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When is Inter-Transaction Time Informative?

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Abstract

We investigate the information content of inter-transaction time and find that it varies both across stocks and over time. On average, inter-transaction time is found to be informative whenever stocks are sufficiently traded. The magnitude of the information content is found to be larger for less liquid, but still fairly actively traded stocks. In general, trades arriving quickly move prices more than trades arriving more slowly. Further, the information content of inter-transaction time is negatively correlated with proxies for the amount of private information in the trading of a particular stock. We then distinguish between trades in the same direction as the previous trade from trades in the reverse direction and find that the price impact of a trade as well as the information content of inter-transaction time is dependent on trade type. In general, reversing trades are more informative. Further, same-direction trades arriving quickly move prices more than same-direction trades arriving more slowly, but reversing trades arriving quickly move prices less than reversing trades arriving more slowly.

According to market microstructure models, prices respond to trades because trades convey information regarding the underlying value of the security. In its simplest interpretation, when traders buy, price rises as market makers revise upward their estimate of the securities true value. The reverse holds true for sell orders. The literature has documented many factors that influence by how much a trade moves price, the so-called price impact of a trade. Because the price impact of a trade is related to the perceived quantity of private information held by the buyer or seller, the price impact of a trade will be related to the probability that the order comes from an "informed" rather than an "uninformed" e.g. noise trader. Other factors that have been identified in the microstructure literature are characteristics of the trade being executed. For instance, the size of a trade might convey information about its information content and thus influence its price impact.

The focus of this paper is the impact of a particular trade characteristic that determines price impact, inter-transaction time. Market microstructure literature has argued that the time interval between trades conveys information. In Admati and Pfleiderer (1988), for example, discretionary liquidity traders try to avoid losing money to the better informed by clustering their trading close together in time. Thus, the observation of multiple transactions occurring together suggests the presence of predominantly uninformed traders. The empirical prediction of this model would be that trades that arrive more rapidly have lower price impact on average. Contrast this intuition with that modeled by Easley and O'Hara (1992). In their model, they allow for the possibility that no new information exists and for informed traders to be in a hurry to trade in order to take advantage of their information advantage. As a result, an increase in trading activity indicates that information has arrived, and therefore, order flow is more informative when transactions are occurring rapidly.

Because theoretical models have an ambiguous prediction as to the relationship between the time between trades and the price impact of trading, deciding upon the "correct" model becomes an empirical question. The empirical evidence gathered to date suggests that the relationship between inter-transaction time and price impact depends on the market. In foreign exchange markets, Lyons (1996) documents that trades are less informative when they occur when transaction intensity is high, a finding consistent with the theoretical result of Admati and Pfleiderer (1988). Lyons describes it as hot-potato trading whereby foreign exchange dealers rapidly and repeatedly lay off unwanted inventory in response to an initial potentially informed trade. Because inventory adjustment by dealers is not informative as to the fundamental value of a currency, these trades do not generally move prices. Dufour and Engle (2000) find the opposite empirical relationship in equity markets. In a study of actively traded stocks, they find that when equity markets are most active, i.e., inter-transaction times are short, the dynamic impact of order flow on prices is enhanced. Spierdijk et. al. (2002) explores whether the relationship between price impact and inter-transaction time is present in a sample of very illiquid stocks. They find that the information content of inter-transaction time is greater for illiquid stocks than for the actively traded stocks examined in Dufour and Engle (2000). In US treasury markets, Furfine and Remolona (2002) find results similar to Dufour and Engle (2000). That is, trades of US Treasuries arriving more quickly tend to have a greater price impact.

The aforementioned empirical studies generally focussed on both a limited number of securities and on a fairly limited sample period. Thus, the first contribution of the current paper is to determine whether previous results can be generalized across time and across a larger number of securities. To some extent, Spierdijk et. al. (2002) study of illiquid stocks addresses the cross-security issue, but the findings of their study may also be difficult to generalize because they focus only on *very* infrequently traded stocks. In the present paper, we examine 100 stocks that essentially span the range of trading levels from those studied by Dufour and Engle (2000) to those in Spierdijk et. al. (2002). The second and more fundamental contribution of the present paper is to document how and try to explain why the information content of the time between trades changes over time. This question is motivated primarily by the observation that equity market trading volume has increased dramatically during the past decade. Figure 1 indicates the number of trades of NYSE-listed companies increased from around 3.5 million in January 1993 to over 30 million in December 2001. The value of these trades has risen similarly, from around $200 billion in January 1993 to nearly $800 billion by the end of 2001. During the market peaks of early 2000, monthly trading value approached $1.2 trillion. To put these numbers into the trading context used in this paper, consider NYSE-listed companies grouped into deciles based on their average daily number of trades.[1] Figure 2 indicates that infrequently traded stocks, e.g. those in the 9th decile, traded approximately once every 23 minutes in January 1993, but by December 2001 traded once every 5 minutes. The most frequently traded stocks saw a similar decline in the average time between trades, from around once every 37 seconds to one trade every 10 seconds. Figure 3 examines more closely the trading of stocks in the first decile. The median time between trades, which was 22 seconds in January 1993, had declined to less than 7 seconds in December 2001. Twenty-five percent of trades of the most actively traded stocks occur within 3 seconds of the previous trade.

Given the tremendous increase in the amount of trading, it may be easy to imagine that the information content of the time between trades has declined as trading activity has increased. To see why this might be the case, consider the following hypothetical example. Suppose that

[1] Unlike the data in Figure 1, the data in Figures 2 and 3 are based on the sample of companies used in this study and not on a sample of all NYSE-listed companies.

250 uninformed traders of a particular stock will transact randomly and uniformly during a 6.5 hour trading day. If there is an information event, an additional 50 "informed" traders will transact. Market makers will see trades approximately every 93 seconds when there is no information and every 78 seconds when there is. Suppose this 16% reduction in average inter-transaction time is sufficient to inform a market maker that a new information event has occurred. Now assume that several years later, "uninformed" trading in this stock has increased to 750 trades per day, but the number of potential informed traders remains at 50. Evidence that such a relative increase in the "uninformed" has occurred is supported by Easley et. al. (2001). Market makers would then see an average inter-transaction time of 31 seconds when there is no information and 29 seconds when there is. Given the variability of inter-transaction times around their mean, it is conceivable that this difference is not considered economically meaningful to convey information. Intuitively, as average inter-transaction times fall, one might believe that the information content of time declines. Thus, in light of the observed increase in trading activity, it is interesting to determine whether inter-transaction time remains informative.

The coming sections of the paper present the following empirical evidence on the information content of inter-transaction time. First, using tick-by-tick data on a sample of 100 stocks over 9 years, we document that the time between trades generally conveys information, but only when a stock is traded fairly actively. Second, we find that among those stocks for which inter-transaction time is informative, the information content itself varies across time. Typically, faster trading is viewed as more informative, but we document cases where the reverse is true. Third, we find that for actively traded stocks, variation in the information content of inter-transaction time is related to *changes* in average inter-transaction time and average price impact. Specifically, an increase in the average time between trades or a decrease in average price impact is correlated with an increase in the information content of inter-transaction time. Finally, we document that the relationship between inter-transaction time and price impact is dependent on whether a trade is in the same direction or in the opposite direction as the previous trade. In particular, same-direction trades arriving quickly move prices more than same-direction trades arriving more slowly. However, reversing trades arriving quickly move prices less than reversing trades arriving slowly.

The paper is organized as follows. Section I describes the data used in the study. Section II reviews the Dufour and Engle (2000) model of price discovery implemented in the paper. Section III presents empirical results for the stock of Disney (ticker DIS) that is illustrative for the remainder of the paper. Section IV presents results from the full sample of 100 NYSE-listed companies. Section V explores an extension to Dufour and Engle (2000) methodology, specifically, the importance of whether or not a given trade is in the same direction as the preceding trade. Section VI concludes.

I. The Data

The transaction data were extracted from the NYSE TAQ (Trades and Quotes) database covering the 2268 trades days beginning January 4, 1993 and ending on December 31, 2001. Because information on market capitalization was used to perform various robustness checks, sample companies were also required to be included in the CRSP daily stock files over the same period. To abstract from potential differences in the price impact of trading across different exchanges, only firms listed on the NYSE for the entire sample were considered.[2] We also

[2] The study hopes to analyze the time-series behavior of a cohort of firms where cohorts are determined by a measure of trading intensity. Many NASDAQ firms were very infrequently traded in 1993, yet traded virtually every second by 2001, complicating the definition of cohorts. Thus, to alleviate this difficulty, only NYSE-listed companies were included.

require our sample firms to trade under the same ticker symbol throughout the 9-year period. Because our main interest is to measure how the price impact of trades in the shares of a given firm changes through time, we want to mitigate other factors that are changing through time. In particular, major corporate mergers, which may lead to a ticker change, may mask any secular change. Following Hasbrouck (1991), we also impose a minimum price requirement on each company's stock. We require each stock to be trading for at least $5, on average, during both January 1993 and December 2001. Also following Hasbrouck (1991), we require a minimum level of trading activity. Stocks were required to trade, on average, at least 8 trades per day during January 1993 and 39 trades per day in December 2001.[3] We then selected 100 of the remaining stocks randomly, and then grouped them into 10 deciles according to their average time between trade over the entire sample, with decile 1 corresponding to the most frequently traded stocks.

The data are then adjusted according to procedures common in the microstructure literature. Following Hasbrouck (1991), we keep only New York quotes and consider multiple trades on a regional exchange for the same stock at the same price and time to be one trade. Then, the trade data (for each company and day) are sorted by time, with the prevailing quote at transaction t defined to be the last quote that was posted at least five seconds before the transaction (Lee and Ready (1991)).

A complete listing of the stocks used in this study is given in Table I. As could be expected, there is a positive although far-from-perfect negative correlation between the average time between trades and a company's market capitalization. Generally, larger firms have stocks that trade more frequently. As closer examination of decile 1 stocks will be forthcoming, these

[3] Hasbrouck (1991) chose a threshold of approximately 8 trades a day for data in 1989. 39 trades per day in December 2001 is the same percentile of the distribution of trading frequency as 8 trades in January 1993.

have been printed in bold. Also, note that the information regarding the time between trades of each stock are listed in minutes for 1993, but are given in seconds for 2001.

II. Empirical framework

The dependent variable of interest is the trade-to-trade return on a given stock. We denote this return r_t, and define it formally as the change in the natural logarithm of the midquote of a given stock that follows the trade at time *t*. That is,

$$r_t = 100\left(\ln\left(\frac{bid_{t+1} + ask_{t+1}}{2} \right) - \ln\left(\frac{bid_t + ask_t}{2} \right) \right). \tag{1}$$

Following Hasbrouck (1991), we define the variable x_t^0 as an indicator of the trade direction of the trade occurring at time *t*. If the trade is initiated by the buyer, the variable $x_t^0 = 1$. If the trade is initiated by the seller, then the variable $x_t^0 = -1$. We assume trades at a transaction price greater than the midquote were buyer-initiated and trades below the midquote were seller-initiated. For trades at the midquote, x_t^0 is assigned to equal zero. We also define T_t as the time, in seconds, between the trade at time *t* and the trade at time *t-1*.

We adopt the empirical specification of Dufour and Engle (2000), which allows both the trade indicator and the time between trades to affect returns. Defining D_t as an indicator that equals 1 if trade *t* occurs during the first 30 minutes of the trading day, Dufour and Engle propose an empirical relationship between trades, inter-transaction times, and returns given by equation 2.[4]

[4] Dufour and Engle (2000) specify additional equations for x_t^0 as well as trading intensity T_t. This allows the computation of impulse response functions to see how inter-transaction time affects the dynamic path of price adjustment in response to a trade. Our focus in this paper is on the narrower question of how the relationship between inter-transaction time and price impact changes over time. Thus, we examine only the single equation.

$$r_t = \sum_{i=1}^{5} a_i r_{t-i} + \lambda_{open}^r D_t x_t^0 + \sum_{i=0}^{5} \left[\gamma_i^r + \delta_i^r \ln(1+T_{t-i}) \right] x_{t-i}^0 + \nu_t \quad (2)$$

Because purchases should put upward pressure on prices, we expect that $\gamma_i^r + \delta_i^r \ln(1+T_{t-i})$ should evaluate to be positive over the range of relevant values of *T* for some or all of the trade lags *i*. This prediction follows from traditional microstructure theory. In Glosten and Milgrom (1985), for example, market makers set a positive bid-ask spread as compensation for trades made with counterparties with superior information. As a sequence of sell orders arrive, market makers lower bid prices, incorporating the probability that the order flow implies that better-informed investors believe the previous price was too high. The reverse occurs when a sequence of buy orders arrives.

As indicated in the introduction, however, there are theories that suggest that δ_i^r could be either positive or negative. In their analysis of 18 actively traded NYSE stocks, Dufour and Engle (2000) find that δ_i^r, when statistically significant, is generally negative, meaning that trades that occur with a shorter inter-transaction time generally lead to price adjustments larger than those following trades with larger inter-transaction intervals. In other words, stocks become less liquid when trades arrive faster. This empirical finding is consistent with the intuition of Easley and O'Hara (1992). That is, when trades arrive more quickly, market makers upwardly adjust the probability that an information event has occurred. Thus, the probability of receiving an order from an informed trader has risen and therefore prices must adjust more in response to a given trade.

III. Results for Walt Disney

To set the stage for the full-sample results presented in Section IV, in this section we analyze the results for a single actively traded stock. The stock we pick is that of the Walt Disney Company (ticker DIS). Table II presents selected coefficient estimates from a least squares estimation of equation (2), with results presented separately for stock trades that occurred during March 1993 and also those from April 1998. Standard errors are adjusted according to White (1980).[5] The first three columns of Table II reveal results quite similar to those presented by Dufour and Engle (2000). In particular, the coefficients on the first three lags of the trade indicator are all positive and statistically significant, and the coefficients on the first two lags of the interaction of the trade indicator and the time between trade variable are negative and significant. Thus, for DIS during March 1993, trades arriving faster moved prices more. Contrast this finding with the results from estimating the same equation using trading data from April 1998. Like before, the coefficient on the trade indicator variable is positive and significant at low lag levels. The coefficient capturing the effect of the time between trades, however, is now positive and statistically significant. That is, in April 1998, trades of Disney stock arriving faster moved prices less.

The results of Table II suggest that market makers for Disney believed trades arriving faster conveyed more information in March 1993, yet contained less information in April 1998. One possible explanation is depicted in Figure 4. The dotted line in Figure 4 plots the sum of the δ_i^r coefficients from the estimation of equation 2, where the equation was estimated separately for each of the 108 months between January 1993 and December 2001. The solid line depicts the

[5] In these and all subsequent regressions, price changes across days are omitted, as are return observations in the extreme 0.25% tails of the distribution. These latter observations occur mainly due to infrequent, yet obvious errors in either the bid or ask price of the stock.

average time between trades for Disney over the sample period. At least two observations are worth making about Figure 4. First, the observations for March 1993 and April 1998 were the most extreme observations for the δ_i^r coefficients over the sample period. Second, there appears to be a negative correlation between changes in the average time between trades and the δ_i^r coefficients. That is, when the time between trades declines sharply, this is generally associated with an increase in the estimated value of the δ_i^r coefficients. That is, an increase in trading activity tends to reduce the negative relationship between inter-transaction time and price impact. In the extreme case of April 1998, the relationship between inter-transaction time and price impact became positive.

Although wanting to be cautious from making conclusions based on one observation, the observation for Disney in April 1998 is interesting in that it coincided with the company's April 23rd announcement of a 3-for-1 stock split. Starting on that date, trading activity in Disney increased dramatically. As shown in Figure 4, trades of Disney stock occurred every 21 seconds in March of 1998. Disney's average inter-transaction time fell to just over 5 seconds by July of that year. To the extent that market makers perceived the increase in trading activity as reflecting new interest in the stock caused by a pending stock split and unrelated to new fundamental information regarding the proper price level, the results of Figure 4 make sense. That is, trades that were arriving much faster were viewed, on average, to be less informative about the price.

Thus far, we have commented on the evolution of the δ_i^r coefficients for the Disney Company between 1993 and 2001. From an economic standpoint, it is perhaps more useful to compare measures of price impact rather than values of coefficients. In figure 5, we plot an estimate of the price impact of trading, $\gamma_i^r + \delta_i^r \ln(1+T_{t-i})$, summed across all lags, evaluated for different values of the time between trading.[6] The dotted line in figure 5 plots the price impact of a trade that has occurred at that month's average inter-transaction time. As the dotted line indicates, the average price impact of a trade varies significantly over time. It is generally lower at the end of the sample than at the beginning, indicating a general increase in market liquidity for DIS stock. Analysis of the movements of the time series of liquidity measures such as that depicted by the dotted line would be comparable to the work of Chordia et. al. (2001), who analyze the variation of liquidity of common stocks both in cross-section and over time.

The focus of the present paper, however, is not on movements of the average liquidity of stocks, but rather on the relationship between the time between trades and price impact. In Figure 5, this can be seen as the difference between the solid line and the line ticked with boxes. Consider again the two observations highlighted in Table II. In March 1993, a trade occurring with the average time since the previous trade moved the price of Disney stock by 1.4 basis points. A trade arriving quickly, here defined as one arriving at the 10th percentile of the inter-transaction time distribution for Disney stock during March 1993, moved the price of DIS stock by an estimated 1.5 basis points. "Slowly" arriving trades, defined as those arriving at the 90th percentile of the inter-transaction time distribution, moved prices by only 1.32 basis points. Contrast that with the finding for April 1998. Liquidity, in general, was higher in that trades occurring at the average inter-transaction time moved prices by only 1 basis point. Fast arriving trades, perhaps because they were associated with news of the pending stock split, were considered to be relatively uninformative, and moved prices *less*, by less than ½ basis point. Slowly arriving trades moved prices by 1.24 basis points.

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[6] This estimated price impact is an approximate calculation that neglects the possibly endogenous nature of inter-transaction time as well as the feedback of past returns on trading.

To more formally examine the relationship between trading activity and the significance of the time between trades, we need a proxy for the information content of inter-transaction time. In the empirical results to follow, we define

$$y_m \equiv \sum_{i=0}^{5} \left[\gamma_{im}^r + \delta_{im}^r \ln(1+T_z) \right]_{z=90th\,\%tile}^{z=10th\,\%tile} \tag{3}$$

as a measure of the information content of inter-transaction time. That is, y_m is calculated by evaluating the sum of the $\gamma_{im}^r + \delta_{im}^r \ln(1+T_z)$ coefficients at the 10th percentile of the inter-transaction time distribution and subtracting the sum of the $\gamma_{im}^r + \delta_{im}^r \ln(1+T_z)$ coefficients evaluated at the 90th percentile. This quantity is a measure of the relative information content of fast trades. Graphically, y_m is the distance between the solid line and the line with boxes in Figure 5 during month *m*. The quantity y_m is positive whenever faster trades are estimated to be more informative, and therefore move prices more than more slowly arriving trades. We analogously define the average price impact of a trade during month *m* as

$$\overline{L}_m \equiv \sum_{i=0}^{5} \left[\gamma_{im}^r + \delta_{im}^r \ln(1+T_z) \right]^{z=average} . \tag{4}$$

Defining $\overline{T}_m$ as the average time between trades during month *m* and Δ as the first difference operator, we then estimate equation (5) using least squares.[7]

$$y_m = \sum_{i=1}^{4} a_i y_{m-i} + \sum_{i=0}^{4} b_i \Delta \overline{T}_m + \sum_{i=0}^{4} c_i \Delta \overline{L}_m + e_m \tag{5}$$

Coefficient estimates from equation (5) for the Disney Company are given in Table III.

[7] The specification chosen was based on the finding that average inter-transaction time and average liquidity have a notable downward trend, but the information content of inter-transaction time does not. In fact, no statistically significant trend was found in the information content of inter-transaction time for any of the 100 firms in the sample.

The coefficient on the contemporaneous change in the average time between trades is positive and significant. Thus, for the Disney Company, a decrease in the level of trading on average (e.g. an increase in the average time between trades) is associated with a higher differential price impact of fast arriving and slow arriving trades. In other words, when trading becomes slower on average, faster arriving trades are thought to convey relatively more information, and therefore move prices more. In addition to being statistically significant, Table III indicates that this simple empirical specification explains a significant part, 39%, of the time series variation in the information content of inter-transaction time. The high degree of explanatory power is not solely due to the presence of lagged dependent variables in the estimation. As the second column of Table III indicates, such variables account for 23% of the total variation.

IV. Results for the full sample

The analysis for the Disney Company in Section III suggests two things about the information content of the time between trades. First, the information content of inter-transaction time is itself, time varying. Second, the information content of time appears to be related to changes in the average arrival rate of trades. In this section, we replicate the empirical exercises of Section III on the full sample of 100 NYSE stocks. This entails estimating equation 2 for each of 100 stocks for each of 108 months during the sample. Tables IV and V attempt to summarize the basic findings from these 10,800 regressions.

The columns of Tables IV and V refer to stocks in different deciles, arranged from the most actively traded issues in column 1 to the least actively traded issues in column 10. The rows correspond to averages taken across the 12 months in the given year. Each cell in Table IV and V contain three items. In Table IV, the first entry in each cell is the average value of the sum of the γ_i^r coefficients averaged across the 10 stocks in the decile and across the 12 months of the given year (120 values). These coefficients measure the price impact of the given trade at lag *i* that is unrelated to the time since the previous trade. The second entry in each cell in Table IV is the percentage of the 120 individual observations of the sum of the γ_i^r coefficients that were estimated to be positive and statistically significant. The final entry in each cell is the percentage of individual observations of the first item that were estimated to be negative and statistically significant. For example, the cell in the upper left-hand corner of Table IV indicates that the average sum of the γ_i^r coefficients for the ten stocks in the most actively traded decile during 1993 is 0.018. Of the 120 estimated values of this quantity, 99.2% (e.g. 119) were estimated to be both positive and statistically significant, whereas none were estimated to be negative and statistically significant. Each cell in Table V is analogous to its counterpart in Table IV, except that the first entry in each cell refers to the sum of the δ_i^r coefficients, which measures the price impact of a given trade that is related to the time since the last trade. For example, reading from the upper left-hand cell in Table V indicates that the average sum of the δ_i^r coefficients for the most actively traded stocks during 1993 was -0.119. Recall a negative number indicates that faster arriving trades carry more information and thus, move prices more. The remaining entries in the cell indicate that 1.7% of the observations (2 out of 120) were positive and statistically significant and 24.2% (29 out of 120) were statistically significantly negative.

The results presented in Table IV document that the relationship between trades and returns is robust across time and across stocks of different levels of trading. For stocks in the more actively traded deciles, regression estimates are virtually all positive and statistically significant. For most years, average estimates of the γ_i^r coefficients are increasing with trading inactivity, suggesting that less frequently traded stocks are less liquid (because a given trade moves prices more). The degree to which the results are found to be statistically significant tends to increase through time for each decile, likely reflecting, in part, the increase in the number of observations (e.g. trades) over time.

The results in Table V suggest that the negative relationship between inter-transaction time and price impact found for the Disney Company in March 1993 is not robust across stocks, either within trading activity deciles or across time. For the most actively traded decile of stocks, the fraction of observations where we estimate a statistically significant negative relationship between the time between trades and the information content of a trade is 86.7% in 1996, but only 24.2% in 1993 and 50.0% in 2001. Looking throughout Table V, the average value of the sum of the δ_i^r coefficients is always negative, but for many deciles, especially during the early part of the sample, most of the estimated coefficients are not statistically different from zero. Only since 1999 have more than half of the trading activity deciles found more than half of the δ_i^r coefficients to be negative and statistically significant.

To give some further meaning to the numbers in Tables IV and V, we plot in Figure 6 the estimated price impact of a trade arriving at the 90th and at the 10th percentile of the inter-transaction time distribution, averaged over the stocks in the first decile. Given the relationship between the importance of the time between trades and the average time between trades for the Disney Company, Figure 6 also plots the average time between trades for stocks in the first decile. As was the case for DIS, Figure 6 indicates that the price impact of a trade varies over time. Furthermore, the information content of a fast arriving trade relative to a slow moving trade varies as well, and does appear to be related to changes in the average time between trades.

To test this relationship more formally across the entire sample, equation (5) was estimated again, with observations pooled across stocks within a given trading activity decile. The results are shown in Table VI. As was the case for the Disney Company, the information content of inter-transaction time is positively correlated with changes in the average time between trades for stocks in the 3 most actively traded and 5 out of the 6 most actively traded deciles of stocks. Table VI also indicates that for stocks in every decile except the most actively traded, there is a negative correlation between the information content of inter-transaction time and the average price impact of a trade. That is, all else equal, when average liquidity in a stock improves (e.g. price impact at average inter-transaction time falls), the information content of inter-transaction time increases (e.g. fast trades move prices relatively more). Thus, changes to the average time between trades and changes to the average price impact are correlated with the information content of inter-transaction time in opposite ways.

These results may seem somewhat perplexing since a decline in the average time between trades and a decline in the average price impact are both often considered to be associated with increases in market liquidity. However, the results here suggest that, holding one measure constant, these two empirical measures have a differently signed correlation with the information content of inter-transaction time. Intuitively, this finding may be explained as follows.

Consider first the negative coefficient on average price impact. The interpretation of this coefficient is that holding the average inter-transaction time constant, an increase in average price impact leads to a decline in the information content of inter-transaction time. Holding average inter-transaction time constant, however, is equivalent to holding the number of trades constant. Thus, an increase in the average price impact of a trade accompanied by no change in the number of trades implies that the quantity of private information in the market has increased.

The negative coefficient on average price impact therefore implies that an increase in the amount of private information in the market is associated with a fall in the information content of inter-transaction time. This may be because market makers rely less on inter-transaction time to discern which traders have information when information is plentiful, i.e. informed traders are relatively common.

Consider now the positive coefficient on average inter-transaction time. The interpretation of this coefficient is that holding average price impact constant, an increase in average inter-transaction time increases the information content of inter-transaction time. Holding average price impact constant, however, is equivalent to assuming that each trade contains the same amount of private information. Thus, an increase in inter-transaction time in this environment implies that the quantity of private information in the market has declined because there are fewer trades. To be consistent with the coefficient on average price impact, lower levels of private information must correlate with a higher information content of inter-transaction time. This is what the positive coefficient on average inter-transaction time is revealing.

Thus, the coefficients on these two empirical measures logically enter with opposite signs. Economically, the results suggest that when information becomes relatively scarce, inter-transaction time becomes more informative.

V. Robustness of results

To this point, the analysis has assumed that all trades have an equal impact on returns. Hasbrouck (1991), however, originally proposed that the price impact of a trade may be a function not only of the direction of the trade but also the size of the trade. That is, a large purchase of stock might be considered more informative than a small one and thus might affect prices more. To consider this, the analysis of Section IV was repeated, replacing the simple trade indicator x_t^0 with a variable x_t, defined as the log of the fraction of a company's market value that was being transacted. For example, a buy-order of 10,000 shares in a company with 10,000,000 shares outstanding would produce $x_t^0 = 1$, but $x_t = -3$. With this new specification, the results of the previous section hold qualitatively. Figure 7 replicates Figure 6, although now, estimated values of the price impact of trades with different inter-transaction times are now also assumed to be of average size, where size is measured here as the log of the share of the given company's market value. Figures 6 and 7 are nearly identical.

Another possible extension of the Dufour and Engle (2000) estimation approach incorporates the suggestion of Peng (2001), who argues that the information content of a trade depends on whether or not the trade is of the same type as the preceding trade. Define a buy order following a buy order or a sell order following a sell order as a same-direction trade. Analogously, define reversing trades as a buy order following a sell order or a sell order following a buy order. Peng's (2001) intuition is that a market maker who sees a same-direction trade does not know whether the trade contains more information than the first or whether it is simply a response to the same information as the first. This holds true especially if the same-direction trade comes quickly after the preceding trade. In contrast, a reversing trade cannot, by definition, simply be a second response to the same information that led to the preceding trade. Thus, on average, reversing trades must be more informative than same-direction trades, regardless of the time elapsed since the preceding trade. To explore the possible interaction between inter-transaction time and trade type (e.g. same-direction or reversing), we estimate equation 6 below, which is an enriched version of equation 2,

$$r_t = \sum_{i=1}^{5} a_i r_{t-i} + \lambda_{open}^{r} D_t x_t^0 + \sum_{i=0}^{5} \left[\gamma_i^r + \delta_i^r \ln(1+T_{t-i}) \right] x_{t-i}^0 + \sum_{i=0}^{5} \left[\gamma_i^{rs} + \delta_i^{rs} \ln(1+T_{t-i}) \right] S_{t-i} x_{t-i}^0 + \nu_{1,t} \quad (6)$$

where the dummy variable S_t equals 1 when the trade at time t is same-direction and 0 otherwise. Thus, the specification in equation 6 allows the price impact and the time impact coefficients to vary depending on whether the trade is same-direction or reversing.

Tables VII through X present the results from this estimation procedure that are analogous to those presented in Tables IV and V. Tables VII and VIII refer to the trade impact and time impact coefficients reported for reversing trades. Tables IX and X relate to trades in the same direction as the previous trade. Like the results of Table IV, Table VII and IX indicate that the price impact coefficients are typically positive for both types of trades. Further, there do not appear to be any major differences between the size of the estimates. However, a comparison of the results in Tables VIII and X with those from Table V highlight that the information content of inter-transaction time varies notably across trade type (e.g. same-direction or reversing). Table X, for example, indicates that for trades in the same direction as the previous trade, faster arrival is associated with more information and therefore greater price impact. This finding is qualitatively similar to that found in Table V. Quantitatively, however, the magnitude of the information content of inter-transaction time is generally stronger, as indicated by numbers of greater absolute value in Table X relative to Table V and are more often statistically significant, especially in more recent years and for more actively traded stocks.

A symmetry argument would therefore lead one to believe that if the information content of inter-transaction time is larger for same-direction trades than for an "average" trade, then it must follow that the information content of inter-transaction time for reversing trades is lower than that found for trades in general. Table VIII indicates, however, that the information content of inter-transaction time is *positive* for reversing trades. That is, faster arriving reversing trades are thought to contain less information and therefore move prices by less than reversing trades that arrive after a longer wait.

To help visualize these empirical results, Figure 8 plots the estimated price impact at various inter-transaction times for both same-direction and reversing trades for stocks in the most actively traded decile. One immediate finding is that reversing trades are considered more informative in that they have a higher price impact. This is consistent with Peng's (2001) argument that same-direction trades may be a response to stale information. Depending on the sample month and the inter-transaction time, a reversing trade is estimated to move the price of an actively traded stock by between 2 and 5 basis. A same-direction trade, however, moves prices between 0.5 and 3 basis points. Figure 8 also illustrates that inter-transaction time affects the price impact of trading in different directions for the two types of trades. That is, a same-direction trade with a low inter-transaction time moves prices by approximately 1 basis point more than a same-direction trade arriving more slowly. Fast-arriving reversing trades move prices by approximately 0.5 basis points *less* than a reversing trade arriving more slowly.

Intuitively, these results can be explained as follows. First, the finding that fast-arriving same-direction trades move prices more than slow-arriving same-direction trades is consistent with the belief that when same-direction trades arrive faster, a market maker increases the probability of an information event having happened. Second, the finding that fast-arriving reversing trades move prices less than slow-arriving reversing trades is consistent with fast-arriving reversing trades signaling an increased presence of "uninformed" traders, who by definition would be equally likely to buy or sell. Thus, market makers interpret rapid arrival of reversing trades to be less informative than those arriving more slowly.

Tables XI and XII complete the robustness exercise by re-estimating equation (5) separately for same-direction and reversing trades. Table XI reports the coefficient estimates when the dependent variable is the same proxy for the information content of inter-transaction time as was used to estimate (5), except that price impacts are constructed only for reversing trades. That is, the dependent variable measures the difference between the top two lines of Figure 8. Recall, however, that since fast-arriving reversing trades are considered less informative than slow-arriving reversing trades, the dependent variable is always negative. Table XII reports the analogous results for same-direction trades. In this case, the dependent variable is positive, just as it was when equation (5) was estimated without consideration of whether a trade was same-direction or reversing. The independent variables (e.g. average inter-transaction time and average price impact) are calculated only for reversing trades or same-direction trades, respectively. As Tables XI and XII indicate, the information content of inter-transaction time remains positively correlated with changes in the average time between trades and negatively correlated with average price impact. For same-direction trades, the interpretation remains the same, namely that higher average inter-transaction time or lower average price impact correlate with less private information. Less private information correlates with an increased information content of inter-transaction time. To be more precise, fast trades are more informative when private information is lower. For reversing trades, however, because the dependent variable is negative, the interpretation of the coefficients reported in Table XI is somewhat different. The interpretation is that a decrease in the quantity of private information is correlated with an increase in a negative number, implying that the difference between the price impact of fast and slow reversing trades becomes *less*.

VI. Conclusion

In this paper, we apply the method of Dufour and Engle (2000) to a larger cross section of stocks and a notably longer time series. Doing so allows us to document many features of the role that inter-transaction time plays in the price discovery process. First, the information content of inter-transaction time varies across stocks and across time. At any point in time and for relatively actively traded stocks, trades that arrive faster generally move prices more than trades that arrive more slowly. However, secular declines in inter-transaction time have not eliminated the information content of inter-transaction time. Second, we find empirical measures that help to explain the time-series behavior of the information content of inter-transaction time. Our results suggest that when the level of private information in a market falls, inter-transaction time becomes more informative in a particular way. Specifically, faster trading tends to move prices more relative to slow trading. Finally, we document that the direction of a trade relative to the previous trade is an important factor in determining a trade's price impact. Same-direction trades are generally less informative. Further, the correlation between inter-transaction time and price impact is different for the two types of trades. Fast arriving same-direction trades move prices more than slow-arriving same-direction trades, but fast-arriving reversing trades move prices less than slow-arriving reversing trades.

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Table I

Summary Statistics for Sample Firms

The data are based on a sample of 100 stocks taken from the TAQ and CRSP databases. Market values are taken in January 1993 and December 2001 from the CRSP database. Trading statistics are averaged over the entire year (1993 or 2001) based on trades in the TAQ database. For 1993, time is quoted in minutes. For 2001, time is quoted in seconds.

		1993					2001				
		Market value	Daily trading	Ave. time between trades	10th percentile of time between trades	90th percentile off time between trades	Market value	Daily trading	Ave. time between trades	10th percentile of time between trades	90th percentile off time between trades
Ticker	Company name	($ billions)	(# of trans.)	(minutes)			($ billions)	(# of trans.)	(seconds)		
ACG	A C M INCOME FUND INC	0.54	62.48	6.80	0.34	17.12	1.20	216.75	127.45	7.51	318.75
ACV	ALBERTO CULVER CO	0.40	20.44	21.05	1.11	58.10	1.46	264.06	96.08	4.82	253.00
ADM	ARCHER DANIELS MIDLAND CO	8.57	371.88	1.10	0.08	2.65	9.49	892.91	28.08	2.98	67.64
ALA	ALCATEL ALSTHOM	0.31	32.82	12.92	0.55	33.20	1.37	856.95	29.61	3.09	71.24
ALK	ALASKA AIRGROUP INC	0.22	47.18	9.35	0.41	24.30	0.77	330.68	90.00	5.11	240.25
AMD	**ADVANCED MICRO DEVICES INC**	**1.64**	**531.53**	**0.95**	**0.07**	**2.41**	**5.39**	**3842.20**	**7.40**	**1.37**	**16.30**
ASA	A S A LTD	0.32	131.53	3.69	0.14	10.04	0.19	80.87	366.25	9.39	1034.56
ATO	ATMOS ENERGY CORP	0.16	13.90	28.29	2.54	75.50	0.87	140.54	179.41	6.30	480.89
AWK	AMERICAN WATER WORKS INC	0.78	38.06	11.27	0.37	29.79	4.18	307.23	90.95	3.94	233.46
AXP	**AMERICAN EXPRESS CO**	**11.10**	**529.76**	**0.85**	**0.06**	**2.12**	**47.60**	**3538.40**	**7.81**	**1.88**	**16.74**
BDG	BANDAG INC	0.78	37.41	12.01	0.30	32.41	0.29	62.61	446.57	16.48	1193.62
BEC	BECKMAN COULTER INC	0.71	30.54	14.35	0.54	38.73	2.70	324.22	78.87	4.28	204.69
BGG	BRIGGS & STRATTON CORP	0.83	50.13	8.47	0.21	23.09	0.92	201.18	134.08	5.05	359.68
BJS	B J SERVICES CO	0.25	28.77	19.94	3.65	52.49	5.12	1515.73	17.08	2.10	41.24
BLS	**BELLSOUTH CORP**	**25.50**	**359.74**	**1.14**	**0.08**	**2.80**	**71.60**	**1850.04**	**13.90**	**2.31**	**31.85**
BMY	**BRISTOL MYERS SQUIBB CO**	**31.00**	**1633.39**	**0.28**	**0.04**	**0.65**	**98.70**	**2833.93**	**9.45**	**1.94**	**20.75**
BOW	BOWATER INC	0.76	30.54	14.71	0.51	39.69	2.61	423.07	58.46	3.35	150.71
BPT	B P PRUDHOE BAY ROYALTY TRUST	0.65	48.42	9.11	0.55	22.16	0.32	170.54	154.42	5.85	422.08
BR	BURLINGTON RESOURCES INC	5.65	166.53	2.63	0.15	6.73	7.54	1129.28	22.02	2.72	52.53
BUD	ANHEUSER BUSCH COS INC	16.30	265.93	1.58	0.11	3.93	40.00	1418.15	17.91	2.10	43.88
CAG	CONAGRA INC	7.68	220.58	1.95	0.10	4.92	12.80	1097.13	23.00	2.57	55.92
CC	CIRCUIT CITY STORES INC	2.47	255.68	1.86	0.10	4.87	5.41	992.71	26.99	2.60	65.38
CDN	CADENCE DESIGN SYSTEMS INC	0.97	116.91	4.51	0.14	12.17	5.36	813.81	31.05	3.18	76.00
CIN	CINERGY CORP	2.17	74.36	5.52	0.32	13.87	5.32	552.29	45.74	3.88	113.10
CMA	COMERICA INC	3.46	108.46	3.93	0.19	9.89	10.20	908.65	28.11	2.70	68.77
CPQ	**COMPAQ COMPUTER CORP**	**3.97**	**603.23**	**0.76**	**0.06**	**1.88**	**16.60**	**3853.76**	**7.60**	**1.62**	**16.56**
CSL	CARLISLE COMPANIES	0.38	10.12	37.00	5.97	97.06	1.12	160.25	157.16	5.89	418.53
CTL	CENTURYTEL INC	1.28	63.86	6.58	0.23	17.48	4.63	510.45	49.69	3.20	126.27
DCN	DANA CORP	2.16	61.19	6.83	0.26	18.30	2.06	650.69	38.99	2.83	96.61
DDS	DILLARDS INC	5.07	166.09	2.60	0.09	6.81	1.28	509.17	51.36	3.00	131.94
DIS	**DISNEY WALT CO**	**23.90**	**991.88**	**0.44**	**0.05**	**1.05**	**42.20**	**3586.39**	**8.39**	**1.73**	**18.22**
DLX	DELUXE CORP	3.64	123.16	3.39	0.16	8.64	2.76	421.44	62.69	3.99	161.21
DME	DIME BANCORP INC NEW	0.20	79.49	5.99	0.25	15.87	4.27	481.36	55.06	3.38	141.62
DOL	DOLE FOOD INC	1.95	75.31	5.91	0.20	15.75	1.50	292.58	95.50	4.36	255.13
EDE	EMPIRE DISTRICT ELEC CO	0.29	16.53	23.68	0.76	66.96	0.41	77.75	330.08	8.97	904.58
FED	FIRSTFED FINANCIAL CORP	0.25	7.52	39.78	12.94	90.17	0.44	123.04	218.51	6.14	599.95
FNM	**FEDERAL NATIONAL MORTGAGE ASSN**	**21.80**	**413.52**	**0.99**	**0.11**	**2.39**	**79.60**	**2207.25**	**11.94**	**2.13**	**27.15**
GMT	G A T X CORP	0.67	31.11	14.08	0.35	38.99	1.58	322.68	87.89	4.05	230.83
GP	GEORGIA PACIFIC CORP	5.32	235.00	1.88	0.09	4.93	6.34	926.40	26.77	2.74	66.67
HAL	HALLIBURTON COMPANY	3.12	211.42	2.02	0.11	5.25	5.62	2886.46	10.41	1.92	23.17
HI	HOUSEHOLD INTERNATIONAL INC	2.59	84.32	5.16	0.13	14.11	26.50	1676.98	16.03	2.39	37.02
HIT	HITACHI LIMITED	0.18	19.16	26.28	2.76	73.11	0.79	115.13	214.11	4.85	572.96
HKF	HANCOCK FABRICS INC	0.29	23.03	17.40	1.01	46.22	0.24	80.05	524.09	38.95	1437.33
HLT	HILTON HOTELS CORP	2.29	96.89	4.83	0.10	13.23	4.03	693.01	36.50	2.79	91.49

Table I continued

Summary Statistics for Sample Firms

		1993					2001				
		Market value	Daily trading	Ave. time between trades	10th percentile of time between trades	90th percentile off time between trades	Market value	Daily trading	Ave. time between trades	10th percentile of time between trades	90th percentile off time between trades
Ticker	Company name	($ billions)	(# of trans.)	(minutes)			($ billions)	(# of trans.)	(seconds)		
JEC	JACOBS ENGINEERING GROUP INC	0.64	33.23	12.77	0.56	34.12	1.78	406.21	72.42	3.19	189.59
JNJ	**JOHNSON & JOHNSON**	**28.80**	**927.54**	**0.48**	**0.06**	**1.15**	**181.00**	**3173.42**	**8.67**	**1.91**	**18.64**
K	KELLOGG CO	14.80	238.71	1.77	0.11	4.47	12.20	688.33	37.09	3.18	91.33
KEY	KEYCORP NEW	2.87	107.37	3.94	0.21	10.07	10.30	973.65	25.65	2.90	62.58
KF	KOREA FUND INC	0.33	42.49	14.78	0.52	41.43	0.65	60.07	488.75	12.23	1369.83
KM	**K MART CORP**	**9.44**	**827.74**	**0.52**	**0.05**	**1.23**	**2.72**	**1292.16**	**20.88**	**2.52**	**49.79**
LEO	DREYFUS STRATEGIC MUNICIPALS INC	0.56	37.96	10.76	0.68	27.59	0.59	49.21	489.42	7.55	1397.87
LM	LEGG MASON INC	0.25	10.89	35.10	6.81	90.48	3.20	467.10	55.19	3.38	140.40
LNC	LINCOLN NATIONAL CORP IN	3.06	72.26	5.84	0.26	15.12	9.20	744.31	33.43	2.72	84.11
LTC	L T C PROPERTIES INC	0.08	9.07	40.93	9.44	96.78	0.12	41.13	557.94	9.70	1590.99
LTD	LIMITED INC	9.96	437.18	1.03	0.08	2.52	6.31	826.70	30.73	2.81	76.47
MAS	MASCO CORP	4.94	143.64	2.93	0.13	7.52	11.20	949.32	26.56	2.48	65.73
MEA	MEAD CORP	2.25	81.81	5.30	0.16	14.15	3.06	593.47	43.17	4.01	104.92
MUR	MURPHY OIL CORP	1.61	31.94	14.58	0.37	41.08	3.81	585.66	45.45	2.87	114.32
N	INCO LTD	2.43	60.41	7.30	0.29	19.98	3.08	550.46	45.73	3.01	116.81
NFG	NATIONAL FUEL GAS CO N J	1.00	57.68	7.30	0.29	18.70	1.96	243.59	103.37	4.99	266.68
NMK	NIAGARA MOHAWK HOLDINGS INC	2.72	227.62	1.79	0.14	4.37	2.84	281.87	92.61	4.81	237.32
NPM	NUVEEN PREMIUM INC MUNI FD 2 INC	0.52	29.53	13.01	1.14	31.86	0.57	30.70	791.29	12.89	2218.20
NQM	NUVEEN INVT QUALITY MUNI FUND	0.61	28.70	13.54	0.86	34.27	0.51	25.22	950.30	24.47	2665.78
NQS	NUVEEN SELECT QLTY MUNI FUND INC	0.51	36.43	10.93	0.70	27.37	0.48	26.07	951.83	19.36	2614.28
NSC	NORFOLK SOUTHERN CORP	8.88	127.36	3.22	0.15	8.52	7.07	876.83	28.68	3.04	70.63
NWK	NETWORK EQUIPMENT TECHNOLOGIES	0.17	34.80	12.97	0.37	37.49	0.12	28.92	750.57	24.83	2137.98
OH	OAKWOOD HOMES CORP	0.30	47.48	10.31	0.27	28.63	0.05	50.33	556.05	21.73	1528.77
PCP	PRECISION CASTPARTS CORP	0.38	31.44	13.97	0.61	37.73	1.46	424.35	61.08	4.00	153.12
PH	PARKER HANNIFIN CORP	1.58	46.08	9.34	0.22	25.48	5.38	528.79	48.46	3.95	122.00
PMT	PUTNAM MASTER INCOME TRUST	0.47	52.89	7.51	0.36	19.56	0.34	49.73	481.02	15.21	1291.62
PNM	P N M RESOURCES INC	0.44	53.30	7.66	0.22	21.13	1.09	279.43	98.32	4.71	254.75
POS	CATALINA MARKETING CORP	0.37	22.88	21.40	1.51	62.03	1.91	260.16	98.94	3.88	264.00
PSD	PUGET ENERGY INC	1.54	100.85	4.76	0.28	11.89	1.90	401.26	64.70	4.16	164.55
RAD	RITE AID CORP	1.80	98.55	4.21	0.18	10.90	2.61	1315.07	21.76	2.30	52.55
RGS	R G S ENERGY GROUP INC	0.91	42.37	10.18	0.64	25.40	1.30	135.58	190.45	7.49	495.96
ROH	ROHM & HAAS CO	3.64	46.11	9.42	0.27	25.23	7.63	755.90	34.12	3.04	84.11
RVT	ROYCE VALUE TR INC	0.20	20.96	18.65	1.17	48.91	0.61	91.10	284.43	10.06	755.03
S	**SEARS ROEBUCK & CO**	**17.00**	**472.19**	**0.91**	**0.10**	**2.21**	**15.40**	**1215.50**	**21.54**	**3.07**	**51.23**
SEI	SEITEL INC	0.07	25.81	21.06	2.31	55.72	0.33	273.93	98.18	4.85	256.78
SNV	SYNOVUS FINANCIAL CORP	0.93	29.38	15.12	0.60	40.23	7.30	634.87	40.38	3.28	102.61
SPW	S P X CORP	0.24	19.90	21.33	2.70	57.93	5.53	638.35	41.55	2.54	108.29
SRR	STRIDE RITE CORP	0.99	132.17	3.17	0.15	7.93	0.27	75.47	323.89	12.27	884.33
STU	STUDENT LOAN CORP	0.57	23.06	26.67	2.54	69.67	1.61	40.53	885.01	112.19	2283.08
SWY	SAFEWAY INC	1.37	129.49	3.56	0.16	9.39	21.00	1615.92	15.88	2.88	36.28
TEK	TEKTRONIX INC	0.69	48.81	9.79	0.42	26.25	2.37	536.14	45.97	3.02	116.82
TII	THOMAS INDUSTRIES INC	0.10	7.36	42.32	11.12	93.13	0.38	25.97	1222.07	229.00	3194.75
TOL	TOLL BROTHERS INC	0.50	71.24	6.76	0.31	18.61	1.57	517.54	51.83	3.10	132.13
TRR	T R C COMPANIES INC	0.05	6.52	44.50	13.18	94.25	0.41	197.44	301.83	10.77	866.50
TXU	T X U CORP	9.45	285.21	1.44	0.11	3.50	12.50	1164.52	21.87	2.81	52.86
TYC	TYCO INTERNATIONAL LTD NEW	2.10	67.45	6.25	0.17	16.65	127.00	4485.28	6.46	1.35	13.77
UFI	UNIFI INC	1.91	75.02	6.74	0.20	18.03	0.39	86.09	265.51	8.84	707.76
UGI	U G I CORP	0.67	48.03	8.59	0.24	22.83	0.83	127.74	196.95	7.35	515.07
UHT	UNIVERSAL HEALTH RLTY INCM TR	0.11	15.80	25.78	2.91	65.85	0.27	60.33	861.04	110.00	2169.16
VOD	VODAFONE GROUP PLC NEW	0.95	72.28	7.58	0.27	20.54	23.20	1243.70	20.14	2.66	47.14
WBK	WESTPAC BANKING CORP	0.03	26.25	17.46	0.66	47.22	0.18	17.74	1402.31	142.78	3602.08
WCS	WALLACE COMPUTER SERVICES INC	0.66	26.90	14.77	0.34	40.91	0.78	136.99	181.28	7.20	476.36
WEN	WENDYS INTERNATIONAL INC	1.29	187.12	2.26	0.12	5.74	3.05	481.68	51.98	3.05	132.47
WGL	W G L HOLDINGS INC	0.76	36.30	11.46	0.51	29.32	1.41	196.57	125.27	4.09	337.67

Table II

Estimated Coefficients for the Return Equation for the Disney Company (DIS)

Coefficient estimates and robust standard errors (in parenthesis) for the equation

$$r_t = \sum_{i=1}^{5} a_i r_{t-i} + \lambda_{open}^{r} D_t x_t^0 + \sum_{i=0}^{5} \left[\gamma_i^r + \delta_i^r \ln(1+T_{t-i})\right] x_{t-i}^0 + \nu_t$$

r_t, is the change in the natural logarithm of the midquote of a given stock that follows the trade at time *t*, x_t^0 is the trade indicator (1 for a buy, -1 for a sale, 0 if at midquote), T_t is the time (in seconds) between the transaction at *t* and the transaction at *t-1*, D_t is an indicator that equals 1 if the trade is in the first 30 minutes of trading. The coefficients in columns 2-4 reflect all trades in DIS during March 1993. The coefficients in columns 5-7 reflect all trades in DIS during April 1998.

	March 1993			April 1998		
Lag number	Quote Revision (a_i)	Trade (γ_i^r)	Trade * Duration (δ_i^r)	Quote Revision (a_i)	Trade (γ_i^r)	Trade * Duration (δ_i^r)
0		0.0093	-0.0010		0.0017	0.0013
		(0.0009)**	(0.0003)**		(0.0002)**	(0.0001)**
1	-0.0212	0.0075	-0.0010	0.0040	0.0005	0.0007
	(0.0082)**	(0.0009)**	(0.0003)**	(0.0056)	(0.0002)**	(0.0001)**
2	-0.0129	0.0026	-0.0002	0.0254	-0.0002	0.0005
	(0.0089)	(0.0009)**	(0.0003)	(0.0058)**	(0.0002)	(0.0001)**
3	0.0046	0.0012	0.0002	0.0266	-0.0004	0.0004
	(0.0086)	(0.0009)	(0.0003)	(0.0064)**	(0.0002)	(0.0001)**
4	0.0042	0.0016	-0.0001	0.0286	-0.0009	0.0002
	(0.0093)	(0.0009)	(0.0003)	(0.0058)**	(0.0002)**	(0.0001)*
5	0.0179	0.0011	-0.0002	0.0259	-0.0011	0.0003
	(0.0085)*	(0.0009)	(0.0003)	(0.0059)**	(0.0002)**	(0.0001)**
	17587 observations Adj. R2: 0.05			41047 observations Adj. R2: 0.07		

Robust standard errors in parentheses
* significant at 5%; ** significant at 1%

Table III

Estimated Coefficients for the Information Content of Inter-Transaction Time Equation for the Disney Company (DIS)

Coefficient estimates and robust standard errors (in parenthesis) for the equation

$$y_m = \sum_{i=1}^{4} a_i y_{m-i} + \sum_{i=0}^{4} b_i \Delta \overline{T}_m + \sum_{i=0}^{4} c_i \Delta \overline{L}_m + e_m$$

are reported in column 1. y_m is the proxy for the information content of inter-transaction time in month *m* defined as $y_m \equiv \sum_{i=0}^{5} \left[\gamma_{im}^r + \delta_{im}^r \ln(1+T_z) \right]_{z=90th\,\%tile}^{z=10th\,\%tile}$. γ_{im}^r and δ_{im}^r are estimated from equation 2. T_Z is the *z-percentile* of the inter-transaction time distribution for month *m*. The values of y_m are represented visually as the difference between the two solid lines graphed in Figure 5. $\overline{T}_m$ is the average inter-transaction time during month *m*. $\overline{L}_m$ is the average price impact of a trade, defined as $\overline{L}_m \equiv \sum_{i=0}^{5} \left[\gamma_{im}^r + \delta_{im}^r \ln(1+T_z) \right]^{z=average}$, and Δ represents first differences. Related empirical specifications reported in columns (2)-(4).

	Specification			
Independent variable	(1)	(2)	(3)	(4)
Lags of y				
a_1	0.2926	0.3272	0.3386	
	(0.1250)*	(0.1142)**	(0.1245)**	
a_2	0.2587	0.1720	0.1496	
	(0.1003)*	(0.1043)	(0.1122)	
a_3	0.2057	0.1587	0.1518	
	(0.0978)*	(0.0959)	(0.1008)	
a_4	-0.0978	-0.0931	-0.0871	
	(0.1121)	(0.0944)	(0.0964)	
Lags of $\Delta \overline{T}$				
b_0	0.0167			0.0140
	(0.0041)**			(0.0039)**
b_1	0.0031			
	(0.0061)			
b_2	-0.0040			
	(0.0061)			
b_3	-0.0061			
	(0.0048)			
b_4	-0.0036			
	(0.0042)			
Lags of $\Delta \overline{L}$				
c_0	-0.1379		0.0083	-0.1257
	(0.0758)		(0.0818)	(0.0655)
c_1	0.0260		0.0701	
	(0.0971)		(0.1000)	
c_2	0.0168		0.0945	
	(0.1009)		(0.0953)	
c_3	-0.0021		-0.0211	
	(0.1128)		(0.0886)	
c_4	0.0479		-0.0363	
	(0.1002)		(0.0841)	
Constant	0.0004	0.0005	0.0005	0.0011
	(0.0003)	(0.0003)	(0.0003)	(0.0002)**
Observations	103	104	103	107
R-squared	0.39	0.23	0.25	0.12

Robust standard errors in parentheses
* significant at 5%; ** significant at 1%

Table IV

Summary of Sign and Statistical Significance of the γ_i^r Coefficients: Full Sample

Entries in the table derive from the estimates of the γ_i^r coefficients from the equation

$$r_t = \sum_{i=1}^{5} a_i r_{t-i} + \lambda_{open}^r D_t x_t^0 + \sum_{i=0}^{5} \left[\gamma_i^r + \delta_i^r \ln(1+T_{t-i})\right] x_{t-i}^0 + \nu_t$$

estimated for the full sample of 100 stocks over the 108 months from January 1993 to December 2001. The first entry in each cell represents the average value of the sum of the γ_i^r coefficients for all firms in the given firm decile and the given year. The second entry is the share of the 120 individual observations (10 firms x 12 months) that were statistically significant and positive. The third entry is the share of the 120 individual observations that were statistically significant and negative.

	Firm category									
year	Most actively traded				…					Least actively traded
1993	0.018	0.052	0.065	0.111	0.091	0.136	0.126	0.146	0.116	0.233
	0.992	0.933	0.975	0.8	0.658	0.65	0.583	0.429	0.25	0.284
	0	0	0	0	0	0	0	0	0.008	0
1994	0.022	0.056	0.071	0.12	0.1	0.097	0.119	0.197	0.146	0.344
	0.983	0.975	0.992	0.875	0.725	0.6	0.55	0.533	0.336	0.231
	0	0	0	0	0	0	0	0	0	0.01
1995	0.019	0.051	0.063	0.104	0.101	0.111	0.125	0.149	0.132	0.235
	0.992	0.975	1	0.958	0.908	0.775	0.617	0.608	0.378	0.26
	0	0	0	0	0	0	0	0	0	0
1996	0.026	0.058	0.072	0.092	0.091	0.12	0.128	0.135	0.126	0.258
	1	1	1	0.983	0.95	0.875	0.783	0.6	0.445	0.228
	0	0	0	0	0	0	0	0	0	0
1997	0.022	0.048	0.062	0.072	0.07	0.089	0.109	0.111	0.103	0.265
	1	1	1	1	0.933	0.883	0.892	0.85	0.529	0.246
	0	0	0	0	0	0	0	0	0	0
1998	0.019	0.041	0.062	0.069	0.062	0.102	0.103	0.121	0.109	0.398
	0.992	1	1	1	1	0.95	0.967	0.942	0.717	0.342
	0	0	0	0	0	0	0	0	0	0
1999	0.018	0.036	0.054	0.065	0.06	0.109	0.105	0.134	0.11	0.249
	1	1	1	1	1	0.975	0.958	0.95	0.85	0.439
	0	0	0	0	0	0	0	0	0	0
2000	0.021	0.042	0.061	0.068	0.066	0.109	0.146	0.126	0.137	0.215
	1	1	1	1	1	0.967	0.983	0.983	0.817	0.403
	0	0	0	0	0	0	0	0	0	0
2001	0.014	0.023	0.029	0.032	0.036	0.062	0.1	0.08	0.079	0.102
	1	1	0.992	1	1	0.983	0.9	0.967	0.808	0.6
	0	0	0	0	0	0	0	0	0	0

Table V

Summary of Sign and Statistical Significance of the δ_i^r Coefficients: Full Sample

Entries in the table derive from the estimates of the δ_i^r coefficients from the equation

$$r_t = \sum_{i=1}^{5} a_i r_{t-i} + \lambda_{open}^r D_t x_t^0 + \sum_{i=0}^{5} \left[\gamma_i^r + \delta_i^r \ln(1 + T_{t-i}) \right] x_{t-i}^0 + \nu_t$$

estimated for the full sample of 100 stocks over the 108 months from January 1993 to December 2001. The first entry in each cell represents the average value of the sum of the δ_i^r coefficients for all firms in the given firm decile and the given year. The second entry is the share of the 120 individual observations (10 firms x 12 months) that were statistically significant and positive. The third entry is the share of the 120 individual observations that were statistically significant and negative.

	Firm category									
	Most actively traded				…					Least actively traded
1993	-0.119	-0.543	-0.625	-0.936	-0.76	-0.919	-1.04	-1.103	-0.659	-1.581
	0.017	0	0.008	0.008	0	0.008	0.017	0	0.033	0.009
	0.242	0.508	0.492	0.242	0.2	0.283	0.225	0.21	0.083	0.155
1994	-0.143	-0.545	-0.65	-0.899	-0.761	-0.554	-0.837	-1.588	-0.851	-2.387
	0.025	0	0	0	0.008	0	0.008	0.008	0.008	0.01
	0.275	0.55	0.542	0.258	0.217	0.158	0.142	0.233	0.109	0.096
1995	-0.173	-0.519	-0.562	-0.875	-0.925	-0.886	-0.955	-1.077	-1.016	-1.555
	0.042	0	0	0	0	0.017	0.008	0	0	0.01
	0.625	0.667	0.592	0.367	0.417	0.242	0.133	0.2	0.134	0.125
1996	-0.306	-0.662	-0.77	-0.789	-0.887	-1.056	-0.975	-1.034	-1.124	-2.019
	0.017	0	0	0	0	0	0.008	0.008	0	0
	0.867	0.858	0.725	0.467	0.525	0.35	0.25	0.2	0.193	0.096
1997	-0.152	-0.484	-0.585	-0.579	-0.563	-0.681	-0.91	-0.883	-0.817	-1.787
	0.108	0	0	0	0	0	0	0	0	0
	0.6	0.733	0.592	0.458	0.5	0.417	0.308	0.283	0.227	0.105
1998	-0.074	-0.373	-0.538	-0.543	-0.526	-0.867	-0.987	-1.02	-0.893	-4.607
	0.117	0.008	0.008	0	0	0.008	0.008	0.008	0	0
	0.442	0.742	0.592	0.533	0.542	0.375	0.508	0.442	0.225	0.105
1999	-0.094	-0.312	-0.453	-0.543	-0.547	-0.891	-0.953	-1.122	-0.973	-2.124
	0.108	0.042	0.008	0.008	0	0	0	0	0.008	0.026
	0.533	0.725	0.667	0.633	0.675	0.333	0.542	0.475	0.317	0.07
2000	-0.155	-0.371	-0.531	-0.633	-0.597	-0.839	-1.335	-1.039	-1.249	-1.694
	0.117	0	0	0	0	0	0	0	0	0.008
	0.592	0.742	0.692	0.75	0.775	0.367	0.45	0.55	0.358	0.109
2001	-0.087	-0.216	-0.26	-0.323	-0.347	-0.597	-0.963	-0.735	-0.744	-0.87
	0.092	0.008	0	0	0	0	0	0	0.008	0.008
	0.5	0.767	0.733	0.825	0.733	0.642	0.567	0.658	0.358	0.275

Table VI

Estimated Coefficients for the Information Content of Inter-Transaction Time Equation for the Full Sample

Coefficient estimates and robust standard errors (in parenthesis) for the equation $y_m = \sum_{i=1}^{4} a_i y_{m-i} + \sum_{i=0}^{4} b_i \Delta\overline{T}_m + \sum_{i=0}^{4} c_i \Delta\overline{L}_m + e_m$.

Each column reports coefficients for the given decile of firms. y_m is the proxy for the information content of inter-transaction time in month m defined as $y_m \equiv \sum_{i=0}^{5}\left[\gamma_{im}^r + \delta_{im}^r \ln(1+T_z)\right]_{z=90th\%tile}^{z=10th\%tile}$. γ_{im}^r and δ_{im}^r are estimated from equation 2. T_Z is the *z-percentile* of the inter-transaction time distribution for month *m*. $\overline{T}_m$ is the average inter-transaction time during month *m*. $\overline{L}_m$ is the average price impact of a trade, defined as $\overline{L}_m \equiv \sum_{i=0}^{5}\left[\gamma_{im}^r + \delta_{im}^r \ln(1+T_z)\right]^{z=average}$, and Δ represents first differences.

	Firm category									
	Most actively traded					…			Least actively traded	
Lags of y										
a_1	0.4011	0.2778	0.3471	0.2913	0.2254	0.2723	0.3523	0.2231	0.1900	0.2220
	(0.0438)**	(0.0468)**	(0.0505)**	(0.0536)**	(0.0568)**	(0.0492)**	(0.1433)*	(0.0445)**	(0.0415)**	(0.0437)**
a_2	0.1988	0.1741	0.1759	0.1313	0.1671	0.1496	0.2241	0.1886	0.0365	0.0296
	(0.0471)**	(0.0404)**	(0.0669)**	(0.0677)	(0.0489)**	(0.0479)**	(0.0758)**	(0.0579)**	(0.0408)	(0.0310)
a_3	0.0821	0.1409	0.0467	0.1430	0.1102	0.1266	0.0049	0.1351	0.1554	0.0514
	(0.0510)	(0.0403)**	(0.0538)	(0.0595)*	(0.0459)*	(0.0515)*	(0.0862)	(0.0442)**	(0.0367)**	(0.0281)
a_4	0.1582	0.2007	0.1314	0.0771	0.1665	0.0963	0.0369	0.0745	-0.0167	0.0278
	(0.0470)**	(0.0456)**	(0.0538)*	(0.0446)	(0.0526)**	(0.0468)*	(0.0660)	(0.0566)	(0.0568)	(0.0285)
Lags of $\Delta\overline{T}$										
b_0	0.0196	0.0059	0.0081	0.0007	0.0037	0.0035	0.0012	0.0012	-0.0006	-0.0004
	(0.0021)**	(0.0016)**	(0.0020)**	(0.0015)	(0.0013)**	(0.0012)**	(0.0008)	(0.0007)	(0.0007)	(0.0006)
b_1	0.0075	0.0021	0.0046	0.0007	0.0036	0.0018	0.0011	0.0019	-0.0013	0.0007
	(0.0020)**	(0.0015)	(0.0021)*	(0.0015)	(0.0014)*	(0.0011)	(0.0009)	(0.0006)**	(0.0009)	(0.0007)
b_2	0.0035	0.0002	0.0030	0.0018	-0.0003	0.0009	0.0002	0.0013	0.0004	0.0002
	(0.0019)	(0.0014)	(0.0021)	(0.0014)	(0.0012)	(0.0010)	(0.0009)	(0.0008)	(0.0009)	(0.0008)
b_3	0.0024	0.0004	0.0032	0.0035	-0.0016	0.0018	-0.0005	0.0016	0.0006	0.0002
	(0.0021)	(0.0014)	(0.0020)	(0.0023)	(0.0011)	(0.0009)	(0.0008)	(0.0007)*	(0.0007)	(0.0008)
b_4	-0.0016	-0.0008	0.0005	-0.0025	-0.0034	0.0024	0.0010	0.0014	0.0008	0.0010
	(0.0019)	(0.0013)	(0.0019)	(0.0010)*	(0.0012)**	(0.0009)*	(0.0008)	(0.0006)*	(0.0008)	(0.0007)
Lags of $\Delta\overline{L}$										
c_0	-0.0518	-0.1857	-0.1970	-0.4805	-0.5425	-0.6752	-0.5619	-0.7836	-0.6137	-0.1748
	(0.0456)	(0.0588)**	(0.0653)**	(0.1184)**	(0.0983)**	(0.0835)**	(0.1360)**	(0.0692)**	(0.0510)**	(0.0249)**
c_1	-0.0286	0.0709	0.1704	0.1235	-0.1093	-0.3309	-0.3242	-0.3174	-0.3428	-0.0340
	(0.0460)	(0.0625)	(0.0757)*	(0.1036)	(0.0971)	(0.0928)**	(0.1486)*	(0.0870)**	(0.0850)**	(0.0119)**
c_2	0.0117	0.0919	0.0307	0.0366	-0.0827	-0.1727	0.0826	-0.1052	-0.3236	-0.0262
	(0.0471)	(0.0678)	(0.0745)	(0.0916)	(0.1140)	(0.0852)*	(0.1526)	(0.0790)	(0.0723)**	(0.0101)*
c_3	0.0676	-0.0021	0.1042	-0.0862	0.2169	-0.2129	-0.1766	-0.0256	-0.0025	-0.0119
	(0.0461)	(0.0618)	(0.0893)	(0.0940)	(0.0971)*	(0.0742)**	(0.1351)	(0.0871)	(0.0666)	(0.0073)
c_4	-0.0257	0.1001	0.0087	-0.0888	0.1921	-0.1396	-0.1272	0.0240	0.0151	-0.0020
	(0.0455)	(0.0589)	(0.0749)	(0.1195)	(0.0812)*	(0.0631)*	(0.1164)	(0.0623)	(0.0491)	(0.0014)
Constant	0.0008	0.0030	0.0061	0.0090	0.0080	0.0112	0.0158	0.0171	0.0244	0.0259
	(0.0002)**	(0.0005)**	(0.0009)**	(0.0016)**	(0.0015)**	(0.0021)**	(0.0056)**	(0.0029)**	(0.0037)**	(0.0055)**
Obs	1030	1030	1030	1030	1030	1030	1030	1030	1030	1000
R-squared	0.57	0.46	0.37	0.36	0.34	0.30	0.30	0.39	0.25	0.20

Robust standard errors in parentheses
* significant at 5%; ** significant at 1%

Table VII

Summary of Sign and Statistical Significance of the γ_i^r Coefficients when Controlling for Trade Type

Entries in the table derive from the estimates of the γ_i^r coefficients from the equation

$$r_t = \sum_{i=1}^{5} a_i r_{t-i} + \lambda_{open}^r D_t x_t^0 + \sum_{i=0}^{5} \left[\gamma_i^r + \delta_i^r \ln(1+T_{t-i})\right] x_{t-i}^0 + \sum_{i=0}^{5} \left[\gamma_i^{rs} + \delta_i^{rs} \ln(1+T_{t-i})\right] S_{t-i} x_{t-i}^0 + \nu_{1,t}$$

estimated for the full sample of 100 stocks over the 108 months from January 1993 to December 2001. S_t equals 1 if the current trade is in the same direction as the preceding trade, 0 otherwise. The first entry in each cell represents the average value of the sum of the γ_i^r coefficients for all firms in the given firm decile and the given year. The second entry is the share of the 120 individual observations (10 firms x 12 months) that were statistically significant and positive. The third entry is the share of the 120 individual observations that were statistically significant and negative.

	Firm category									
Year	Most actively traded				…					Least actively traded
1993	0.022	0.06	0.075	0.124	0.103	0.158	0.139	0.161	0.148	0.203
	0.992	0.95	0.992	0.892	0.75	0.725	0.65	0.442	0.325	0.375
	0	0	0	0	0	0	0	0.008	0	0.05
1994	0.026	0.063	0.081	0.13	0.112	0.11	0.134	0.22	0.16	0.216
	0.992	0.983	1	0.892	0.808	0.633	0.608	0.6	0.342	0.208
	0	0	0	0	0	0	0	0	0.008	0.2
1995	0.023	0.057	0.071	0.113	0.11	0.127	0.138	0.162	0.155	0.281
	0.992	0.983	1	0.958	0.942	0.833	0.725	0.633	0.35	0.283
	0	0	0	0	0	0	0	0	0.008	0.167
1996	0.031	0.066	0.08	0.101	0.1	0.135	0.14	0.148	0.14	0.24
	1	1	1	0.983	0.958	0.908	0.825	0.658	0.5	0.283
	0	0	0	0	0	0	0	0	0.008	0.125
1997	0.026	0.054	0.069	0.078	0.077	0.102	0.118	0.12	0.114	0.211
	1	1	1	1	0.95	0.908	0.933	0.85	0.575	0.275
	0	0	0	0	0	0	0	0	0.008	0.083
1998	0.022	0.047	0.07	0.076	0.069	0.111	0.111	0.13	0.117	0.25
	1	1	1	1	1	0.975	0.975	0.958	0.75	0.367
	0	0	0	0	0	0	0	0	0	0.075
1999	0.021	0.041	0.062	0.072	0.066	0.117	0.113	0.145	0.12	0.268
	1	1	1	1	1	0.975	0.975	0.967	0.875	0.45
	0	0	0	0	0	0	0	0	0	0.067
2000	0.025	0.05	0.07	0.077	0.073	0.117	0.159	0.137	0.149	0.231
	1	1	1	1	1	0.983	0.992	0.983	0.85	0.4
	0	0	0	0	0	0	0	0	0	0.008
2001	0.019	0.03	0.036	0.04	0.045	0.073	0.115	0.094	0.093	0.117
	1	1	1	1	1	0.992	0.917	0.958	0.883	0.642
	0	0	0	0	0	0	0	0	0	0

Table VIII

Summary of Sign and Statistical Significance of the δ_i^r Coefficients when Controlling for Trade Type

Entries in the table derive from the estimates of the δ_i^r coefficients from the equation

$$r_t = \sum_{i=1}^{5} a_i r_{t-i} + \lambda_{open}^r D_t x_t^0 + \sum_{i=0}^{5} \left[\gamma_i^r + \delta_i^r \ln(1+T_{t-i})\right] x_{t-i}^0 + \sum_{i=0}^{5} \left[\gamma_i^{rs} + \delta_i^{rs} \ln(1+T_{t-i})\right] S_{t-i} x_{t-i}^0 + \nu_{1,t}$$

estimated for the full sample of 100 stocks over the 108 months from January 1993 to December 2001. S_t equals 1 if the current trade is in the same direction as the preceding trade, 0 otherwise. The first entry in each cell represents the average value of the sum of the δ_i^r coefficients for all firms in the given firm decile and the given year. The second entry is the share of the 120 individual observations (10 firms x 12 months) that were statistically significant and positive. The third entry is the share of the 120 individual observations that were statistically significant and negative.

	Firm category									
	Most actively traded				…					Least actively traded
1993	0.16	-0.026	0.005	0.072	-0.124	0.008	-0.188	-0.295	0.454	0.88
	0.408	0.075	0.075	0.058	0.025	0.042	0.008	0	0.067	0.067
	0.008	0.067	0.058	0.05	0.083	0.092	0.05	0.067	0.017	0.025
1994	0.16	0.042	0.092	-0.003	-0.07	0.19	-0.093	-0.636	0.009	2.117
	0.317	0.058	0.083	0.033	0.075	0.033	0.033	0.033	0.033	0.15
	0.008	0.05	0.067	0.025	0.05	0.033	0.058	0.067	0.075	0.117
1995	0.158	-0.025	0.104	-0.087	-0.326	-0.041	-0.364	-0.277	0.039	1.698
	0.367	0.108	0.092	0.017	0.008	0.042	0.017	0.033	0	0.133
	0.008	0.083	0.067	0.058	0.092	0.042	0.042	0.033	0.033	0.1
1996	0.245	0.04	0.051	-0.077	-0.222	-0.029	-0.334	-0.271	-0.417	2.066
	0.475	0.108	0.05	0.033	0.025	0.017	0.017	0.033	0.017	0.125
	0	0.092	0.1	0.075	0.092	0.033	0.1	0.033	0.075	0.092
1997	0.239	0.081	0.091	-0.037	-0.095	0.094	-0.291	-0.379	-0.164	3.556
	0.667	0.158	0.108	0.058	0.033	0.075	0.008	0.017	0.017	0.075
	0	0.067	0.083	0.1	0.1	0.033	0.092	0.083	0.05	0.075
1998	0.234	0.038	0.022	0.015	-0.144	-0.207	-0.335	-0.378	-0.376	2.163
	0.7	0.142	0.075	0.033	0.017	0.067	0.033	0.025	0.008	0.092
	0	0.075	0.075	0.042	0.058	0.042	0.167	0.075	0.083	0.083
1999	0.24	0.166	0.135	0.006	-0.112	-0.221	-0.288	-0.155	-0.128	-0.458
	0.8	0.267	0.15	0.133	0.05	0.067	0.025	0	0.033	0.067
	0	0.05	0.058	0.042	0.1	0.058	0.133	0.067	0.05	0.083
2000	0.257	0.247	0.221	0.026	-0.057	-0.008	0.286	-0.203	-0.339	0.02
	0.708	0.408	0.275	0.133	0.033	0.125	0.008	0.017	0.008	0.025
	0	0.008	0.033	0.017	0.058	0.025	0.042	0.075	0.058	0.033
2001	0.489	0.575	0.659	0.678	0.707	0.673	1.058	0.788	0.67	0.799
	0.992	0.975	0.858	0.867	0.808	0.425	0.3	0.483	0.092	0.125
	0	0	0	0	0.008	0	0.008	0.008	0	0.008

Table IX

Summary of Sign and Statistical Significance of the $\gamma_i^r + \gamma_i^{rs}$ Coefficients when Controlling for Trade Type

Entries in the table derive from the estimates of $\gamma_i^r + \gamma_i^{rs}$ coefficients from the equation

$$r_t = \sum_{i=1}^{5} a_i r_{t-i} + \lambda_{open}^r D_t x_t^0 + \sum_{i=0}^{5} \left[\gamma_i^r + \delta_i^r \ln(1+T_{t-i})\right] x_{t-i}^0 + \sum_{i=0}^{5} \left[\gamma_i^{rs} + \delta_i^{rs} \ln(1+T_{t-i})\right] S_{t-i} x_{t-i}^0 + \nu_{1,t}$$

estimated for the full sample of 100 stocks over the 108 months from January 1993 to December 2001. S_t equals 1 if the current trade is in the same direction as the preceding trade, 0 otherwise. The first entry in each cell represents the average value of the sum of the γ_i^r coefficients for all firms in the given firm decile and the given year. The second entry is the share of the 120 individual observations (10 firms x 12 months) that were statistically significant and positive. The third entry is the share of the 120 individual observations that were statistically significant and negative.

	Firm category									
Year	Most actively traded				…					Least actively traded
1993	0.022	0.059	0.071	0.117	0.1	0.147	0.143	0.15	0.131	0.193
	0.975	0.942	0.983	0.808	0.717	0.683	0.633	0.417	0.258	0.367
	0	0	0	0	0	0	0	0.008	0	0.042
1994	0.025	0.066	0.084	0.132	0.113	0.102	0.138	0.228	0.15	0.22
	0.983	0.967	1	0.892	0.775	0.625	0.608	0.583	0.308	0.308
	0	0	0	0	0	0	0	0	0.008	0.15
1995	0.022	0.057	0.074	0.113	0.11	0.126	0.145	0.163	0.152	0.391
	0.992	0.967	1	0.967	0.95	0.825	0.733	0.617	0.342	0.317
	0	0	0	0	0	0	0	0	0.008	0.133
1996	0.03	0.067	0.084	0.102	0.101	0.132	0.142	0.146	0.136	0.277
	1	1	1	0.975	0.958	0.9	0.808	0.642	0.517	0.325
	0	0	0	0	0	0	0	0	0.008	0.083
1997	0.026	0.054	0.071	0.076	0.081	0.097	0.114	0.119	0.113	0.206
	0.992	1	1	1	0.95	0.883	0.908	0.833	0.567	0.317
	0	0	0	0	0	0	0	0	0.008	0.067
1998	0.021	0.044	0.068	0.072	0.066	0.107	0.106	0.127	0.115	0.285
	0.992	1	1	1	1	0.933	0.958	0.9	0.717	0.383
	0	0	0	0	0	0	0	0	0	0.05
1999	0.02	0.039	0.06	0.069	0.062	0.113	0.113	0.151	0.122	0.27
	1	1	1	1	1	0.975	0.967	0.967	0.842	0.45
	0	0	0	0	0	0	0	0	0	0.05
2000	0.025	0.047	0.068	0.073	0.07	0.119	0.158	0.135	0.16	0.231
	1	1	1	1	1	0.967	0.983	0.967	0.883	0.442
	0	0	0	0	0	0	0	0	0	0.008
2001	0.018	0.028	0.034	0.037	0.042	0.069	0.114	0.087	0.089	0.123
	1	1	1	1	1	0.992	0.942	0.95	0.817	0.675
	0	0	0	0	0	0	0	0	0	0

Table X

Summary of Sign and Statistical Significance of the $\delta_i^r + \delta_i^{rs}$ Coefficients when Controlling for Trade Type

Entries in the table derive from the estimates of $\delta_i^r + \delta_i^{rs}$ coefficients from the equation

$$r_t = \sum_{i=1}^{5} a_i r_{t-i} + \lambda_{open}^r D_t x_t^0 + \sum_{i=0}^{5} \left[\gamma_i^r + \delta_i^r \ln(1+T_{t-i})\right] x_{t-i}^0 + \sum_{i=0}^{5} \left[\gamma_i^{rs} + \delta_i^{rs} \ln(1+T_{t-i})\right] S_{t-i} x_{t-i}^0 + \nu_{1,t}$$

estimated for the full sample of 100 stocks over the 108 months from January 1993 to December 2001. S_t equals 1 if the current trade is in the same direction as the preceding trade, 0 otherwise. The first entry in each cell represents the average value of the sum of the δ_i^r coefficients for all firms in the given firm decile and the given year. The second entry is the share of the 120 individual observations (10 firms x 12 months) that were statistically significant and positive. The third entry is the share of the 120 individual observations that were statistically significant and negative.

	Firm category									
	Most actively traded				…					Least actively traded
1993	-0.21	-0.741	-0.889	-1.264	-1.036	-1.263	-1.257	-1.269	-1.118	-1.237
	0.008	0	0	0	0	0	0.017	0	0.008	0.05
	0.467	0.667	0.675	0.4	0.333	0.342	0.25	0.183	0.133	0.183
1994	-0.257	-0.731	-0.873	-1.148	-1.038	-0.808	-1.169	-2.075	-0.927	-0.353
	0.008	0	0	0	0	0	0	0	0.017	0.125
	0.533	0.708	0.65	0.383	0.333	0.242	0.192	0.25	0.192	0.217
1995	-0.277	-0.693	-0.751	-1.107	-1.115	-1.175	-1.169	-1.286	-1.4	-1.623
	0.025	0	0	0	0	0	0	0	0	0.125
	0.733	0.742	0.667	0.5	0.5	0.4	0.192	0.258	0.158	0.183
1996	-0.461	-0.871	-0.976	-1.025	-1.09	-1.387	-1.202	-1.291	-1.285	-1.884
	0.008	0	0	0	0	0	0	0.008	0	0.092
	0.95	0.95	0.825	0.625	0.658	0.45	0.317	0.217	0.183	0.183
1997	-0.311	-0.687	-0.748	-0.759	-0.728	-0.958	-1.085	-1.067	-0.942	-1.114
	0.05	0	0	0	0	0	0	0	0.008	0.058
	0.833	0.917	0.742	0.65	0.6	0.483	0.425	0.333	0.258	0.142
1998	-0.214	-0.55	-0.784	-0.782	-0.696	-1.036	-1.144	-1.223	-0.995	-1.616
	0.058	0	0.008	0	0	0.008	0.008	0.008	0	0.05
	0.725	0.867	0.833	0.725	0.65	0.425	0.508	0.475	0.258	0.158
1999	-0.248	-0.55	-0.745	-0.809	-0.766	-1.098	-1.138	-1.39	-1.176	-1.764
	0.025	0.017	0	0.008	0	0	0	0	0.008	0.075
	0.85	0.933	0.842	0.858	0.817	0.483	0.55	0.533	0.375	0.083
2000	-0.357	-0.726	-0.927	-0.973	-0.867	-1.088	-1.653	-1.353	-1.385	-2.062
	0.025	0	0	0	0	0	0	0	0	0.017
	0.875	0.992	0.967	0.95	0.9	0.492	0.533	0.65	0.392	0.125
2001	-0.333	-0.499	-0.552	-0.607	-0.648	-0.878	-1.313	-1.054	-0.929	-1.148
	0	0.008	0	0	0	0	0	0	0	0
	0.958	0.992	0.975	0.992	0.975	0.8	0.683	0.808	0.425	0.292

Table XI

Estimated Coefficients for the Information Content of Inter-Transaction Time Equation for Reversing Trades

Coefficient estimates and robust standard errors (in parenthesis) for the equation $y_m = \sum_{i=1}^{4} a_i y_{m-i} + \sum_{i=0}^{4} b_i \Delta \overline{T}_m + \sum_{i=0}^{4} c_i \Delta \overline{L}_m + e_m$.

Each column reports coefficients for the given decile of firms. y_m is the proxy for the information content of inter-transaction time in month *m* defined as $y_m \equiv \sum_{i=0}^{5} \left[\gamma_{im}^r + \delta_{im}^r \ln(1+T_z)\right]_{z=90th\,\%tile}^{z=10th\,\%tile}$. γ_{im}^r and δ_{im}^r are estimated from equation 6. T_Z is the *z-percentile* of the inter-transaction time distribution for month *m* for reversing trades. $\overline{T}_m$ is the average inter-transaction time for reversing trades during month *m*. $\overline{L}_m$ is the average price impact of a reversing trade, defined as $\overline{L}_m \equiv \sum_{i=0}^{5} \left[\gamma_{im}^r + \delta_{im}^r \ln(1+T_z)\right]^{z=average}$, and Δ represents first differences.

	Firm category									
	Most actively traded				…				Least actively traded	
Lags of y										
a_1	0.4026	0.3315	0.3726	0.2735	0.2200	0.2440	0.2933	0.2002	0.1704	0.1308
	(0.0435)**	(0.0443)**	(0.0548)**	(0.0674)**	(0.0539)**	(0.0559)**	(0.0385)**	(0.0495)**	(0.0404)**	(0.0377)**
a_2	0.2365	0.1962	0.1879	0.0835	0.1805	0.1285	0.2176	0.1519	0.1169	0.0442
	(0.0460)**	(0.0407)**	(0.0579)**	(0.0831)	(0.0475)**	(0.0575)*	(0.0758)**	(0.0484)**	(0.0398)**	(0.0444)
a_3	0.1037	0.1315	0.0861	0.1623	0.1013	0.1907	0.1122	0.1253	0.1676	0.0788
	(0.0483)*	(0.0410)**	(0.0463)	(0.0628)**	(0.0455)*	(0.0565)**	(0.0488)*	(0.0414)**	(0.0411)**	(0.0390)*
a_4	0.1659	0.2000	0.1532	0.0902	0.1572	0.1213	0.2077	0.0630	0.0450	0.1340
	(0.0427)**	(0.0415)**	(0.0454)**	(0.0571)	(0.0548)**	(0.0545)*	(0.0422)**	(0.0443)	(0.0480)	(0.0449)**
Lags of $\Delta\overline{T}$										
b_0	0.0146	0.0056	0.0061	0.0030	0.0024	0.0030	0.0007	0.0008	0.0002	-0.0000
	(0.0016)**	(0.0011)**	(0.0013)**	(0.0013)*	(0.0008)**	(0.0009)**	(0.0005)	(0.0005)	(0.0004)	(0.0005)
b_1	0.0033	0.0022	0.0013	-0.0003	0.0028	0.0023	0.0005	0.0020	-0.0003	0.0008
	(0.0016)*	(0.0011)*	(0.0015)	(0.0015)	(0.0009)**	(0.0008)**	(0.0005)	(0.0006)**	(0.0006)	(0.0006)
b_2	0.0018	0.0003	-0.0006	0.0017	-0.0002	0.0016	0.0001	0.0009	0.0006	0.0003
	(0.0016)	(0.0009)	(0.0016)	(0.0010)	(0.0008)	(0.0008)*	(0.0005)	(0.0005)	(0.0005)	(0.0006)
b_3	0.0010	-0.0005	-0.0000	0.0016	-0.0014	0.0013	-0.0003	0.0012	0.0006	0.0007
	(0.0016)	(0.0009)	(0.0014)	(0.0013)	(0.0008)	(0.0008)	(0.0006)	(0.0005)**	(0.0005)	(0.0007)
b_4	-0.0017	-0.0011	-0.0011	0.0007	-0.0017	0.0008	0.0005	0.0012	0.0006	0.0015
	(0.0015)	(0.0008)	(0.0013)	(0.0006)	(0.0008)*	(0.0006)	(0.0005)	(0.0004)**	(0.0005)	(0.0006)*
Lags of $\Delta\overline{L}$										
c_0	-0.3432	-0.3683	-0.3770	-0.2708	-0.3602	-0.3644	-0.3610	-0.3547	-0.2613	-0.0631
	(0.0220)**	(0.0256)**	(0.0371)**	(0.0522)**	(0.0292)**	(0.0377)**	(0.0251)**	(0.0187)**	(0.0180)**	(0.0110)**
c_1	-0.1615	-0.1598	-0.1671	-0.1086	-0.2207	-0.2269	-0.1802	-0.2237	-0.1805	-0.0457
	(0.0237)**	(0.0287)**	(0.0440)**	(0.0625)	(0.0382)**	(0.0515)**	(0.0438)**	(0.0282)**	(0.0254)**	(0.0102)**
c_2	-0.1110	-0.0864	-0.0541	-0.1388	-0.1123	-0.1470	-0.0640	-0.1317	-0.1258	-0.0399
	(0.0260)**	(0.0289)**	(0.0443)	(0.0549)*	(0.0371)**	(0.0451)**	(0.0481)	(0.0290)**	(0.0249)**	(0.0079)**
c_3	-0.0275	-0.0752	-0.0620	-0.1041	-0.0917	-0.0997	-0.1036	-0.0827	-0.0550	-0.0300
	(0.0233)	(0.0332)*	(0.0353)	(0.0471)*	(0.0430)*	(0.0373)**	(0.0457)*	(0.0294)**	(0.0222)*	(0.0083)**
c_4	0.0043	0.0300	-0.0163	-0.0304	-0.0106	-0.0407	0.0131	-0.0233	-0.0274	-0.0101
	(0.0182)	(0.0274)	(0.0272)	(0.0372)	(0.0250)	(0.0268)	(0.0313)	(0.0187)	(0.0153)	(0.0053)
Constant	-0.0005	-0.0008	-0.0012	-0.0005	0.0001	-0.0009	-0.0004	0.0031	0.0009	-0.0046
	(0.0002)*	(0.0003)*	(0.0004)**	(0.0007)	(0.0006)	(0.0010)	(0.0012)	(0.0013)*	(0.0014)	(0.0047)
Obs	1030	1030	1030	1030	1030	1030	1030	1030	1030	1000
R-squared	0.66	0.55	0.51	0.39	0.40	0.46	0.58	0.56	0.40	0.38

Robust standard errors in parentheses
* significant at 5%; ** significant at 1%

Table XII

Estimated Coefficients for the Information Content of Inter-Transaction Time Equation for Same-Direction Trades

Coefficient estimates and robust standard errors (in parenthesis) for the equation $y_m = \sum_{i=1}^{4} a_i y_{m-i} + \sum_{i=0}^{4} b_i \Delta\overline{T}_m + \sum_{i=0}^{4} c_i \Delta\overline{L}_m + e_m$. Each column reports coefficients for the given decile of firms. y_m is the proxy for the information content of inter-transaction time in month *m* defined as $y_m \equiv \sum_{i=0}^{5}\left[\gamma_{im}^{r} + \delta_{im}^{r}\ln(1+T_z)\right]_{z=90th\%tile}^{z=10th\%tile} + \sum_{i=0}^{5}\left[\gamma_{im}^{rs} + \delta_{im}^{rs}\ln(1+T_z)\right]_{z=90th\%tile}^{z=10th\%tile}$. Parameters are estimated from equation 6. T_Z is the *z-percentile* of the inter-transaction time distribution for month *m* for reversing and same-direction trades, depending on which sum is being evaluated. $\overline{T}_m$ is the average inter-transaction time for same-direction trades during month *m*. $\overline{L}_m$ is the average price impact of a same-direction trade, defined as $\overline{L}_m \equiv \sum_{i=0}^{5}\left[\gamma_{im}^{r} + \delta_{im}^{r}\ln(1+T_z)\right]^{z=average} + \sum_{i=0}^{5}\left[\gamma_{im}^{rs} + \delta_{im}^{rs}\ln(1+T_z)\right]^{z=average}$, and Δ represents first differences.

	Firm category									
	Most actively traded					…			Least actively traded	
Lags of y										
a_1	0.4457	0.3478	0.3440	0.3484	0.2638	0.2013	0.4400	0.1860	0.1211	0.0709
	(0.0433)**	(0.0459)**	(0.0458)**	(0.0480)**	(0.0477)**	(0.0442)**	(0.1212)**	(0.0477)**	(0.0451)**	(0.0598)
a_2	0.1540	0.1911	0.1820	0.1585	0.1560	0.1637	0.1740	0.1923	0.1074	0.0229
	(0.0447)**	(0.0389)**	(0.0673)**	(0.0698)*	(0.0480)**	(0.0462)**	(0.0511)**	(0.0542)**	(0.0393)**	(0.0399)
a_3	0.0876	0.0872	0.0431	0.1681	0.0637	0.2000	-0.0428	0.1466	0.1315	0.1505
	(0.0475)	(0.0436)*	(0.0514)	(0.0540)**	(0.0470)	(0.0463)**	(0.0795)	(0.0441)**	(0.0411)**	(0.0742)*
a_4	0.1778	0.1952	0.1061	0.0404	0.1813	0.0612	0.1176	0.1078	0.0232	0.0703
	(0.0417)**	(0.0429)**	(0.0529)*	(0.0467)	(0.0562)**	(0.0458)	(0.0511)*	(0.0460)*	(0.0460)	(0.0604)
Lags of $\Delta\overline{T}$										
b_0	0.0277	0.0088	0.0103	-0.0013	0.0051	0.0019	0.0003	0.0003	-0.0011	0.0001
	(0.0029)**	(0.0020)**	(0.0028)**	(0.0011)	(0.0019)**	(0.0013)	(0.0010)	(0.0008)	(0.0008)	(0.0013)
b_1	0.0089	0.0032	0.0048	-0.0022	0.0050	0.0019	0.0014	0.0010	-0.0002	-0.0002
	(0.0030)**	(0.0019)	(0.0028)	(0.0013)	(0.0017)**	(0.0013)	(0.0011)	(0.0008)	(0.0009)	(0.0015)
b_2	0.0064	-0.0002	0.0005	-0.0007	-0.0005	0.0004	-0.0006	0.0010	0.0011	-0.0014
	(0.0027)*	(0.0017)	(0.0029)	(0.0013)	(0.0017)	(0.0013)	(0.0011)	(0.0007)	(0.0008)	(0.0012)
b_3	0.0021	-0.0006	0.0020	0.0009	-0.0011	0.0010	-0.0001	0.0010	0.0008	-0.0001
	(0.0029)	(0.0019)	(0.0025)	(0.0011)	(0.0013)	(0.0011)	(0.0012)	(0.0008)	(0.0007)	(0.0013)
b_4	-0.0046	-0.0006	-0.0004	-0.0010	-0.0031	0.0021	0.0006	0.0005	0.0003	-0.0004
	(0.0025)	(0.0017)	(0.0026)	(0.0010)	(0.0014)*	(0.0010)*	(0.0011)	(0.0006)	(0.0007)	(0.0009)
Lags of $\Delta\overline{L}$										
c_0	0.0335	-0.2108	-0.1825	-0.3704	-0.6461	-0.4569	-0.4400	-0.5153	-0.4613	-0.0940
	(0.0511)	(0.0640)**	(0.0696)**	(0.0483)**	(0.0888)**	(0.0645)**	(0.0736)**	(0.0603)**	(0.0455)**	(0.0197)**
c_1	0.0302	0.0410	0.0850	-0.0105	-0.2477	-0.2516	-0.1397	-0.2129	-0.2833	-0.0813
	(0.0535)	(0.0651)	(0.0775)	(0.0578)	(0.0723)**	(0.0756)**	(0.0744)	(0.0701)**	(0.0719)**	(0.0163)**
c_2	0.0245	0.0434	0.0976	0.0982	-0.0682	-0.1548	-0.1517	-0.0393	-0.1937	-0.0732
	(0.0615)	(0.0585)	(0.0799)	(0.0652)	(0.0935)	(0.0635)*	(0.0861)	(0.0704)	(0.0576)**	(0.0158)**
c_3	0.0680	-0.0077	0.1319	-0.0446	0.1304	-0.0730	-0.1984	0.0094	-0.0346	-0.0308
	(0.0532)	(0.0580)	(0.0800)	(0.0673)	(0.1070)	(0.0632)	(0.1117)	(0.0665)	(0.0417)	(0.0135)*
c_4	0.0382	0.0617	-0.0641	-0.0055	0.0923	-0.0664	-0.0541	0.0434	0.0341	-0.0052
	(0.0555)	(0.0585)	(0.0814)	(0.0563)	(0.0800)	(0.0487)	(0.0805)	(0.0392)	(0.0291)	(0.0079)
Constant	0.0013	0.0040	0.0095	0.0095	0.0113	0.0161	0.0164	0.0201	0.0288	0.0359
	(0.0003)**	(0.0008)**	(0.0015)**	(0.0022)**	(0.0020)**	(0.0024)**	(0.0063)**	(0.0034)**	(0.0045)**	(0.0089)**
Obs	1030	1030	1030	1030	1030	1030	1030	1030	1030	1000
R-squared	0.64	0.52	0.36	0.46	0.36	0.25	0.33	0.31	0.24	0.18

Robust standard errors in parentheses
* significant at 5%; ** significant at 1%

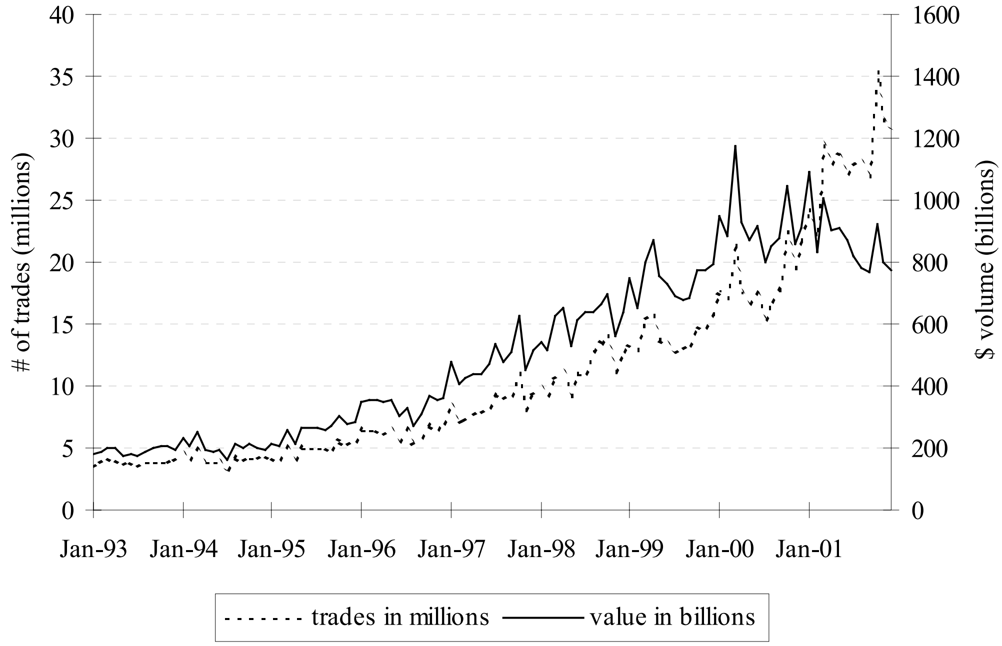

Figure 1. Trading activity on the NYSE. The dotted line graphs the aggregate number of trades for all stocks listed on the NYSE each month from January 1993 to December 2001. The solid line graphs the dollar value of these same trades. Source: NYSE.

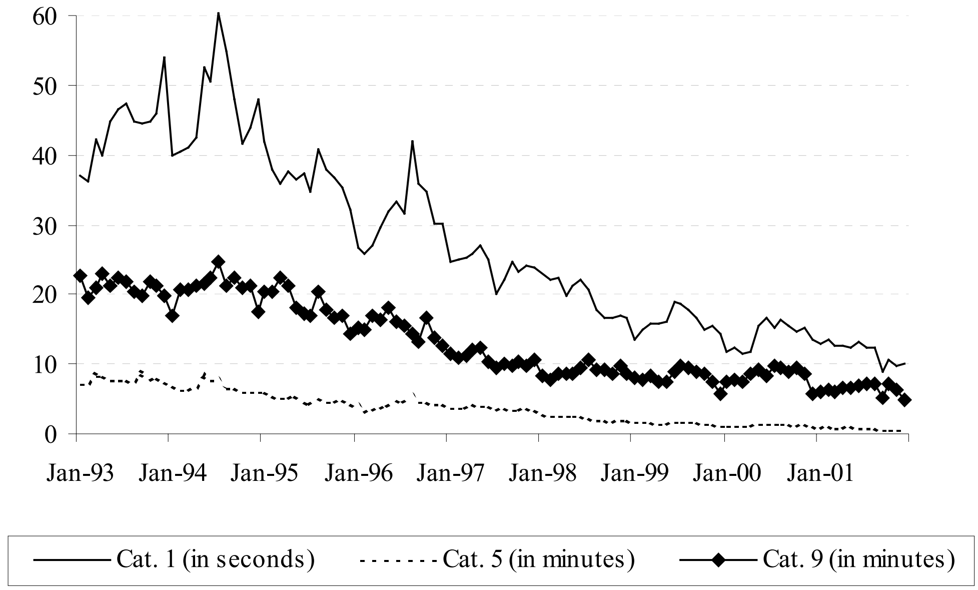

Figure 2. The evolution of trading activity across stocks. Plots the average time between trades for stocks with different levels of average trading activity during each month between January 1993 and December 2001. Firms in each category were based on the 100 firms listed in Table I and were grouped into 10 deciles according to their total number of trades over the 9 year sample period. Stocks in category one were the most actively traded and stocks in category ten were the least actively traded. Source: TAQ.

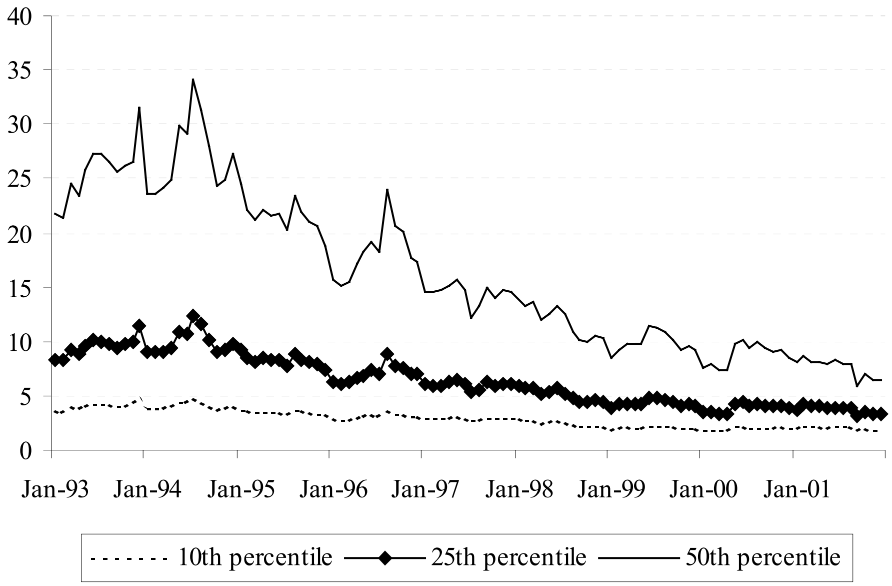

Figure 3. The changing distribution of inter-transaction time for actively traded stocks. Plots the 10th, 25th, and 50th percentile of the distribution of inter-transaction time for stocks in the most actively traded decile of firms listed in Table I each month from January 1993 to December 2001. Source: TAQ.

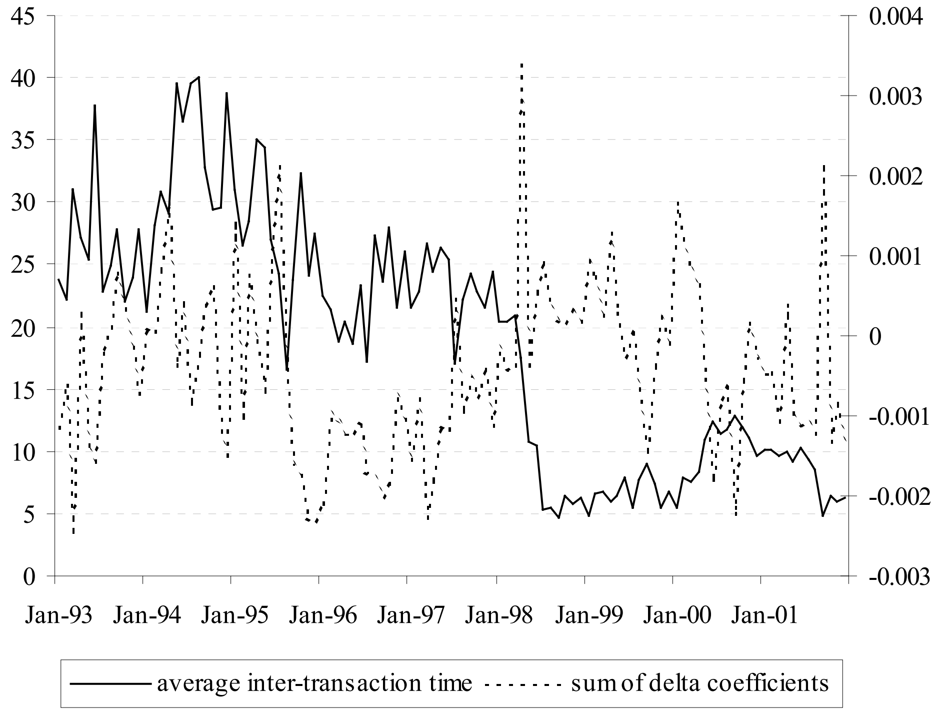

Figure 4. Trade activity and the information content of inter-transaction time for the Disney Company. The solid line plots the average time, in seconds, between trades in stock of the Disney Company, ticker symbol DIS. The dotted line plots the sum of the δ_i^r coefficients from the equation

$$r_t = \sum_{i=1}^{5} a_i r_{t-i} + \lambda_{open}^r D_t x_t^0 + \sum_{i=0}^{5} \left[\gamma_i^r + \delta_i^r \ln(1+T_{t-i})\right] x_{t-i}^0 + \nu_t$$

estimated each month from January 1993 to December 2001 using TAQ data for DIS.

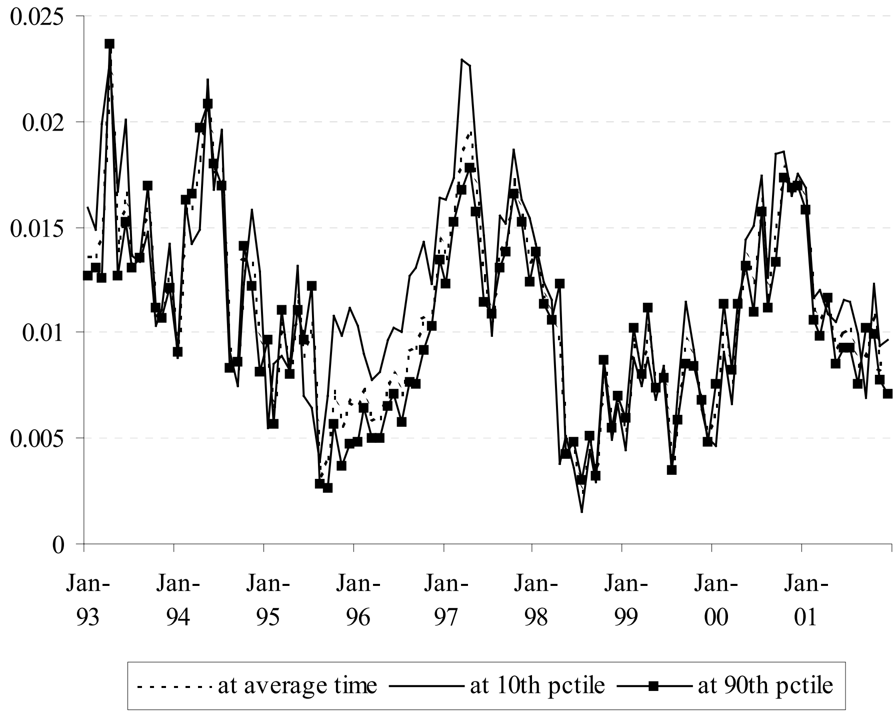

Figure 5. Estimated price impact of trading of stock in the Disney Company at different inter-transaction times. The dotted line plots the sum of the $\gamma_i^r + \delta_i^r \ln(1+T_{t-i})$ coefficients estimated each month from the equation

$$r_t = \sum_{i=1}^{5} a_i r_{t-i} + \lambda_{open}^r D_t x_t^0 + \sum_{i=0}^{5} \left[\gamma_i^r + \delta_i^r \ln(1+T_{t-i})\right] x_{t-i}^0 + \nu_t$$

evaluated at the mean inter-transaction time for that month. The two solid lines plot the same quantity, only evaluated at the 10th and 90th percentile of each month's inter-transaction time distribution.

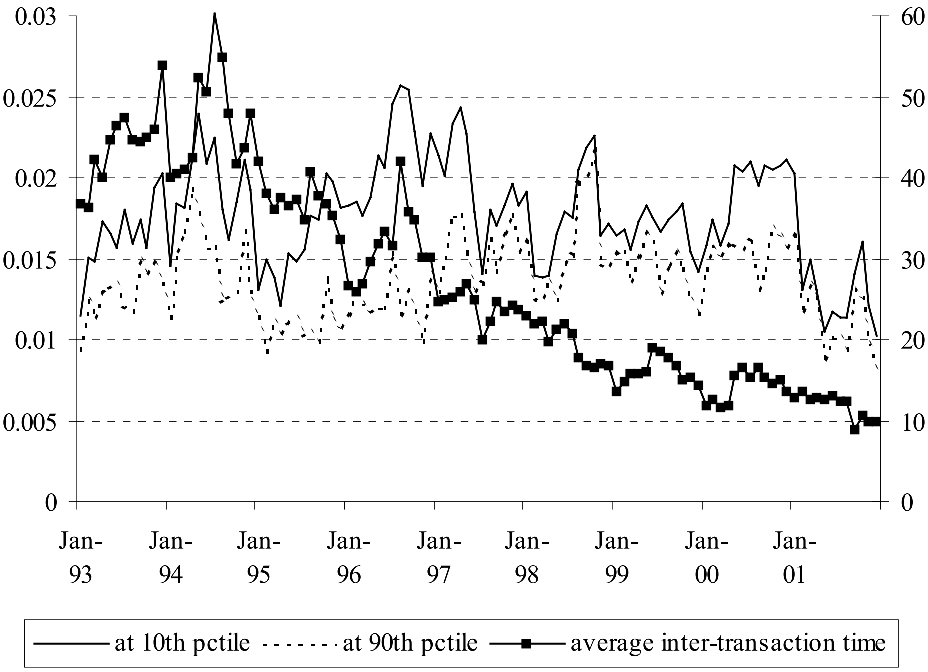

Figure 6. Estimated price impact of trading at different inter-transaction times and average inter-transaction time for actively traded stocks. The dotted line plots the sum of the $\gamma_i^r + \delta_i^r \ln(1+T_{t-i})$ coefficients estimated each month from the equation

$$r_t = \sum_{i=1}^{5} a_i r_{t-i} + \lambda_{open}^r D_t x_t^0 + \sum_{i=0}^{5} \left[\gamma_i^r + \delta_i^r \ln(1+T_{t-i})\right] x_{t-i}^0 + \nu_t$$

evaluated at the 90th percentile of the inter-transaction distribution and then averaged across all stocks in the most heavily traded decile. The solid line is the analogous calculation for the 10th percentile. The boxed line is the average inter-transaction time across all stocks in the most heavily traded decile.

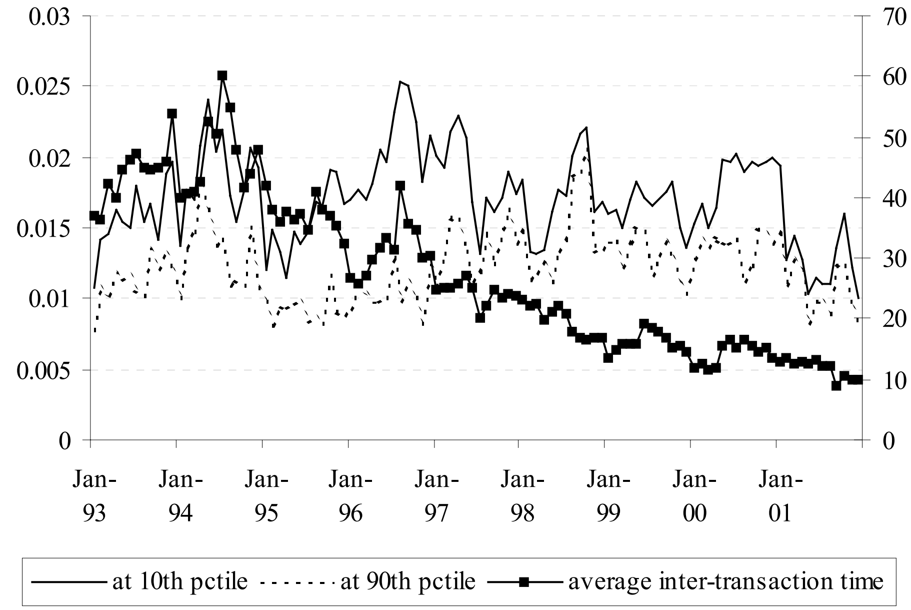

Figure 7. Estimated price impact of trading at different inter-transaction times and average inter-transaction time for actively traded stocks when the trade indicator measures the (log of the) share of market value transacted. The dotted line plots the sum of the $\gamma_i^r + \delta_i^r \ln(1+T_{t-i})$ coefficients estimated each month from the equation

$$r_t = \sum_{i=1}^{5} a_i r_{t-i} + \lambda_{open}^r D_t x_t + \sum_{i=0}^{5} \left[\gamma_i^r + \delta_i^r \ln(1+T_{t-i})\right] x_{t-i} + \nu_t$$

evaluated at the 90[th] percentile of the inter-transaction distribution and then averaged across all stocks in the most heavily traded decile. The solid line is the analogous calculation for the 10[th] percentile. The boxed line is the average inter-transaction time across all stocks in the most heavily traded decile.

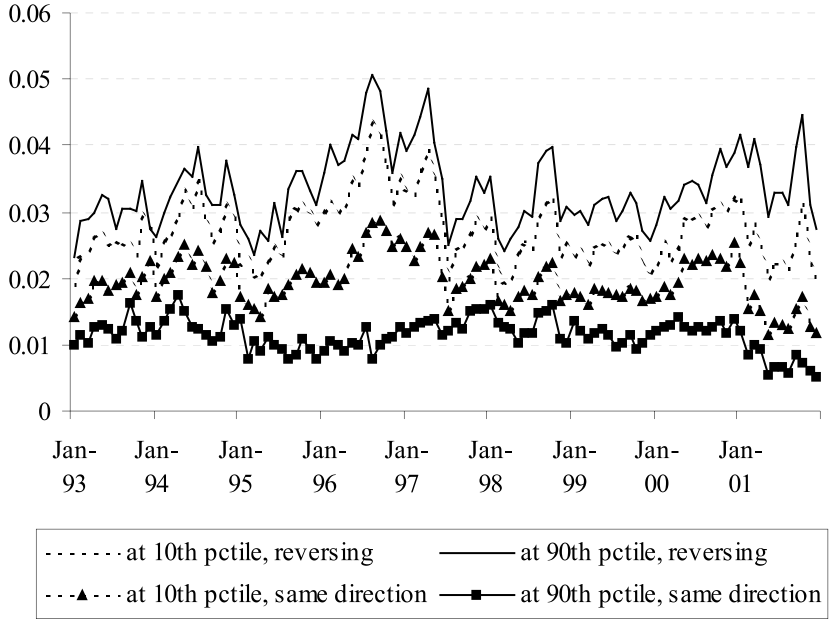

Figure 8. Estimated price impact of trading at different inter-transaction times for actively traded stocks when the specification controls for whether each trade is same-direction or reversing. The dotted line plots the sum of the $\gamma_i^r + \delta_i^r \ln(1+T_{t-i})$ coefficients estimated each month from the equation

$$r_t = \sum_{i=1}^{5} a_i r_{t-i} + \lambda_{open}^r D_t x_t^0 + \sum_{i=0}^{5}\left[\gamma_i^r + \delta_i^r \ln(1+T_{t-i})\right]x_{t-i}^0 + \sum_{i=0}^{5}\left[\gamma_i^{rs} + \delta_i^{rs} \ln(1+T_{t-i})\right]S_{t-i}x_{t-i}^0 + \nu_{1,t}$$

evaluated at the 10th percentile of the inter-transaction distribution and then averaged across all stocks in the most heavily traded decile. The solid line is the analogous calculation for the 90th percentile. The lines with triangles and squares report the analogous values for reversing trades, namely $\gamma_i^r + \delta_i^r \ln(1+T_{t-i}) + \gamma_i^{rs} + \delta_i^{rs} \ln(1+T_{t-i})$ evaluated at the 10th and 90th percentile of inter-transaction time for same-direction trades.

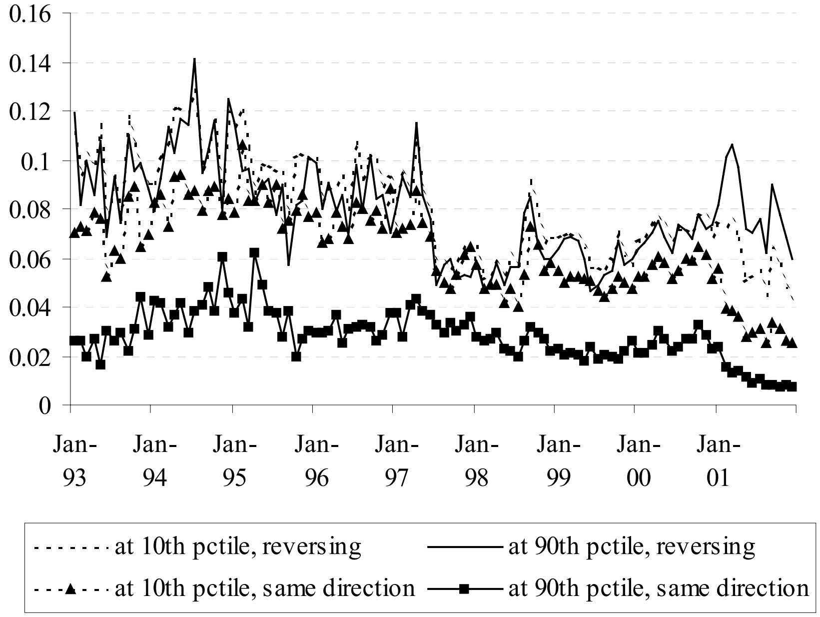

Figure 9. Estimated price impact of trading at different inter-transaction times for stocks in the fifth decile of trading activity when the specification controls for whether each trade is same-direction or reversing. The dotted line plots the sum of the $\gamma_i^r + \delta_i^r \ln(1+T_{t-i})$ coefficients estimated each month from the equation

$$r_t = \sum_{i=1}^{5} a_i r_{t-i} + \lambda_{open}^r D_t x_t^0 + \sum_{i=0}^{5} \left[\gamma_i^r + \delta_i^r \ln(1+T_{t-i})\right] x_{t-i}^0 + \sum_{i=0}^{5} \left[\gamma_i^{rs} + \delta_i^{rs} \ln(1+T_{t-i})\right] S_{t-i} x_{t-i}^0 + \nu_{1,t}$$

evaluated at the 10th percentile of the inter-transaction distribution and then averaged across all stocks in the fifth decile of trading activity. The solid line is the analogous calculation for the 90th percentile. The lines with triangles and squares report the analogous values for reversing trades, namely $\gamma_i^r + \delta_i^r \ln(1+T_{t-i}) + \gamma_i^{rs} + \delta_i^{rs} \ln(1+T_{t-i})$ evaluated at the 10th and 90th percentile of inter-transaction time for same-direction trades.

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