, effective spread, quoted depth, and volume around the earnings announcements

	Quoted spread	Quoted depth	Effective spread	Volume
A: Full sample ($N = 606$)				
−2 Day	1.28	−3.09	1.43	−2.11
	(0.03)	(0.11)	(0.06)	(0.62)
−1 Day	1.44	−5.25	2.33	1.97
	(0.04)	(0.02)	(0.01)	(0.26)
Event interval	8.18	−4.37	18.62	93.14
	(0.00)	(0.10)	(0.00)	(0.00)
+1 Day	1.70	2.04	3.28	59.57
	(0.01)	(0.75)	(0.00)	(0.00)
+2 Day	0.30	1.86	1.30	18.33
	(0.32)	(0.77)	(0.10)	(0.00)
B: Absolute return >2% ($N = 193$)				
−2 Day	2.01	−8.07	1.74	6.64
	(0.03)	(0.02)	(0.20)	(0.19)
−1 Day	2.67	−8.58	4.03	21.32
	(0.01)	(0.02)	(0.01)	(0.01)
Event interval	12.47	−3.96	21.91	170.96
	(0.00)	(0.24)	(0.00)	(0.00)
+1 Day	3.29	2.07	5.33	145.74
	(0.01)	(0.71)	(0.00)	(0.00)
+2 Day	1.03	−0.28	3.24	42.40
	(0.19)	(0.45)	(0.04)	(0.00)

This table reports the percentage deviation during the event period of each statistic from the mean of its corresponding reference distribution determined in nonevent periods. Numbers in parentheses represent significance levels in one-tailed tests. The event interval is the half-hour containing the earnings announcement. The +1 (−1) day periods are the 13 half-hour trading periods after (before) the event period, not including the event half hour, and the +2 (−2) day periods are the 13 half-hour trading periods from +14 to +26 (−14 to −26), inclusive.

reported for the quoted spread. For example, in the half-hour interval of the announcement, the average effective spread increases by 18.6 percent.[29]

To examine the extent to which the market anticipated the magnitude of the subsequent price movement, we consider separately only those announcements that result in a one-day return of greater than 2 percent (or less than −2 percent), computed from the announcement time to the same time on the next trading day.[30] The

[29] If the pricing schedule is upward-sloping, as in Kyle (1985), the effective spread is expected to be higher for larger trades. Since the average trade size is somewhat higher after the news release, the effective spread measure may be upwardly biased in the postannouncement period. However, preannouncement results should not be affected, since the average trade size does not increase in the period before the news release.

[30] We calculated the return using quote midpoints to reduce the effect of bid–ask bounce. The 2 percent cutoff is selected arbitrarily after review of the distribution of all one-day returns for the sample announcements. It is chosen solely to ensure a sufficient number of obsrvations above the cutoff to provide statistical power. The results are similar if the median return is used to partition the sample.

same Monte Carlo method used in the earlier univariate tests is used for calculating the statistics and reference distributions for these subsamples. In Panel B of Table 5, we report the univariate results for this "large price move" subsample.

Comparing panels A and B, the anticipatory effects appear greater for the subsample of announcements with the larger subsequent price move. For example, the change in percentage depth for day −2 prior to the event period is almost three times greater in the subsample (−8 percent versus −3 percent) than in the full sample. Although the large price move sample has greater anticipatory effects on all three liquidity measures, only the difference in preannouncement depth is individually significant.[31] Separate analyses performed on the small price move sample (not reported) show a significant decrease in liquidity prior to the news release, so our conclusions are not driven solely by the large price move announcements.

These results imply that the specialist (and other liquidity suppliers) can distinguish which upcoming announcements are likely to have a greater price impact. What cues do liquidity suppliers use to accomplish this? The nonevent period averages for the four statistics in the large price move subsample are similar to those from the full sample, so differences in sample composition do not appear to explain this result.[32] Interestingly, Patell and Wolfson (1981) document a parallel result in a somewhat different context. In their study, the implied volatility (calculated from option prices) before earnings announcements foreshadows the price variability associated with the upcoming announcement. Both findings suggest a market in which the liquidity suppliers are able to anticipate, to some extent, the price informativeness of an upcoming earnings release. This phenomenon may warrant further study.

5.3 Multivariate test results

In Figure 3, we show that the spread increase persists for more than one full trading day following the earnings announcement. This spread increase is consistent with the Kim and Verecchia (1991b) hypothesis that earnings may increase information asymmetry. In fact, the announcements do appear to cause differences in opinion among

[31] The significance levels for the difference between the large price move and small price move samples are .14, .09, and .21 for preannouncement quoted spreads, quoted depths, and effective spread, respectively.

[32] One possibility is firm size; that is, liquidity suppliers infer the magnitude of the price change from the size of the firm. The accounting literature has long documented a stronger average market reaction to earnings news in small firms [see Ro (1989) for summary]. However, the evidence for a firm size effect in this sample is not strong. Firms in our "large price move" subsample do tend to be somewhat smaller, but the median large price move firm is still in the fourth largest size decile of NYSE firms, the same as for the overall sample.

investors, as evidenced by the large increase in trading volume. However, it is unclear from this figure whether the postannouncement liquidity effects are due to the earnings news per se or to the general relation between volume and liquidity observed in Section 4.

In the Kim and Verrecchia (1991b) model, the source of the information asymmetry risk is the release of a public signal. The presence of traders with superior abilities to interpret this signal should generate additional risk to liquidity suppliers, beyond what is normally conveyed through increased volume. Thus, Kim and Verrecchia would predict a drop in liquidity *after* controlling for the general relation between volume and liquidity. In this section, we use a multiple regression test to examine whether announcement period liquidity effects are still significant after controlling for the volume reaction.[33]

In Table 6, we report the results. This table is similar to Table 4 except for its inclusion of dummy variables to capture liquidity shifts during the event period. We performed a time-series regression for each firm and for each dependent variable (quoted spread, quoted depth, and effective spread). The coefficients on the indicator variables represent changes in the mean of each liquidity variable during the event period, after conrolling for volume. Table values are cross-sectional averages for our sample firms.

The indicator variables confirm a significant positive mean shift in the spread a full day before the announcement, as well as during the announcement interval. Similarly, the quoted depth is significantly negative in the preannouncement period. The magnitude of these effects is similar to that reported for the full sample in the univariate tests of Table 5. Thus, we see that controlling for volume does not affect the preannouncement results.

However, in the postannouncement period, neither the quoted nor effective spreads are significant after controlling for the abnormal volume. These results suggest that any increase in information asymmetry risk immediately following the earnings announcement is resolved quickly. Certain traders may possess private information, by virtue of their superior ability to analyze the public signal, but the risk they impose on liquidity suppliers appears to dissipate within hours of the release.

Finally, a word about economic significance may be warranted. Through finer data and improved statistical design, we have confirmed several theoretical predictions about the effect of earnings news on

[33] Since Kim and Verrecchia (1991b) do not model the general relation between volume and liquidity, our design may overcontrol for the volume increase. For example, perhaps only some announcements give advantages to information processors. In this case, as in Easley and O'Hara (1992), liquidity providers would use volume to infer the presence of informed traders. Our control for volume would effectively eliminate this type of postannouncement liquidity effect.

Table 6
Changes in liquidity around earnings announcements controlling for volume

	Intercept (α)	$\sqrt{\text{Volume}}$ (β)	AR(1) parameter (γ)	Day −2 (θ_1)	Day −1 (θ_2)	Event interval (θ_3)	Day +1 (θ_4)	Day +2 (θ_5)
Quoted spread	−4.3	5.6	0.458	1.22	1.61	5.93	0.42	0.17
	(−20.5)	(25.4)	(37.1)	(1.82)	(2.14)	(3.91)	(0.61)	(0.26)
Quoted depth	2.7	−3.6	0.638	−3.12	−4.12	−0.60	2.96	2.04
	(11.3)	(−14.6)	(66.8)	(−1.70)	(−1.95)	(−0.18)	(1.31)	(1.13)
Effective spread	−3.7	4.1	0.167	1.00	1.61	10.96	0.84	−0.62
	(−10.2)	(10.4)	(42.7)	(1.21)	(2.03)	(4.80)	(1.06)	(−0.78)

The table values represent cross-sectional averages of the coefficients obtained from firm-by-firm regressions of quoted spread, quoted depth, and effective spread on trading volume, and event-period dummy variables. The averages are weighted by the number of intraday earnings announcements for each firm. The numbers in parentheses are the t-statistics under the null hypothesis that the cross-sectional mean of the coefficients equals zero. For each of the 209 firms that had at least one intraday announcement, a time-series regression is estimated with the following model:

$$\mathrm{LIQ}_t = \alpha + \beta \mathrm{VOL}_t + \sum \theta_j \, \mathrm{DUM}_{jt} + \omega_t$$

where

$$\mathrm{LIQ}_t = \text{liquidity measure at the end of time interval } t$$
$$= (\mathrm{Stat}_t/\mathrm{AvgStat}_t - 1) \times 100,$$

Stat_t is the actual liquidity statistic at the end of time interval t (i.e., either quoted spread, quoted depth, or effective spread) and $\mathrm{AvgStat}_t$ is the mean of that statistic for that firm and time of day,

$$\mathrm{VOL}_t = \text{normalized volume} = \sqrt{\mathrm{SHR}_t/\mathrm{AvgShr}_t},$$

SHR_t is the number of shares traded during the interval and AvgShr_t is the mean number of shares traded for that firm and time of day,

$$\mathrm{DUM}_{jt} = 1 \text{ if observation } t \text{ is in the event interval } j,\ 0 \text{ otherwise},$$

$$\omega_t = \text{error term} = \epsilon_t + \gamma\omega_{t-1},$$

where γ is the AR(1) parameter and ϵ_t is i.i.d. normal with mean zero and constant variance.

liquidity. However, the changes in spreads and depths documented here may not represent an important increase in trading costs for individual traders. Even during the event period, the 19 percent increase in the effective spread is an increase of only $0.03 per share in the cost per round trip. While the increase may be economically important to the specialist, the change in absolute cost to an individual trader is not large. Consequently, the overall economic significance of these effects may depend on one's perspective.

6. Summary

We examine the intraday behavior of NYSE specialists' quotes in light of existing theory on information asymmetry costs. Since spread and depth are two dimensions of market liquidity, both variables should be important to specialists and other liquidity providers in the management of information asymmetry costs. We highlight this distinction and examine some of its empirical implications. We show that, in theory, both spread and depth are needed to infer changes in liquidity unambiguously. Specifically, a widening (narrowing) of the spread, combined with a decrease (increase) in depth, is sufficient to infer a decrease (increase) in liquidity.

Using this criterion, we investigate liquidity changes in response to incoming trades and earnings announcements. In the first part of the article, we show that both spreads and depths are associated with trading volume: spreads widen and depths drop in response to an increase in volume. These results, consistent with Easley and O'Hara (1992), suggest an unambiguous drop in liquidity after volume shocks. Interpreted in the context of their model, liquidity suppliers use increased volume to infer the presence of informed traders.

In the second part of this article, we show that spreads widen and depths drop in advance of the Broad Tape announcement of quarterly earnings. Again, the combination of wider spreads and lower depths implies liquidity is lower before earnings announcements. The magnitude of this anticipatory liquidity drop is positively related to the magnitude of the subsequent price reaction. These findings are consistent with existing models that predict an increase in information asymmetry risk before anticipated news events. The results for spreads stand in contrast to the mixed results of Morse and Ushman (1983), Venkatesh and Chiang (1986), and Skinner (1991). However, the difference seems to reflect primarily the increased statistical power of our intraday analyses.

Consistent with Skinner (1991) and Patel (1991), we find increased spreads during and after an earnings release. The sharpest increase in both effective and quoted spread occurs in the half hour containing the announcement. This increase in spreads continues for at least one trading day after the announcement, while depths revert to normal levels within three trading hours. After controlling for the contemporaneous increase in volume, the postannouncement liquidity effect is only significant in the half hour containing the announcement. The postannouncement drop in liquidity may be due to increased information asymmetry risks, as suggested by Kim and Verrecchia (1991b). However, except for the half hour of the announcement, our results show such effects are not easily distinguishable from the general volume and liquidity relation predicted by Easley and O'Hara (1992).

In summary, our main conclusion is that specialists and other liquidity providers actively manage information asymmetry risk by adjusting both spreads and depths. Our results highlight the importance of the quantity dimension (depth) of market liquidity. We also provide empirical support for models that predict liquidity should be affected by incoming trades and anticipated news events. In particular, we show that liquidity drops after periods of high trading volume and immediately before earnings announcements. These findings are consistent with an increase in information asymmetry risk after volume shocks and before earnings releases.

Our results suggest several avenues for further research. First, we did not attempt to model formally the interaction between volume and quote characteristics. A more detailed treatment of these important aspects of the specialist's behavior, along the lines of Easley and O'Hara (1992), would benefit future research. Second, although we consider the effect of volume on spreads and depths, we do not examine the effect that the quoted spreads and depths may have on volume. The effect of quoted liquidity on volume introduces an interesting endogeneity, which we leave for future research.

Finally, we find the market anticipates some aspects of an upcoming earnings news (i.e., the size of the price effect), but we do not investigate how the market is able to acquire this knowledge. A more detailed study of the firm or news characteristics that help the market to distinguish the more important announcements would be instructive. Such a study could improve our understanding of how the market acquires and processes information.

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