Testing the Market Power of NYSE Specialists and the Role of Intraday Information Costs

James P. Weston[1]
Department of Economics, University of Virginia
114 Rouss Hall, Charlottesville, VA, 22903
(804) 924-1358, jpw9t@virginia.edu

This version: November 1999

[1]We would like to thank Tim Bollerslev, T. Wake Epps, George Alayannis, Roger Huang, Yong Joe, and Larry Kochard for useful suggestions. We also thank seminar participants at University of Virginia.

Testing the Market Power of the NYSE Specialist and the Role of Intraday Information Costs

Abstract

This paper examines the exercise of market power by the New York Stock Exchange Specialist. Notably large quoted bid-ask spreads near the opening and close of the market have been interpreted by some researchers as the exercise of monopoly power by the specialist who is able to price discriminate during hours of peak demand. We test the hypothesis that this intraday variation in bid-ask spreads arises from the monopoly position of the specialist. To accomplish this we decompose the bid-ask spread into information costs, order-processing costs, and market maker rents. Unlike previous research in this area, we present an extension of the Glosten and Harris (1988) trade indicator model that allows for periodic time variation in the components of the spread. Using data for 20 large volume NYSE-listed stocks, we find that the reverse-J pattern in intraday quoted spreads arises mostly from information costs. On average, we find that 73 percent of the increase in spreads during the first hour of trading can be explained by changing information costs. We reject the hypothesis that large spreads in the morning are due to monopoly pricing. Our findings support existing information-based models of specialist behavior.

1 Introduction

This paper examines whether the system of trading on the New York Stock Exchange (NYSE) enables intermediaries to earn monopoly profits. On the NYSE, all transactions for a given stock are cleared through a single financial intermediary - the specialist. The price that the specialist charges for clearing trades is determined by the wedge driven between the buying and selling price of an asset. This spread between bid and ask prices enables the market maker to buy low and sell high, offering a relatively low price (the *bid*) to buy from investors and charging a relatively high price (the *ask*) to sell. We investigate whether the monopoly position of the specialist results in price discrimination leading to large transactions costs during periods of peak demand.

The composition and behavior of these transaction costs has important implications for both efficient markets and public policy. The assertion of implicit collusion on the Nasdaq by Christie and Schultz (1994) and the evidence of unusually large Nasdaq spreads, relative to other trading systems, have shown that the organization of an exchange mechanism can have a serious impact on its economic performance.[1] If the NYSE specialist is able to exercise market power and maintain supra-competitive spreads this could lead to serious inefficiencies. On a market that trades a total dollar volume of over $30 billion per day, even the smallest market frictions could impose enormous costs.[2]

Evidence supporting the assertion of imperfect competition on the NYSE has been previously documented. McInish and Wood (1992) find that quoted bid-ask spreads on the NYSE follow a reverse-J pattern over the day, with large spreads at the market open declining throughout the day, and then rising slightly towards the close of trading. Brock and Kleidon (1992) argue that this intra-day shape in spreads is the result of a price-discriminating monopolist (the specialist) who charges large spreads in the face of high-inelastic demand for trading near the market open and close.

While this market power story is plausible, there may be other explanations for the intra-

[1] For example, Huang and Stoll (1996) and Bessembinder and Kaufman (1997) find that trading costs for the NASDAQ are considerably larger than on the NYSE. Similarly, Barclay (1997) and Barclay et al. (1998) find that firms realize a decrease in spreads when they switch exchange listing from the Nasdaq to the NYSE.

[2] Figure obtained from the NYSE website at http://www.nyse.com/public/invprot/5d/5dix.htm

day shape in spreads. Information-based models, e.g. Glosten and Milgrom (1985), suggest that the specialist faces a cost when trading with investors who have superior information; this cost is embedded in the specialist's spread. Further, Admati and Pfliederer (1988) and Foster and Viswanathan (1996) suggest that these informed agents may strategically time their trades near the open and close of the market. That is, in the presence of more informed traders, the specialist may widen the spread in the absence of any market power. In addition, recent empirical evidence by Nyholm (1998) and Madhavan, Richardson, and Roomans (1997) shows that informed trading may be highest near the market open. Thus, according to these information-based models, the bid-ask spread may follow a reverse-J pattern without the exercise of any market power.

In this paper, we test the hypothesis that large spreads on the NYSE near the market open and close arise from the exercise of monopoly power. In order to capture intraday variations, we extend the trade indicator model of Glosten and Harris (1988) to allow the information component of the spread to be estimated as a continuous function of the time of day. To accomplish this, we decompose the bid-ask spread into information, order-processing costs and economic profits. While previous research has uncovered some evidence that the components of the spread may vary throughout the day, no comprehensive study exists for explaining the temporal variation in the components of the spread.[3]

Our results show that information costs peak at the market open (for all 20 stocks in our sample), decline sharply during the first few hours of trading and then remain relatively flat over the day. We interpret these results as consistent with information-based models of specialist behavior and inconsistent with the exercise of market power. Specifically, we find that 73 percent of the increase in quoted spreads during the first 90 minutes of trading can be explained by increased information costs. Using an alternative measure of trading costs, the effective spread, we find that, after accounting for information effects, spreads are actually lowest near the market open. Our results support the theoretical findings of Admati and Pfliederer (1988) and Foster and Viswanathan (1996).

The remainder of the paper is organized as follows. Section 2 provides a brief discussion

[3] Madhavan, Richardson, and Roomans (1997) find that information costs decline over five sub-intervals of the day. Lin, Sanger, and Booth (1995) show that information costs increase with trade size, which varies over the day. Wei (1992) finds a roughly U-shaped pattern in information costs over six sub-intervals of the day.

of the components of the bid-ask spread. Section 3 describes our data and sample selection. Section 4 develops our empirical methodology and estimation technique. Section 5 presents the results of the intraday components of the spread. Section 6 investigates possible explanations for the intraday components of the spread. Section 7 concludes.

2 Previous Research

According to microstructure theory, the spread is typically decomposed into three components: order-processing costs, inventory holding costs, and adverse information costs.[4] In addition to these three real costs, we include here an additional component of the spread - market maker rents.

Order-processing costs arise from the simple fact that the market maker incurs a cost in clearing trades. This was the component first studied by Demsetz (1968) in his estimation of the transaction cost of exchange. order-processing costs include the fixed cost of holding a seat on the exchange, paperwork and administrative costs.

Inventory-holding costs stem from the market maker's personal position in the stock. To clear trades smoothly, the dealer generally holds a positive inventory of shares in his portfolio. Thus, part of the spread stems from the excess return that the market maker must earn to be compensated for holding a non-diversified portfolio. To prevent this inventory from becoming unbalanced, the specialist may adjust the spread to induce orders at the bid or ask side, in order to return his market position to equilibrium.

Adverse information costs have been the most frequently studied component of the spread. In theory, market makers face trades with two stylized types of agents - informed traders and liquidity traders (Kyle 1985). Informed traders have information about the true value of the security that the market maker does not. Liquidity traders, on the other hand, do not execute trades based on any private information. As their name reveals, they buy and sell purely for liquidity purposes. When the market maker trades with informed traders, he faces an adverse selection problem: better informed investors buy when the market maker sets the ask price too low and sell when the bid price is set too high. Faced with this adverse

[4]See O'Hara (1995) for a survey on the components of the spread.

selection cost from informed traders, the market maker will widen the spread (relative to the spread in the absence of informed traders) to mitigate losses. By widening the spread, the market maker gains profits from trading with liquidity traders, offsetting the losses to informed traders.

Market maker rents. Since Bagehot's (1971) argument that the NYSE specialists' position as the "only game in town" may enable them to earn economic profits, the issue of imperfect competition in market making has been a heated debate. Lending support to the existence of rents, Brock and Kleidon (1992) argue that large spreads near the open and close of trading may reflect the NYSE specialists' ability to peak-load price during periods of high-inelastic demand for trading. Additionally, McInish and Wood (1995) find that the bid-ask spread for a sample of NYSE issues is negatively related to competition from regional exchanges. They argue that without this competition for order flow, the specialist may quote larger spreads.

Empirical evidence on the magnitude of these components varies. Stoll (1989) finds that 43 percent of the quoted spread arises from information costs while only 10 percent can be attributed to inventory costs. Similarly, Affleck, *et al.* (1994) find that almost 50 percent of the quoted spread stems from information costs. Lin, Sanger, and Booth (1995) find that the information component of the spread varies from 20 percent to 60 percent and is directly related to trade size (that is, larger trades impose larger information costs). Finally, George, Kaul, and Nimalendran (1991) and Huang and Stoll (1997) attribute only 10-20 percent of the spread to information costs. Nevertheless, all of these studies find that information costs are a significant portion of the spread.

The empirical importance of inventory costs also varies greatly from 20 percent (reported by Huang and Stoll (1997)) to zero percent (see George, Kaul, and Nimalendran (1991)). In fact, in many theoretical models, inventory costs are assumed to be zero.[5] Recent empirical evidence by Madhavan and Sofianos (1998) shows that specialists most often balance their inventory by strategically timing their trades, rather than adjusting their quotes to induce orders at the bid or ask, suggesting that inventory costs (at least as they are embedded in the spread) may be close to zero.

The remaining components of the spread (order-processing costs and market maker rents)

[5] See, for example, George, Kaul, and Nimalendran (1991).

are typically estimated as the residual part of the spread not explained by information or inventory costs. As such, estimates of these components vary from 40 percent to 90 percent. While it is difficult to separate these two effects, Weston (1999) finds evidence that marker maker rents constituted a significant portion of the bid-ask spreads for a sample of Nasdaq stocks prior to recent market reforms.

Aside from the level of these components, there is some evidence of intraday variation in the components of the spread. Lin, Sanger, and Booth (1995) and Haung and Stoll (1997) find that information costs increase with trade size. Since larger trade sizes occur more frequently around the market open and close (see Figure 3), it may be the case that information costs increase during these times. Additionally, Wei (1992) and Madhavan, Richardson, and Roomans (1997) both allow for intraday variation in these components by estimating the components over sub-intervals of the day. Wei finds some evidence of a U-shaped pattern in information costs over the day while Madhavan *et al.* find that information costs decline throughout the day.

In this study we explicitly model the components of the spread using the trade indicator model developed by Glosten and Harris (1988) and Huang and Stoll (1997). To allow for periodic time variation in the components of the spread, we decompose the spread using the flexible Fourier form, proposed by Gallant (1980) and used recently by Andersen and Bollerslev (1998a, b). Decomposing the spread as a continuous function of the time of day allows us to directly test whether, or to what extent, the time variation in quoted spreads can be explained by the time variation in the components of the spread. While we provide the first comprehensive study of the time variation in the components of the spread, our results have a broader interpretation. We find that the time variation in the components of the spread help address the possible exercise of monopoly power by the NYSE specialist.

3 Data / Sample Description

We collect data from the TAQ database provided by the New York Stock Exchange for all trading days in 1996. From all NYSE-listed common stocks in 1996, we select the 20 largest issues by trading volume that traded every day the market was open in 1996. Additionally, we require that the stocks have no splits over the sample period.

For each issue, we select only those trades which clear on the primary exchange (NYSE) for that stock. All regular way trades are collected for each day. We then filter the data for errors using the following methodology:

1. Exclude quotes and prices if they are not in multiples of 1/16th.
2. Exclude observations where the bid-ask spread if greater than $4 or less than $0.
3. Exclude observations when the price, ask, or bid return is greater than 10 percent.
4. Exclude all quotes with a quoted depth of zero.

In addition, we exclude the first trade on each day since these trades result from a batch auction. These filters eliminate less than three percent of our sample.

Trades are then matched to the relevant quotes using a 16-second delay as suggested by Blume and Goldstein (1998). That is, for each trade, we take the most recent bid and ask quote that was posted at least 16 seconds before the trade was executed. This procedure accounts for the fact that quotes and trades are recorded on separate systems and may be systematically non-synchronous (Lee and Ready (1991)). To the extent that trades take longer than 16 seconds to be reported, we introduce measurement error into estimates that rely on both trade prices and quotes (e.g., effective spreads and our trade indicator variables). Lee and Ready suggest using a five second delay to correct for the different reporting times. While the five-second rule is the most commonly used, Hasbrouck (1993) reports a median delay of 14 seconds. If the delay is too long however, then we could err on the side of matching trades to stale quotes. Nevertheless, these concerns are partially mitigated by the fact that averages are computed over large numbers of transactions for all stocks, and there is no reason to predict any systematic bias using the 16-second algorithm.

3.1 Summary statistics

Table 1 presents summary statistics for our sample of 20 stocks. Average prices are all above $9 per share and below $118. There is considerable variation in the trading activity of these stocks (even though the largest volume stocks were explicitly chosen). Average daily trading volume varies from a low of 900,000 shares per day for Proctor and Gamble (PG) to a high of 4.2 million shares for Micron Technology (MU). The sample represents a wide cross section of industries from volatile stocks in the high-tech sector (e.g. Micron Technology has the largest return volatility) to much less volatile energy stocks (e.g. Exxon [XON] with the lowest return volatility). Finally, all stocks exhibit considerable price variation over the 254 trading days in 1996, as shown by the price range for each stock over the sample period. On average, there are 689 trades per day or about 175,000 observations per stock over the sample period.

3.2 Intraday patterns in trading costs

Figure 1 shows the intraday pattern in average trading costs across the 20 stocks. To estimate the time variation in spreads, we break the trading day into 78 5-minute intervals. Average quoted spreads are constructed as the average $ask-bid$ over all trades for each stock in each 5-minute period. These figures are then averaged over the 20 stocks. Figure 1 clearly shows the well-documented reverse-J shape in quoted spreads over the day. On average, spreads are largest at the open and decline sharply before noon, rising only slightly towards the close of trading. In addition to quoted spreads, Figure 1 also shows the intraday pattern in effective spreads. Effective spreads are a measure of transaction costs that account for the fact that some trades may be executed inside of the specialist's posted spread. The time t effective spread is defined as twice the absolute difference between the time t transaction price, P_t, and the time t midpoint of the quoted spread M_t :

$$Effective\ Spread_t = 2 * |price_t - M_t| \tag{1}$$

The effective spread may more accurately reflect the cost of trading to institutional investors since larger trades are more likely to be executed inside the quoted spread. Figure 1 shows that the effective spread is relatively flat over the day at 11 cents per trade (or roughly $\frac{1}{8}$).

Table 2 provides a breakdown of the intraday pattern in spreads for each of the 20 stocks. We break the day in to three intervals 9:30 a.m.-11:00 a.m., 11:00 a.m.-2:30 p.m., and 2:30 p.m. -4:00 p.m. For all 20 stocks, quoted spreads are larger during the first 90 minutes of trading than at any other time of the day. Additionally, for all 20 stocks, quoted spreads during the last 90 minutes of trading are never smaller than quoted spreads during the mid-day period. However, these patterns are not true for effective spreads. On average, effective spreads are no different during the first 90 minutes of trading than during the mid-day period. Average effective spreads rise only slightly towards the close.

4 Model Specification / Estimation

In order to test whether the intraday pattern in spreads arises from information costs or monopoly pricing we estimate the components of the spread using the empirical model of Huang and Stoll (1997), which is a generalization of Glosten and Harris' (1988) trade indicator model. They derive a simple model that allows a one-step decomposition of the information component as a percentage of the spread. The remaining spread stems from order-processing costs and market maker rents.

The model identifies these components by measuring how the midpoint of the spread, M_t, changes as a function of the direction of the last trade. As in Huang and Stoll (1997), we define an indicator variable, Q_t , which takes on the values $\{-1, 0, 1\}$ based on the direction of the last trade. That is, define P_t as the transaction price at time t and S_t as the time t quoted spread. Q_t is then defined as: $Q_t = -1$ if $P_t < M_t$ (indicates a sell order) ; $Q_t = 0$ if $P_t = Q_t$; $Q_t = 1$ if $P_t > M_t$ (indicates a buy order). ε_t represents the random (iid) public information shock at time t. The regression equation is then specified by:

$$\Delta M_t = (\alpha)\frac{S_{t-1}}{2}Q_{t-1} + \varepsilon_t \tag{2}$$

where α measures the proportion of the time t half spread , S_t, that stems from information costs. The remaining proportion of the spread (1-α) is due to order-processing costs and market maker rents. This specification is slightly different from Huang and Stoll (1997), who assume inventory costs are also captured by α. We assume that inventory costs, as a proportion of the spread, are equal to zero. However, to the extent that inventory costs do exist, they will be captured in our estimate of α. The purpose of our study is to focus on the part of the spread that *cannot* be explained by information and inventory costs, i.e., specialist rents. To this end, our results do not rely on the assumption of zero inventory costs since these would also be captured by α. Moreover, as noted above, recent empirical evidence suggests that inventory costs are likely to be close to zero.[6]

In addition, we do not directly observe order-processing costs or market maker rents. These components are also jointly estimated as the residual of the spread , $(1-\alpha)$. This proportion of the spread therefore includes the specialists' economic profits as well as the cost of administering, clearing, and recording trades. To the extent that the market maker is able to widen spreads beyond these processing costs, this portion of the spread is a measure of the specialists' market power.

To understand the intuition behind this model, consider the limiting cases. If $\alpha = 0$ then previous trades provide no information. As a result, there should be no reason for the midpoint of the spread to change. In this case, orders simply bounce between a fixed bid and ask as the true value of the security follows a martingale sequence. On the other hand, if a = 1, then the last trade signals to the dealer that the trade was fully informative. As a result, the market maker moves the midpoint of the spread to the last transaction price. That is, the dealer moves the spread to straddle the last bid (following a sell order) or ask (following a buy order). For value of α between zero and one, the amount by which the dealer moves the midpoint of the spread in reaction to the last trade measures the amount of the spread attributable to this component.

To allow for time variation in the components of the spread, we modify equation (2) to model the information parameter, α, as a continuous function of the time of the day where the day is chopped into $N = 78$ five-minute intervals. We let $\Delta M_{t,n}$ represent a time t change in the midpoint of the spread that occurs in period n. Using this notation for S and Q as well, we can re-write equation (2) as:

$$\Delta M_{t,n} = \widetilde{\alpha}_n \left[\frac{S_{t-1,n}}{2} Q_{t-1,n} \right] + \varepsilon_t$$

In order to allow flexible time variation we parameterize $\widetilde{\alpha}_n$ using the flexible Fourier form of Gallant (1980) and Andersen and Bollerslev (1997a, 1997b) :

$$\widetilde{\alpha}_n = f(\theta, n) = \theta_0 + \theta_1 \frac{n}{N_1} + \theta_2 \frac{n^2}{N_2} + \left[\sum_{j=1}^{J} \theta_{1,j} \cos\left(\frac{2\pi n j}{N}\right) + \theta_{2,j} \sin\left(\frac{2\pi n j}{N}\right) \right] \quad (3)$$

Where $N_1 = (N+1)/2$ and $N_2 = (N+1)(N+2)/6$ are normalizing constants added for numerical stability. J is equal to the number of sine/cosine parameters included in the

[6] See Madhavan and Sofianos (1998).

regression. The specification in (3) yields the regression equation given by:

$$\Delta M_{t,n} = \left[\theta_0 + \theta_1 \frac{n}{N_1} + \theta_2 \frac{n^2}{N_2} + \sum_{j=1}^{J} \theta_{1,j} \cos\left(\frac{2\pi nj}{N}\right) + \theta_{2,j} \sin\left(\frac{2\pi nj}{N}\right)\right] \left[\frac{S_{t-1,n}}{2} Q_{t-1,n}\right] + \varepsilon_t \tag{4}$$

Equation (4) specifies the intraday variation of the information component of the spread using a very flexible linear-semi-parametric form. The information component of the spread in period n, α_n, depends on the period, n , and our estimates of θ, where θ is a $(3 + 2J)$ by 1 vector of parameters. Rather than including an arbitrary number of time-of-day dummy variables, this technique allows virtually any periodic shape of the parameter α_n with only $3 + 2J$ parameters to estimate.[7]

The parameters of equation (4) are estimated for each stock using generalized method of moments (GMM). GMM is appropriate since it allows for very limited distributional assumptions and for the presence of serial correlation and conditional heteroscedasticity of an unknown form. Since the model specifies a linear relationship, we impose the OLS normal equations as our only orthogonality conditions. That is, we exactly identify the parameter vector, θ. This implies that our estimates are identical to those obtained from OLS, but with robust standard errors. The covariance matrix of our parameters are estimated using the Newey-West procedure. Rather than impose an arbitrary restriction on J (the number of sine/cosine parameters), we allow J to vary for each stock. We estimate the model for all choices of J between zero and five. We then choose J using the specification that maximizes the Schwartz information criteria.

In order to obtain our estimates of α_n, we use the estimated parameters from equation

[7] The model presented above assumes that the serial correlation in order flow is zero. However, a number of studies (e.g. Lin, Sanger, and Booth (1995)) have uncovered that, conditionally, buy trades are more likely to be followed by buy trades, sells more likely to follow sells. One explanation for this is that large orders are often broken up into many small orders. As a result, the direction of the order flow is, to some extent, predictable. Huang and Stoll (1996) and Madhavan, Richardson, and Roomans (1997) account for this by augmenting the trade indicator models to allow the information component to depend only on innovations in order flow that are not expected. Huang and Stoll (1996) suggest the regression equation specified as:

$$\Delta M_t = (\alpha) \frac{S_{t-1}}{2} Q_{t-1} - \alpha(1 - 2\pi) \frac{S_{t-2}}{2} Q_{t-2} + \varepsilon_t \; ; \; \pi = Cov(Q_t, Q_{t-1}) \tag{5}$$

However, Madhavan, Richardson, and Roomans (1997) provide evidence that the serial correlation in order flow does not vary at the intraday level. As a result, there is no reason to expect persistence in order flow to affect the intraday shape of information costs. We have chosen, for simplicity, to present the model and report results without serial correlation in order flow. Including persistence in order flow does not qualitatively change our results.

(4) in equation (3). Standard errors for our estimate of α_n are then constructed via the delta method.

5 Intraday Components of the Spread

Figure 2 presents the results of our GMM estimation of the intraday information component of the spread,α_n, for both Eli Lilly (LLY) and the average over all 20 stocks along with 95 percent pointwise confidence bands (LLY is randomly chosen as a representative firm). We see that, for both LLY and the average, α_n, is largest at the market open, declines sharply over the first two hours of trading and then remains relatively constant. Additionally, the 95 percent pointwise confidence bands show a high level of certainty in the shape of α_n. Figure 2b presents the estimates of α_n for all 20 stocks. All estimates of α_n are statistically significant at the five percent level. The shape of the information component of the spread is roughly similar over most of the stocks. 16 out of the 20 stocks exhibit the same general shape of large information costs declining throughout the morning and remaining roughly constant over the remainder of the day. In four stocks (PG, MO, PFE, & PPG) there is very little variation in the information component of the spread. However, even for these four stocks, we can still reject the hypothesis that the information cost is constant over the day. On average, we estimate the information component to be roughly 25 percent of the spread at the market open. This figure then declines to 15 percent by 11:30 a.m. and remains relatively constant over the rest of the trading day.

Table 3 provides a breakdown of our estimate of α_n for all 20 stocks. For presentation, we present the average of α_n over three sub-intervals of the day as in Table 2. Estimates of α for each of the three intervals are constructed by averaging α_n over the five-minute periods in each interval. Comparing columns 1 and 2 of Table 3 we find that the information cost as a percentage of the spreads is larger during the first 90 minutes of trading (9:30 a.m.-11:00 a.m.) than during the mid-day period (11:30 a.m.-2:00 p.m.) for all 20 stocks (differences are reported in column 4). Further, all differences are significant at the one percent level. On average, information costs are 4.6 percentage points higher during the morning than during the mid-day period. These differences vary from only one percentage point for Phillip Morris (MO) to 11.6 percentage points for Digital Equipment (DEC).

The difference in the information components between the mid-day and last 90 minutes of trading are summarized in Column 5 of Table 3. We find very little evidence of any systematic variation in the information components of the spread between the mid-day period and the last 90 minutes of trading. There is a very small increase in α_n for nine stocks and a small decrease for the remaining 11. On average, there is no change in α towards the market close. Overall, these results are consistent with Madhavan, Richardson and Roomans (1997) who find a decline in information costs over five sub-intervals of the day.

Order-processing costs and market maker rents are captured as the residual portion of the spread not explained by information effects. That is, the percentage of the spread attributable to order costs and rents is $(1-\alpha)$. If large spreads in the morning are due to the exercise of specialist market power, then we should expect to see larger values of these components during these times. Figures 2 and 2b as well as Tables 2 and 3 imply an inverse intraday pattern in these components of the spread. We find that processing costs and rents are lowest at the open of trading and increase until roughly 11:30 a.m. for most stocks and are then constant over the remainder of the day. These results are inconsistent with the market power hypothesis. However, these results only present the components of the spread in percentage terms. Since the spread is also changing over the day, we next construct how the actual dollar cost of these components varies over the day.

5.1 Dollar Value of the Components

The results presented above reflect the intraday changes in the information components of the spread as a percentage of the spread. However, these figures do not represent the actual cost to investors of these components. It may be the case that, even though the information components of the spread explain a portion of the intraday pattern in spreads, they may not explain all of it. That is, to the extent that the specialist does exploit market power during high-volume periods, then the specialist may be able to increase spreads even above these larger information costs. In order to test this hypothesis, we examine the intraday shape of the spread less the portion of the spread stemming from these real costs. To accomplish this, we construct the dollar value of the components of the spread. To construct the dollar costs of these components, we multiply the intraday estimate of the component for period n, α_n, by the period n spread. That is, defining $\$I_n$ as the period n dollar value of information costs and S_n as the period n spread we have:

$$\$I_n = \alpha_n S_n \tag{6}$$

Similarly, taking $\$OR$ to be the dollar value of order-processing costs and market maker rent we have that

$$\$OR = (1 - \alpha_n) S_n \tag{7}$$

This statistic, $\$OR$, reflects the proportion of the spread not due to information costs. This information-adjusted measure of trading costs reflects both the order-processing costs and any specialist rents.

Figures 3 and 4 present the estimates of the intraday patterns in the dollar value of the components of the spread. Figure 3 shows that, for both LLY and the average over all 20 stocks, the dollar value of information costs has the intraday shape that we expect with costs peaking at the market open, declining sharply over the morning hours and remaining flat over the day. This must clearly be the case since both the level of the spread and the percentage of the spread due to this component are largest at the market open.

Figure 4 presents the intraday shape of the dollar value of the order-processing/specialist rent components of the spread. These figures represent the actual transaction costs to investors *less* information costs. If all of the intraday shape in the bid-ask spread can be explained by changes in information costs, then we should expect to see the dollar value of the order-processing/specialist rent components ($\$OR$) to be a flat line over the day. For both our representative firm and the average over all 20 firms, the intraday shape of $\$OR$ is indeed relatively flat over the day. However, while the intraday shape in $\$OR$ has considerably less intraday variation than the intraday pattern in spreads, there still exists a slight U-shaped pattern. Nevertheless, these results suggest that most of the intraday variation in the quoted spread arises from intraday variation in information costs rather than from the exercise of monopoly power.

Table 4 provides a breakdown of the dollar value of the components by firm. Again, for presentation purposes we present the average of these costs over two sub-intervals of the day: 9:30 a.m.-11:00 a.m. and 11:00 a.m.-2:30 p.m.[8] Columns 1-3 compare the average quoted

[8]Results comparing the mid-day period to the last 90 minutes of trading, again, show no real difference. These results are available upon request.

spread during the first 90 minutes of trading with spreads during the mid-day period. As shown in Table 2, quoted spreads are consistently larger during early trading. Columns 4-6 of Table 4 present the dollar value of the order-processing/specialist rent costs of the spread or the information-adjusted spread. Column 6 of Table 4 presents the difference between morning and mid-day quoted spreads *less* information costs. First, we find that for three stocks (CPQ, DEC & XON) information-adjusted spreads are actually lower in the morning than during the mid-day period. For four of the other stocks (FNM, KM, LLY, & USW) we cannot reject the hypothesis that information-adjusted spreads during the first 90 minutes of trading are equal to those during the mid-day period. The magnitude of the difference in spreads for the remaining 13 stocks, while still greater than zero, has significantly declined compared to the difference in the unadjusted quoted spreads (reported in column 3).

Comparing Columns 3 and 6 of Table 4, we find that the difference in quoted spreads between the morning and mid-day trading periods declines significantly after adjusting the quoted spread for information effects. Column 7 of Table 3 records the percentage decline in this morning spread premium. That is, we take the percentage decline in the difference between spreads in the morning and mid-day periods after adjusting the spreads for information effects. We see clearly that the magnitude of the morning spread premium declines for all 20 stocks after accounting for intraday changes in information costs. On average, the difference between morning and mid-day spreads declines by 72.6 percent after accounting for information costs. We interpret this as strong evidence that most of the intraday pattern in spreads is the result of changing information asymmetry over the day, rather than price discrimination or monopoly power.

5.2 Effective Spreads

While the quoted spread reflects the cost of transacting at the specialist's quoted bid or ask price, many trades are actually executed inside of the quoted spread. Thus, the actual cost to investors may be more accurately measured by the effective spread, which accounts for trading within the specialists' quotes. The effective spreads is measured as $2 * |price_t - midpoint\ of\ quoted\ spread_t|$. On average 20 percent of all trades are executed within the quoted spread for our sample of stocks (not reported).

Figure 5 presents the intraday variation in the proportion of trades executed inside the specialists quoted bid-ask spread. Trades executed inside of the quoted spread are identified as any trade where the transaction price is less than the quoted ask and greater than the quoted bid. Proportions of all inside trades are calculated for each stock for 78 5-minute intervals over the trading day. Averages are then computed as the equally weighted mean over the 20 stocks for each interval. Figure 5 clearly shows a pattern very similar to the quoted spread. Inside trades occur most frequently in the first 90 minutes of trading, decline through the morning and then remain relatively flat over the trading day.

These results suggest that for more than 20 percent of all trades, investors do not face the entire quoted spread but only the effective spread. Therefore, since the effective spread is flat over the day (see Figure 1) we interpret this as evidence against the exercise of market power by the specialist, at least for all trades executed inside the quoted spread.

Figure 5 presents the dollar value of order-processing costs and specialist rents in terms of the effective spread for both our representative firm and for the average over all 20 stocks. To compute these costs, we construct information-adjusted effective spreads in the same manner as the information-adjusted quoted spreads. We see that the dollar value of these costs are actually lowest during the morning hours. For both LLY and the average, processing costs and specialist rents rise slightly in the morning, remain flat over most of the day, and rise slightly again towards the close.

Table 5 presents the dollar cost of the components of the spread based on the effective, rather than the quoted, bid-ask spread for all 20 stocks. Our results strongly support information-based models of specialist behavior. We find that information-adjusted effective spreads are lowest in the early hours of trading and increase over the first 90 minutes of trading and then remain relatively flat over the day. These results are, again, inconsistent with the market power hypothesis since we find that this measure of trading costs is actually lowest during hours of peak demand.

6 Explanations of the Intraday Shape in the Spread Components

The evidence presented in Section 5 suggests that most of the intraday shape in quoted and effective spreads results from changes in information costs. In this section we examine possible explanations for this finding. We consider the role of price discovery, informed trading and competition for order flow.

6.1 Price Discovery

Large information costs at the open of trading arise from greater information asymmetry about fundamental values during these times. Recall that the information cost parameter, α_n, measures the extent to which the specialist reacts to order flow as an information signal. The sharp decline in α_n during the morning hours may therefore imply that the specialist becomes less dependent on order flow to infer information. In this context, the large value of α_n during the morning hours for most stocks may not necessarily imply that there are more informed trades necessarily, but rather that spreads decline as the market maker becomes more certain about the fundamental value of the stock. Madhavan, Richardson, and Roomans (1997) also argue that this process of price discovery may drive intraday quoted spreads. This explanation of large information costs in the early hours of trading is also consistent with the fact that trading volume is high during these periods (see Figure 7). Since the specialist infers fundamental values from observing order flow, increased order flow during the morning may facilitate intraday price discovery.

6.2 Informed Trading Over the Day

While price discovery may explain the intraday shape in information flow, increased information costs may also result from a higher proportion of informed traders. Recent theoretical models (e.g. Foster and Viswanathan (1996)) show that, if information is short-lived and multiple informed traders compete for order flow, then informed traders may cluster their trading during certain times of the day. Since there may be information about the fundamental value revealed after the close of trading, it could be the case that informed traders systematically trade in the morning in order to capitalize on their information before it expires.

Nyholm (1998) presents empirical evidence that the probability of informed trading is highest at the market open and declines throughout the first two hours of trading. This evidence is also consistent with both Foster and Visvanathan (1996) and with our measure of intraday information costs. Thus, both intraday price discovery and intraday patterns in informed trading could help explain the observed pattern in information costs.

6.2.1 The probability of informed trading near the market open

The results presented above suggest that the information component of the spread is highest near the market open and declines over the day. These results indicate that the probability of order flow from informed traders may change over the day. In this section, we estimate the probability of informed trading using the sequential trade model of Easley, Kiefer, O'Hara and Paperman (EKOP) (1996). The EKOP model relies on the total number of buy and sell trades during a day to identify informed trading. In this model, information events may occur only before the start of trading on each day.[9] The probability of an information event occuring is given by α. Given that an information event has occured, the probability of *bad* news occurs with probability δ while good news has probability $(1-\delta)$. In this model, there are two types of stylized traders: informed traders who know the true value of the asset and uninformed traders who trade purely for liquidity purposes. The key feature of this model is that the arrival of these two types of traders are governed by independant poisson processes. Regardless of information events, the arrival rate of uninformed traders is ε. Informed traders, on the other hand, will arrive to the market only if an information event has occurred, and then only on one side of the market with arrival rate μ. The probability of informed trading is then given by:

$$PI = \frac{\alpha\mu}{\alpha\mu + 2\varepsilon}$$

Since the distribution of the number of buy and sell trades is governed by poisson processes, the parameters of the model may be estimates via maximum likelihood. The likelihood of

[9]This is in contrast to the Glosten and Harris (1988) model presented above, where information events may occur at any time.

observing B buys and S sells over some time interval T on a given day can therefore be summarized as the sum of three weighted poisson processes where the weights are given by the probability of an information even, α, and the probability of the bad news, δ:

$$
\begin{aligned}
L(B,S|\alpha,\delta,\varepsilon,\mu) \;=\; & (1-\alpha)\left[e^{-(\varepsilon T)}\frac{(\varepsilon T)^B}{B!}\right]\left[e^{-(\varepsilon T)}\frac{(\varepsilon T)^S}{S!}\right] \\
& +\alpha(1-\delta)\left[e^{-((\varepsilon+\mu)T)}\frac{((\varepsilon+\mu)T)^B}{B!}\right]\left[e^{-(\varepsilon T)}\frac{(\varepsilon T)^S}{S!}\right] \\
& +\alpha\delta\left[e^{-(\varepsilon T)}\frac{(\varepsilon T)^B}{B!}\right]\left[e^{-((\varepsilon+\mu)T)}\frac{((\varepsilon+\mu)T)^S}{S!}\right]
\end{aligned}
$$

Assuming that the days are independent, the likelihood of observing a sequence of buys and sells $X = (B_i, S_i)_{i=1}^N$ over N days is simply:

$$
L(X|\alpha,\delta,\varepsilon,\mu) = \prod_{i=1}^{N} = L_i(B_i, S_i|\alpha,\delta,\varepsilon,\mu) \tag{8}
$$

We use constrained maximum likelihood to estimate the parameters of the likelihood function. The probabilites, α and δ are constrained to lie in the interval $(0,1)$ and the arrival rates, ε and μ are constrained to be between zero and five.

To test whether the probability of informed trading varies over the day, we estimate equation (8) over two intervals. First, we estimate the model using only the first two hours of trading on each day. That is, $X = (B_i, S_i)_{i=1}^N$ is constructed using only the number of buy and sell order that arrive to the market between 9:30 a.m. and 11:30 a.m. Then, we estimate equation (8) using the total number of buy and sell orders for the entire day.[10] We then construct the probability of informed trading for each of the 20 stocks in our sample during both the morning hours and again for the entire day. Standard errors for PI are computed by the delta method.

Table 7 presents our estimates for the probability of informed trading. For 17 out of the 20 stocks in our sample, the probability of informed trading is larger during the first two hours of trading than during the entire day. Of these 17 firms, 13 have statistically significant diferences at the five percent level. For the remaining three stocks there is no statistically significant difference in PI between the morning and entire day. On average, we find that

[10]Estimating the model over sub-intervals of the day is inappropriate since the information structure of trades are dependent on previous trading during the same day. That is, we cannot assume that the parameters of the model are independent over sub-intervals of the day.

the probability of informed trading is 23 percent higher during the first two hours of trading than during the entire day.

These results lend support to the hypothesis that the specialist faces an increase in adverse selection costs near the market open. The significantly larger probability of informed trading in the morning hours is consistent with the observed widening of the bid-ask spread during this period and with an increase in the information component of the spread. These results are also consistent with Madhavan, Richardson, and Roomans (1997) and with Nyholm (1998).

6.3 Intraday Trade Size / Depth

Both price discovery and informed trading help explain the observed intraday pattern in quoted spreads. Another aggravating factor leading to large information costs during early trading is the role of trade size and depth. Figure 6 presents intraday patterns in average trade size, volume, and quoted depth for our sample of 20 stocks. We see the well-documented pattern in trade size and depth, namely, that trade size is highest near the open while quoted depth is lowest. Chung, VanNess, and VanNess (1998) show that the pattern in quoted depth results from the fact the specialists' order book is relatively thin at the market open. As the trading process evolves, the limit order book thickens and the specialist is better able to clear trades by matching limit orders, bypassing specialist participation. Thus, at periods when we would expect information costs to be higher, these costs are compounded by the fact that the specialist must participate more frequently in clearing trades, and further, that these trades tend to be large.

6.4 Competition for Order Flow

In section 5 we found very limited evidence that the specialist exercises monopoly power. In the previous sub-sections, we discussed possible economic rationales for why the intraday shape in spreads could arise simply from changing information costs. However, the NYSE specialist does have a monopoly position in clearing trades for a given stock. Since this is the case, there must be factors which prevent the specialist from exercising his market power to increase spreads. In this section, we investigate the possible sources of competition that the specialist faces in attracting order flow.

6.4.1 Limit Orders

While the NYSE specialist system appoints a single specialist to clear all trades for a given stock, the specialist faces significant competition from limit orders. The NYSE is a hybrid market where prices are established not only by the specialist, but also by public limit orders. In fact, the specialist is required by the exchange to post the highest bid and lowest ask prices available in the limit order book whenever these prices are better than the specialists' quotes. Harris and Hasbrouk (1996) find that over 50 percent of all transactions are executed against limit orders rather than against the specialists' own inventory.

Recent empirical evidence by Chung, VanNess, and VanNess (1998) finds that spreads are largest when the specialist alone quotes both the bid and ask price. Further, they find that the specialist participates more frequently during the early hours of trading and that spreads are competed down by increasing competition from limit orders over the day. These findings support the hypothesis that the specialist faces stiff competition in providing liquidity services from public limit orders. While these results imply that the specialist quotes wider spreads in the absence of competition from limit orders, Chung, *et al.* (1998) do not directly account for information costs.

6.4.2 Floor Brokers / Regulation

In addition to competition from limit orders, specialists also face competition from floor brokers. Floor brokers on the NYSE act as agents for investors by bringing orders to the trading crowd at the specialist's post. Floor brokers actively participate in trading with the specialist but may also work orders through the crowd. That is, floor brokers may trade directly with other traders, bypassing the specialist completely if they find the specialist's quotes unattractive. Sofianos and Werner (1997) provide a detailed analysis of floor broker participation for a small sample of NYSE stocks. They find that floor brokers represent roughly 45 percent of the total value of executed orders. Further, they find that almost 25 percent of all orders are executed between two floor brokers. These results suggest that the trading crowd around the specialist's post creates a substantial amount of liquidity on the floor. This provision of additional liquidity is consistent with the hypothesis that floor brokers actively compete with the specialist.

Apart from the sources of competition for order flow listed above, the specialist is a regulated monopolist. The exchange imposes strict rules on specialist quote behavior. First, specialists are required by the SEC to report the highest bid and lowest offer "communicated" to the trading crowd either by the specialist or a floor broker.[11] In addition, the specialist must also expose market orders to the crowd rather than executing them automatically against his posted quote. Thus, market orders can experience price improvement if they are executed at better than quoted prices by floor brokers or others in the trading crowd. In addition, the specialist has an obligation to preserve an orderly market. This obligation forces the specialist to make smooth price changes and preserve liquidity - preventing spreads from becoming too large. Finally, the exchange requires that limit orders take precedence over the specialists' orders. That is, the specialist must work through the orders in the book before trading for his own account. All of these factors help prevent the specialist from exercising monopoly power.

6.4.3 Regional Exchanges

Competition for order flow from regional exchanges also places pressure on specialist spreads. Blume and Goldstein (1997) report that as much as 50 percent of all trades for NYSE listed securities are executed by Nasdaq dealers or though regional exchanges. Additionally, McInish and Wood (1995) find that in a cross-section of NYSE-listed stocks, competition for order flow from regional exchanges has a significant effect on lowering NYSE quoted spreads.

Table 6 summarizes the intraday competition for order flow from "other exchanges" where other exchanges are taken to be all regional exchanges and the Nasdaq (but not proprietary trading systems like INSTINET or SELECT-NET). We present averages over the 20 stocks in our sample for five sub-intervals of the trading day: 9:30 a.m.-10:30 a.m., 10:30 a.m.-11:30 a.m., 11:30 a.m.-2:00 p.m., 2:00-3:00 p.m. and 3:00 a.m.-4:00 p.m. Columns 1 and 2 of Table 7 show that over the trading day almost half of all trades in these 20 stocks are executed through venues other than the NYSE. Further, we find that competition from

[11] See Hasbrouck, Sofianos, and Sosebee (1993).

other exchanges is heaviest during the first hour of trading, when other markets capture 53 percent of all trades. This market share falls over the day to 49 percent by the close of trading. These results hold when looking at market share of other exchanges by total volume as well. Column 4 of Table 7 presents the proportion of total volume executed through other markets. Again, market shares are largest during the first hour of trading and fall over the trading day.

While these results show that regional exchanges actively compete for order flow, the average trade size executed on the NYSE versus the other markets is also significant. Trades executed on other markets are substantialy smaller that those executed on the NYSE. Across all time periods, the average trade size of an execution on the NYSE is roughly five times larger than the average trade on the other markets. Lin Sanger and Booth (1994) find that information costs are proportional to trade size. Thus, competition from other markets could have two effects on quoted spreads. First, competition may force lower spreads (as reported by McInish and Wood (1995)). Second, by "cream skimming" small trades off of the NYSE, the residual larger (more informed) trades on the NYSE may increase information costs. Easley, Kiefer and O'Hara (1996) find that the practice of payments for order flow exacerbates infomation costs on established markets by cream-skimming liquidity traders. Since both effects would increase with the proportion of other exchanges' market share, these effects are also consistent with the observed pattern in the components of the spread.[12]

7 Conclusion / Extensions

In this paper we test the hypothesis that the intraday pattern in bid-ask spreads for the NYSE arises from monopoly pricing by the specialist. To accomplish this, we estimate the components of the bid-ask spread as a continuous function of the day using a very flexible econometric methodology. We find that information, not market power, is the primary source of intraday variation in quoted spreads. Specifically, we find that, on average, 73 percent of the increase in quoted spreads during the first 90 minutes of trading can be explained by information effects. The remaining 23 percent of the morning-spread-premium is due to

[12]Battalio (1996) finds little evidence that "cream-skimming" has a negative effect on Nyse spreads. However, Easley, Keifer and O'Hara (1996) report that "cream-skimming" by regional exchanges does increase information costs.

either market maker rents or changing order-processing costs. Using an alternative measure of trading costs, the effective spread, we find that information-adjusted spreads are actually lowest during the early hours of trading. Overall, these results are largely consistent with existing information-based models of specialist behavior rather than with the exercise of market power. Further, we find that empirical evidence of intraday price discovery, informed trading, and competition for order flow which are consistent with information-based models of spread behavior.

One limitation of this study is that we focus only on 20 large volume stocks. Since bid-ask spreads have been shown to be larger for small, less-frequently traded securities (Demsetz (1968)), one extension of this analysis would be to perform this test on a wider range of stocks. Also, while we find a clear intraday pattern in the components of the spread, we do not explicitly model the determinants of this pattern. Another area of future research is understanding the role that trade size and specialist participation play in determining information costs. That is, equation (4) could be augmented to include factors that control for intraday changes in trade size, volatility, specialist participation etc., rather than the simple time-of-day effects.

Overall, our study sheds light on the institutional efficiency of the NYSE specialist system. We do not argue that the NYSE specialist makes no economic profits or that he holds no market power. Rather, we argue that most of the observed intraday shape in quoted spreads arises from changing information costs. To the extent that specialists do exercise market power, they do so uniformly over the day. These results are inconsistent with the hypothesis that the specialist price discriminates during periods of peak demand.

References

[1] Andersen T. and T.B. Bollerslev, 1997a, Intraday periodicity and volatility persistence in financial markets, *Journal of Empirical Finance.*

[2] Andersen T. and T.B. Bollerslev, 1997b, Deutsche mark-dollar volatility: intraday activity patterns, macroeconomic announcements, and longer run dependencies, *Journal of Finance* 53, 219-265.

[3] Admati, A.R. and Pflieiderer, 1988, A theory of intraday patterns: volume and price variability, *Review of Financial Studies* 1, 3-40.

[4] Affleck-Graves, S. Hedge, and R. Miller, 1994, Trading mechanisms and the components of the bid-ask spread, *Journal of Finance* 49 1471-1488.

[5] Bagehot, Walter (Jack Treynor), 1971, The only game in town, *Financial Analysts Journal* 22,12-14.

[6] Bessembinder, H., 1997, The degree of price resolution and equity trading costs, *Journal of Financial Economics* 35, 9-34.

[7] Bloomfield, R. and M. O'Hara, 1998, Does order preferencing matter?, *Journal of Financial Economics* 50, 3-37.

[8] Blume, M.E., and, M.A. Goldstein, 1997, Quotes, order flow and price discovery, *Journal of Finance* 52, 221-44.

[9] Brock, W.A., and A.W. Kleidon, 1992, Periodic market closure and trading volume, *Journal of Economic Dynamics and Control* 16, 451-89.

[10] Chan, K. C., W.G. Christie, and P.H. Schultz, 1995, Market structure and the intraday pattern of bid-ask spreads for Nasdaq securities, *Journal of Business* 68, 35-60.

[11] Christie, W. and P.H. Schultz, 1994, Why do Nasdaq market makers avoid odd-eighth quotes?, Journal of Finance, 49, 1813-1840.

[12] Chung, Kee, B. Van Ness and, R. A. Van Ness, 1999, Limit orders and the bid-ask spread, *Journal of Financial Economics* 53, 255-87.

[13] Demsetz, H., 1968, The cost of transacting, *Quarterly Journal of Economics* 82, 33-58.

[14] Easley, D., N. Kiefer, and M. O'Hara, 1996, Cream skimming or profit sharing? The curious role of purchased order flow, *Journal of Finance* 51, 811-834.

[15] Easley, D., N. Kiefer, M. O'Hara and, J.B. Paperman, 1996, Liquidity, information, and infrequently traded stocks, *Journal of Finance* 51, 1405-1436.

[16] Foster, F.D., and S. Viswanathan, 1996, Strategic trading when agents forecast the forecasts of others, *Journal of Finance* 51, 1437-1478.

[17] Glosten L.R. and L.E. Harris, 1988, Estimating the components of the bid/ask spread, *Journal of Financial Economics* 21, 123-42.

[18] Glosten L.R., and R. Milgrom, 1985, Bid, ask, and transaction prices in a specialist market with heterogeneously informed traders, *Journal of Financial Economics* 14, 71-100.

[19] Harris, L., and J. Hasbrouck, 1996, Market vs. limit orders: the SuperDot evidence on order submission strategy, *Journal of Financial and Quantitative Analysis* 31, 213-231.

[20] Hansen, L., 1982, Large sample properties of generalized method of moments estimators, *Economtetrica* 50, 1029-1084.

[21] Hasbrouk, J., G. Sofianos, and D. Sosebee, 1995, New York Stock Exchange systems and trading procedures, NYSE Working Paper #93-01.

[22] Huang, R. and H. Stoll, 1997, The components of the bid-ask spread: a general approach, *Review of Financial Studies* 10, 995-1034.

[23] Kandel, E., and L. Marx, 1999, Payments for order flow on Nasdaq, *Journal of Finance* 54, 35-66.

[24] Kyle, A., 1985, Continuous auctions and insider trading, *Econometrica* 53, 1315-35.

[25] Lee, C.M. and M.J. Ready, 1991, Inferring trade direction from intraday data, *Journal of Finance* 46, 733-46.

[26] Lin, J., G.C. Sanger, and G. Booth, 1995, Trade size and components of the bid-ask spread, *Review of Financial Studies* 8, 1158-84.

[27] Gallant, R., 1980, Explicit estimators of parametric functions in nonlinear regression, *Journal of the American Statistical Association* 75, 182-93.

[28] George, T., G. Kaul, and M. Nimalendran, 1991, Estimation of the bid-ask spread and its components: a new approach, *Review of Financial Studies* 4, 623-656.

[29] Madhavan, A., M. Richardson, and M. Roomans, 1997, Why do security prices change? A transaction-level analysis of NYSE stocks, *Review of Financial Studies* 10, 1035-1064.

[30] Madhavan, A. and G. Sofianos, 1998, An empirical analysis of NYSE specialist trading, *Journal of Financial Economics* 48, 189-210.

[31] McInish, T., and R.A. Wood, 1992, An analysis of intraday patterns in bid/ask spreads for NYSE stocks, *Journal of Finance* 47, 753-64.

[32] McInish, T., and R.A. Wood, 1995, Competition, fragmentation and market quality, in *Industrial Organization and Regulation of the Securities Industry*, A. Lo (ed.), The University of Chicago Press (Chicago Ill.).

[33] Nyholm, Ken, 1998, Inferring the private information content of trades: a regime-switching approach, working paper, Aarhus School of Business.

[34] O'Hara, M. 1995, *Market Microstructure Theory*, Blackwell Publishing (New York, NY).

[35] Stoll, H., 1989, Inferring the components of the bid-ask spread: theory and empirical tests, *Journal of Finance* 44, 115-134.

[36] Stoll, H. and R.E. Whaley, 1990, Stock market structure and volatility, *Review of Financial Studies* 3, 37-71.

[37] Wei, P., 1992, Intraday variations in trading activity, price variability and the bid-ask spread, *Journal of Financial Research* 15, 265-76.

[38] Weston, J. P., 1999, Competition on the Nasdaq and the impact of recent market reforms, forthcoming *Journal of Finance.*

Table 1
Summary Statistics

This table presents summary statistics for our sample. Data are collected from the TAQ daily statistics file for all 254 trading days in 1996. The sample contains the 20 largest volume issues which had no stock splits over the sample period. Average prices are based on the closing trade each day. Average volume and number of trades for each stock represents the mean number of shares and trades traded each day, respectively. Return volatility is based on the average of the absolute daily returns. Price range reflects the difference between the highest and lowest closing price for that issue over the sample period.

	Average Daily				
Ticker Symbol	Price ($)	Volume (1,000s of shares)	Number of Trades	Return Volatility	Price Range ($)
CPQ	55.28	2,403	639	1.93	49.25
DEC	47.46	1,543	443	2.48	46.88
DIS	63.15	1,305	557	1.08	23.00
F	32.61	2,399	570	1.18	9.63
FNM	37.23	2,266	529	2.19	97.38
GE	85.35	1,945	934	0.98	34.63
IBM	117.13	2,908	989	1.47	80.13
KM	9.83	2,447	452	2.18	8.25
LLY	63.20	1,173	538	1.55	29.50
LSI	27.67	1,785	636	2.99	20.88
MO	96.79	2,244	796	1.24	32.50
MOT	55.72	2,340	1,133	1.59	22.88
MRK	68.13	2,181	761	1.17	27.25
MU	30.19	4,215	1,372	3.10	24.50
PFE	73.27	1,119	571	1.28	29.75
PG	91.38	900	479	1.01	30.00
T	54.87	3,224	881	1.25	34.75
TXN	52.03	1,653	607	1.93	25.13
USW	32.00	756	427	1.03	9.25
XON	85.45	1,349	465	0.96	22.50
All Firms	58.94	2,008	689	1.63	32.90

Table 2

Intraday Pattern in Quoted and Effective Spreads

This table presents an overview of the intraday pattern in bid-ask spreads. The quoted spread is defined as the prevailing ask quote minus the bid-quote for all trades time-stamped during each period on all 256 trading days in 1996. Effective spreads are constructed as 2*|price-(quote midpoint)|. Average effective spreads are constructed in the same manner as the quoted spreads. The data for all firms represent the equally weighted average of the 20 firms.

	Average Quoted Spread ($)			Average Effective Spread ($)		
Tick	First 90 Minutes	Mid-day	Last 90 Minutes	First 90 Minutes	Mid-day	Last 90 Minutes
CPQ	0.181	0.168	0.171	0.088	0.088	0.087
DEC	0.176	0.157	0.159	0.109	0.104	0.106
DIS	0.161	0.146	0.149	0.107	0.110	0.109
F	0.147	0.137	0.138	0.107	0.114	0.114
FNM	0.151	0.140	0.141	0.107	0.113	0.114
GE	0.159	0.148	0.151	0.110	0.112	0.111
IBM	0.185	0.169	0.179	0.121	0.109	0.114
KM	0.133	0.128	0.129	0.119	0.122	0.122
LLY	0.184	0.169	0.172	0.118	0.115	0.115
LSI	0.168	0.148	0.150	0.114	0.111	0.112
MO	0.187	0.161	0.168	0.125	0.117	0.119
MOT	0.165	0.145	0.145	0.110	0.111	0.112
MRK	0.163	0.151	0.154	0.102	0.105	0.105
MU	0.155	0.141	0.143	0.110	0.114	0.114
PFE	0.171	0.158	0.160	0.120	0.116	0.118
PG	0.187	0.167	0.170	0.118	0.115	0.115
T	0.157	0.146	0.146	0.097	0.106	0.106
TXN	0.200	0.171	0.173	0.113	0.104	0.104
USW	0.157	0.143	0.143	0.107	0.112	0.112
XON	0.152	0.144	0.144	0.108	0.109	0.110
All Firms	0.164	0.150	0.152	0.110	0.110	0.111

Table 3

Intraday Information Component of the Spread

This table presents the average estimates for the adverse-selection (information) component of the spread, α_n, over three sub-intervals of the trading day. Results for the first 90 minutes, mid-day, and last 90 minutes are based on the average information costs for all of the 5-minute intervals estimated within that period. *,**,*** indicate statistical significance at the 10,5, and 1% level respectively.

	Adverse Selection costs (%)			Opening	Closing
	First 90 Minutes	Mid-day	Last 90 Minutes	Difference	Difference
Ticker	(1)	(2)	(3)	(4)=(1)-(2)	(5)=(3)-(2)
CPQ	0.390	0.286	0.311	0.103 ***	0.024 ***
DEC	0.258	0.141	0.144	0.116 ***	0.003
DIS	0.212	0.163	0.165	0.049 ***	0.002 ***
F	0.130	0.092	0.085	0.038 ***	-0.007 ***
FNM	0.212	0.153	0.150	0.059 ***	-0.003 ***
GE	0.182	0.161	0.169	0.021 ***	0.008 ***
IBM	0.286	0.250	0.264	0.035 ***	0.014 ***
KM	0.066	0.034	0.036	0.032 ***	0.002
LLY	0.312	0.258	0.259	0.054 ***	0.001
LSI	0.219	0.186	0.168	0.033 ***	-0.018 ***
MO	0.142	0.132	0.132	0.010 ***	-0.001
MOT	0.119	0.083	0.076	0.036 ***	-0.007 ***
MRK	0.170	0.144	0.152	0.026 ***	0.008 ***
MU	0.154	0.116	0.115	0.038 ***	-0.001
PFE	0.184	0.172	0.172	0.012 ***	-0.001
PG	0.225	0.212	0.200	0.014 ***	-0.012 ***
T	0.118	0.078	0.078	0.040 ***	0.000
TXN	0.151	0.140	0.130	0.011 ***	-0.009 ***
USW	0.159	0.092	0.083	0.067 ***	-0.009 ***
XON	0.323	0.260	0.251	0.064 ***	-0.008 ***
All Firms	0.207	0.160	0.160	0.046 ***	0.000

Table 4
Information Component of the Quoted Spread in Dollar Value

This table presents the average estimates for the adverse-selection (information) component of the spread, α_n, in dollar value over three sub-intervals of the trading day. Dollar values are computed for each 5-minute interval as the information component of the spread multiplied by the average quoted spread. Results for the first 90 minutes, mid-day, and last 90 minutes are based on the average information costs for all of the 5-minute intervals estimated within that period. *,**,*** indicate statistical significance at the 10,5, and 1% level respectively.

	Quoted Spread			Quoted Spread less Information/Inventory costs			
	Morning (1)	Mid-day (2)	Difference (3)=(1)-(2)	Morning (4)	Mid-day (5)	Difference (6)=(4)-(5)	% Decline (7)=[(2)-(6)] / (2)
CPQ	0.18	0.17	0.013 ***	0.11	0.12	-0.010 ***	176.9
DEC	0.18	0.16	0.020 ***	0.13	0.13	-0.004 ***	118.4
DIS	0.16	0.15	0.015 ***	0.13	0.12	0.005 ***	68.8
F	0.15	0.14	0.009 ***	0.13	0.12	0.002 ***	72.2
FNM	0.15	0.14	0.011 ***	0.12	0.12	0.000	95.6
GE	0.16	0.15	0.011 ***	0.13	0.12	0.006 ***	47.9
IBM	0.18	0.17	0.015 ***	0.13	0.13	0.005 ***	68.0
KM	0.13	0.13	0.004 ***	0.12	0.12	0.000	98.9
LLY	0.18	0.17	0.015 ***	0.13	0.13	0.001	92.9
LSI	0.17	0.15	0.020 ***	0.13	0.12	0.011 ***	46.5
MO	0.19	0.16	0.026 ***	0.16	0.14	0.021 ***	20.2
MOT	0.16	0.14	0.020 ***	0.15	0.13	0.013 ***	37.7
MRK	0.16	0.15	0.011 ***	0.13	0.13	0.005 ***	52.7
MU	0.16	0.14	0.014 ***	0.13	0.12	0.007 ***	53.7
PFE	0.17	0.16	0.014 ***	0.14	0.13	0.009 ***	32.0
PG	0.19	0.17	0.020 ***	0.15	0.13	0.013 ***	34.3
T	0.16	0.15	0.011 ***	0.14	0.13	0.004 ***	64.4
TXN	0.20	0.17	0.028 ***	0.17	0.15	0.022 ***	22.2
USW	0.16	0.14	0.013 ***	0.13	0.13	0.001	90.5
XON	0.15	0.14	0.007 ***	0.10	0.11	-0.004 ***	158.8
Average	0.16	0.15	0.014 ***	0.13	0.13	0.004 ***	72.6

Table 5
Information Component of the Effective Spread in Dollar Value

This table presents the average estimates for the adverse-selection (information) component of the spread, α_n, in dollar value over three sub-intervals of the trading day. Dollar values are computed for each 5-minute interval as the information component of the spread multiplied by the average effective spread. Results for the first 90 minutes, mid-day, and last 90 minutes are based on the average information/inventory costs for all of the 5-minute intervals estimated within that period. *,**,*** indicate statistical significance at the 10,5, and 1% level respectively.

	Effective Spread			Effective Spread less Information/Inventory costs			
	Morning (1)	Mid-day (2)	Difference (3)=(1)-(2)	Morning (4)	Mid-day (5)	Difference (6)=(4)-(5)	% Decline (7)=[(2)-(6)] / (2)
CPQ	0.09	0.09	0.000	0.05	0.06	-0.009 ***	693.5
DEC	0.11	0.10	0.004 ***	0.08	0.09	-0.009 ***	306.3
DIS	0.11	0.11	-0.003 ***	0.08	0.09	-0.008 ***	147.5
F	0.11	0.11	-0.007 ***	0.09	0.10	-0.010 ***	51.4
FNM	0.11	0.11	-0.006 ***	0.08	0.10	-0.012 ***	83.4
GE	0.11	0.11	-0.002 ***	0.09	0.09	-0.004 ***	120.6
IBM	0.12	0.11	0.012 ***	0.09	0.08	0.005 ***	61.2
KM	0.12	0.12	-0.003 ***	0.11	0.12	-0.007 ***	107.4
LLY	0.12	0.11	0.004 ***	0.08	0.09	-0.004 ***	203.3
LSI	0.11	0.11	0.003 ***	0.09	0.09	-0.002 ***	168.0
MO	0.12	0.12	0.008 ***	0.11	0.10	0.005 ***	29.1
MOT	0.11	0.11	-0.001	0.10	0.10	-0.005 ***	308.9
MRK	0.10	0.11	-0.003 ***	0.08	0.09	-0.006 ***	63.9
MU	0.11	0.11	-0.004 ***	0.09	0.10	-0.008 ***	92.9
PFE	0.12	0.12	0.004 ***	0.10	0.10	0.002	56.3
PG	0.12	0.12	0.003 ***	0.09	0.09	0.001	73.3
T	0.10	0.11	-0.008 ***	0.09	0.10	-0.011 ***	38.5
TXN	0.11	0.10	0.009 ***	0.10	0.09	0.007 ***	27.7
USW	0.11	0.11	-0.005 ***	0.09	0.10	-0.011 ***	144.8
XON	0.11	0.11	-0.001 ***	0.07	0.08	-0.008 ***	645.1
Average	0.11	0.11	-0.001 ***	0.09	0.09	-0.006 ***	171.1

Table 6

Intraday Competition for Order Flow from Regional Exchanges

This Table present a summary of trade execution patterns across different US exchange over the day. Averages for each series are based on the equally weighted mean across all 20 stocks in the sample for each time period. Regional exchanges include trades executed on the NASDAQ, Boston, Midwest, Pacific, American, Cincinnati, and Philadelphia exchanges.

	Average Number of Trades per Hour					
Time Period	On the NYSE (1)	On Other Exchanges (2)	Proportion of Trades Executed on Other Exchanges (3)	Proportion of Total Volume Executed on Other Exchanges (4)	Average Trade Size On NYSE (5)	Average Trade Size On Other Exchanges (6)
9:30-10:30	28.5	31.6	53%	23%	2,986	654
10:30-11:30	22.9	23.9	51%	19%	2,804	564
11:30-2:00	17.0	17.7	51%	21%	2,519	580
2:00-3:00	19.9	19.8	50%	19%	2,607	499
3:00-4:00	25.2	24.6	49%	18%	2,507	515

Table 7
Probability of Informed Trading

This table reports tests of the hypothesis that the probability of informed trading is higher near the open of trading. The probability of informed trading is estimated using the empirical model of Easley, Kiefer, O'Hara, and Paperman (1996). Data are collected from TAQ for the first 60 trading days in 1996. The probability of informed trading during the morning is estimated using transactions that occur between 9:30 a.m. and 11:00 a.m. Results for the entire day use all trades over the trading day. *,**,*** indicate statistical significance at the 10,5, and 1% level respectively using two-sided T-tests.

Ticker	Probability of Informed Trading		
Symbol	Morning	Entire Day	% Difference
CPQ	0.134	0.106	26.42 **
DEC	0.189	0.135	40.00 ***
DIS	0.176	0.182	-3.30
F	0.243	0.162	50.00 ***
FNM	0.189	0.109	73.39 ***
GE	0.079	0.072	9.72
IBM	0.180	0.147	22.45 ***
KM	0.166	0.134	23.88 *
LLY	0.206	0.222	-7.21
LSI	0.213	0.176	21.02 ***
MO	0.063	0.057	10.53
MOT	0.132	0.110	20.00 **
MRK	0.128	0.125	2.40
MU	0.168	0.100	68.00 ***
PFE	0.145	0.124	16.94 **
PG	0.115	0.121	-4.96
T	0.104	0.092	13.04
TXN	0.171	0.133	28.57 ***
USW	0.216	0.174	24.14 ***
XON	0.126	0.094	34.04 ***
All Firms	0.157	0.129	23.45 **

Figure 1

Inttraday Pattern in Bid-Ask Spreads

This figure presents the intraday pattern in quoted and effective bid-ask spreads for our sample of 20 stocks. The quoted spread is defined as the ask price - bid price. Effective spreads are calculated as twice the absolute difference between the trasaction price and the midpoint of the prevailing quoted spread at the time of the transaction. Average quoted and effective spreads are constructed by taking the mean spread over all trades for each stock for 78 five-minute intervals over the trading day. We then construct an equally weighted average across all 20 stocks in the sample for each five-minute interval.

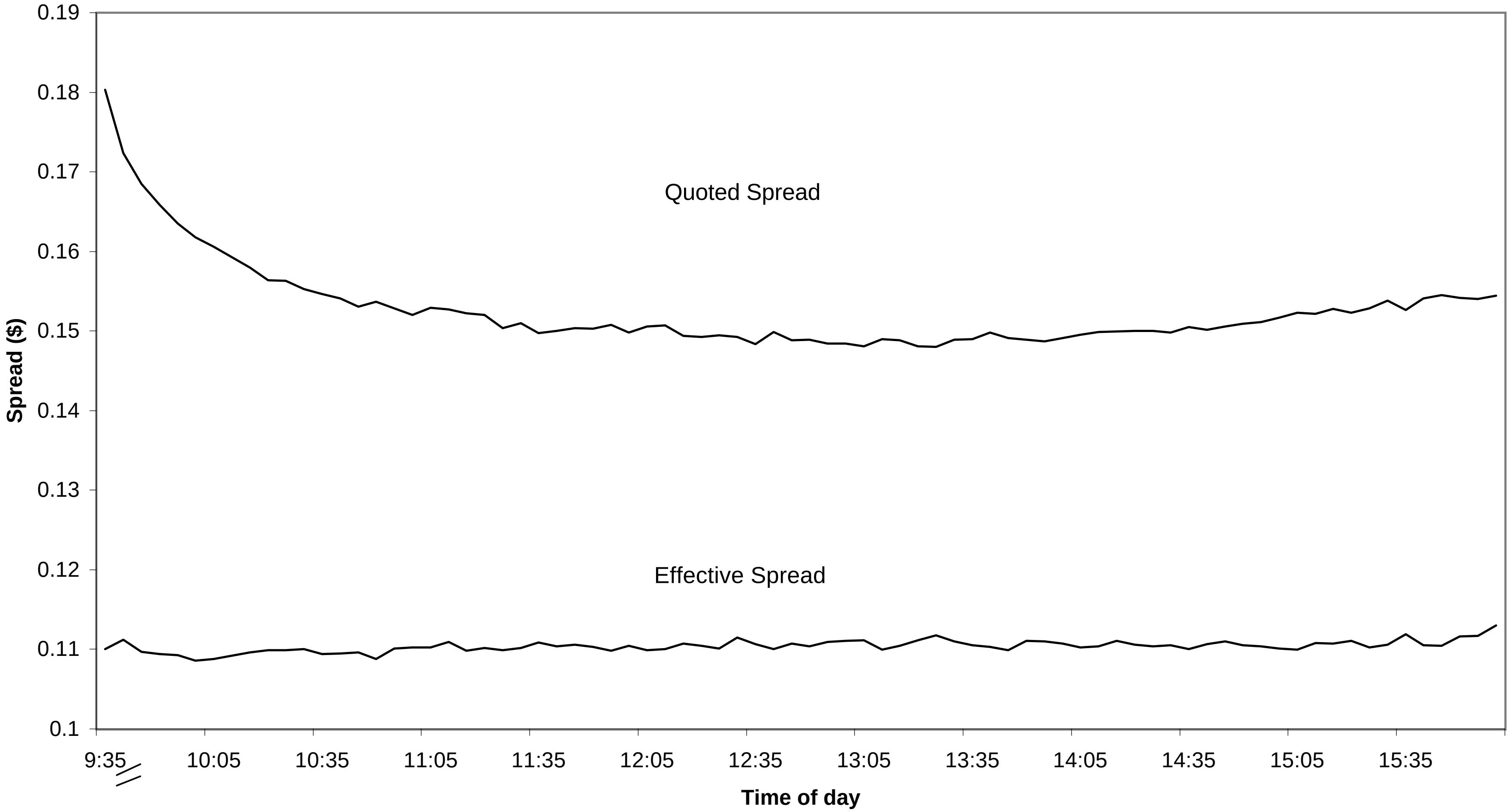

Figure 2

Intraday Information Costs as a Percentage of the Spread

(with 95% pointwise confidence bands)

This figure presents our estimates of the information component of the spread over the day. Information costs are estimated from regression equation (5) . 95% pointwise confidence bands are constructed via the delata method . The average over all 20 stocks is computed as the equally weighted mean for each of the 78 five-minute intervals.

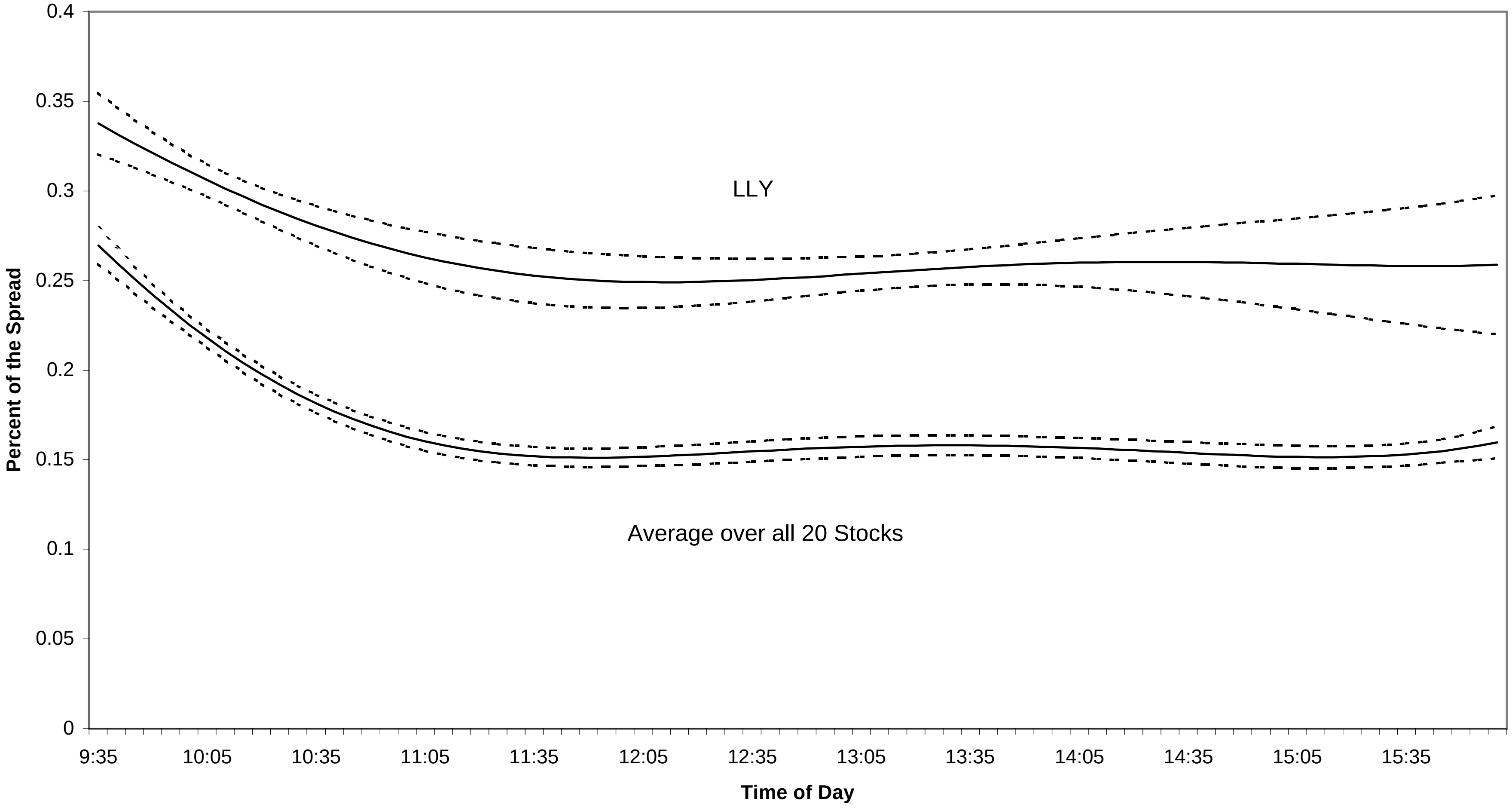

Figure 2b

Intraday Information Costs as a Percentage of the Spread

This figure presents estimates of the intraday information component of the spread for the 20 stocks in our sample. Information costs are estimated from regression equation (5).

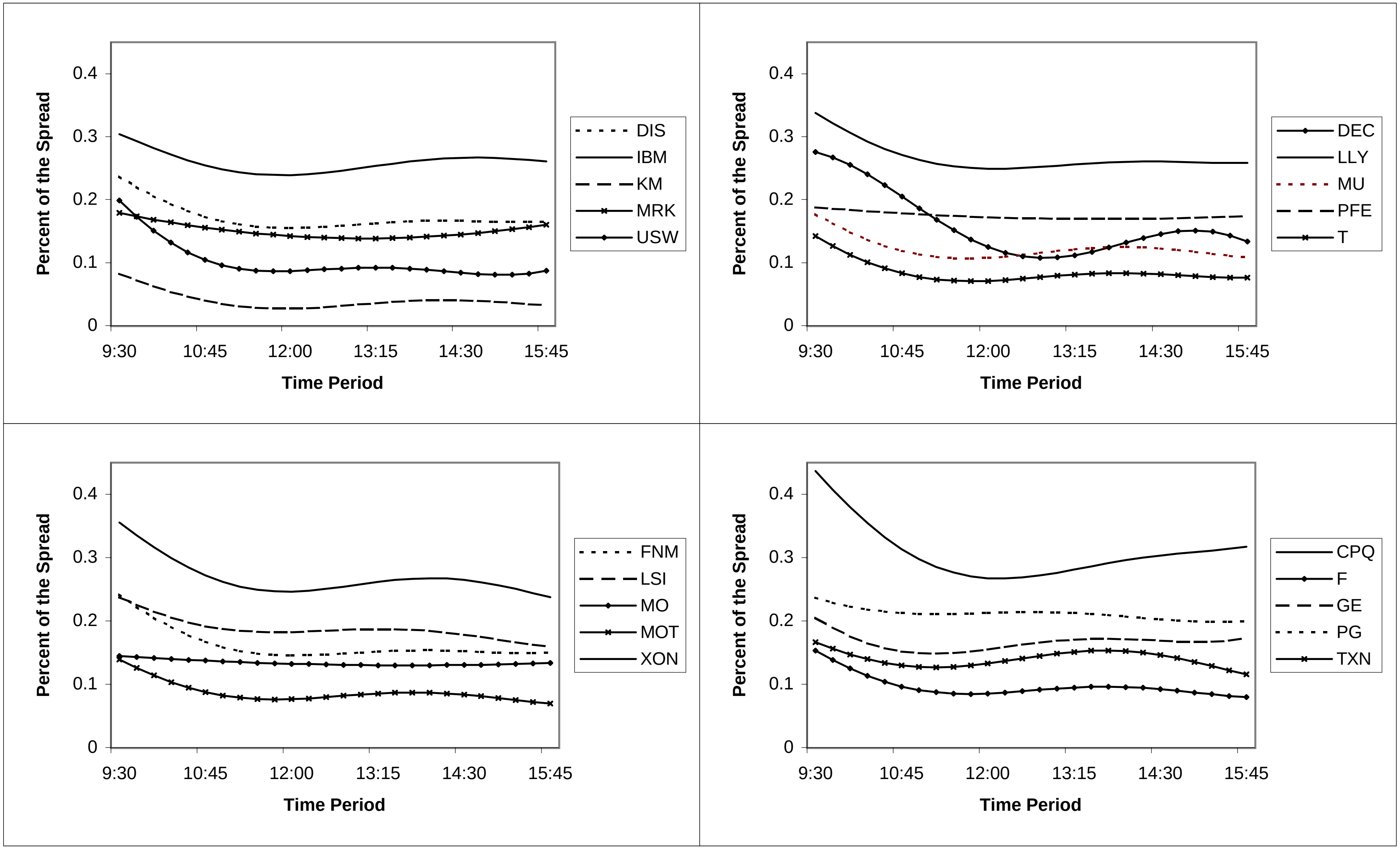

Figure 3

Dollar Value of Information Component of the Quoted Spread

This figure presents the dollar value of the information component of the bid-ask spread. The dollar value of the information component is constructed by multiplying the five-minute estimate of the information component of the spread by the five-minute average quoted bid-ask spread over all trades in each time interval. The average over all 20 stocks is computed as the equally weighted mean for each of the 78 five-minute intervals.

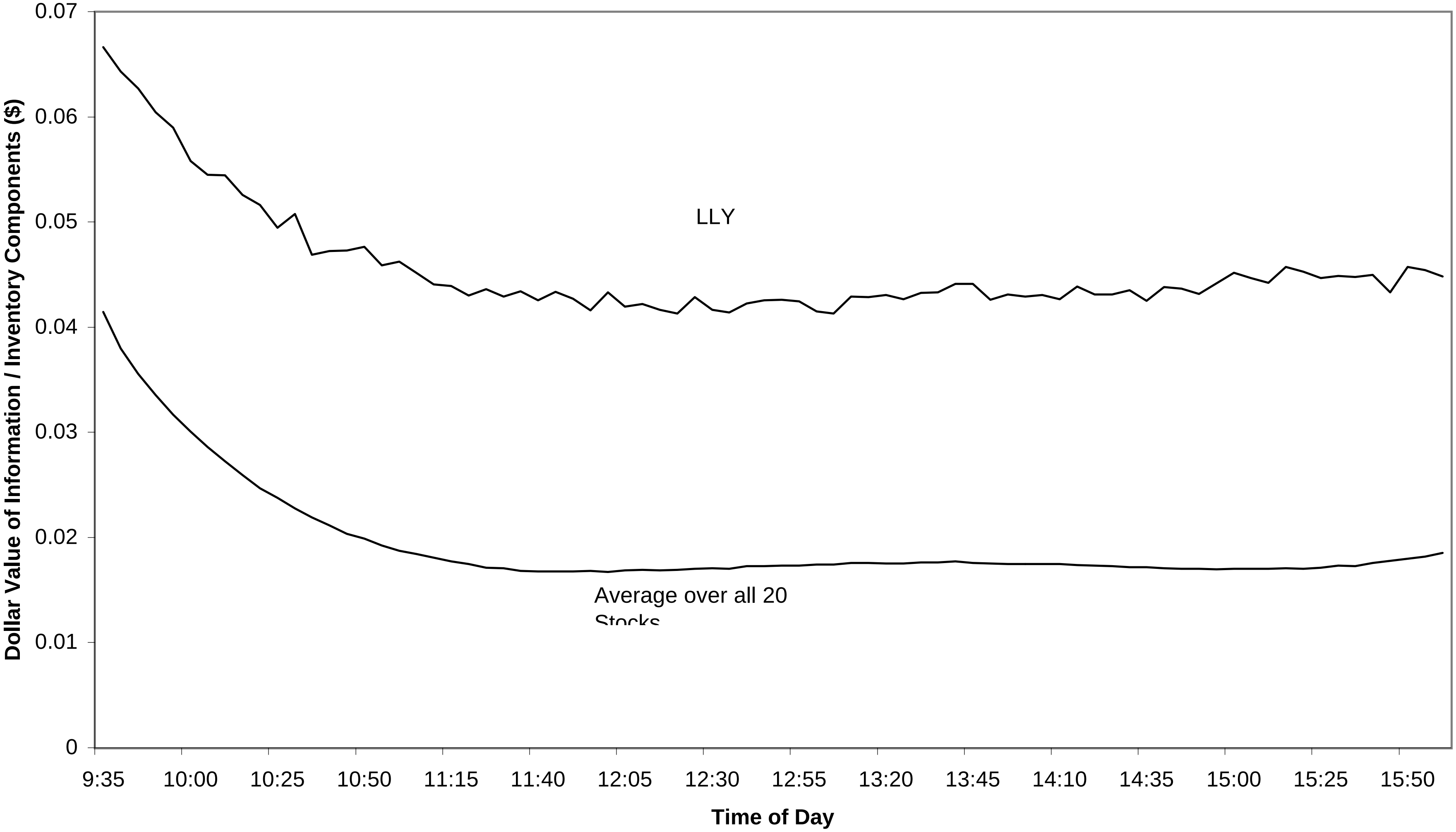

Figure 4

Dollar Value of Order Processing and Specialist Rent Components of the Quoted Spread

This figure presents the dollar value of the order processing and specialist rents component of the bid-ask spread. The dollar value of the components are constructed by multiplying the five-minute estimate of the order processing and specialist rent component of the spread by the five-minute average quoted-bid-ask spread over all trades in each time interval. The average over all 20 stocks is computed as the equally weighted mean for each of the 78 five-minute intervals.

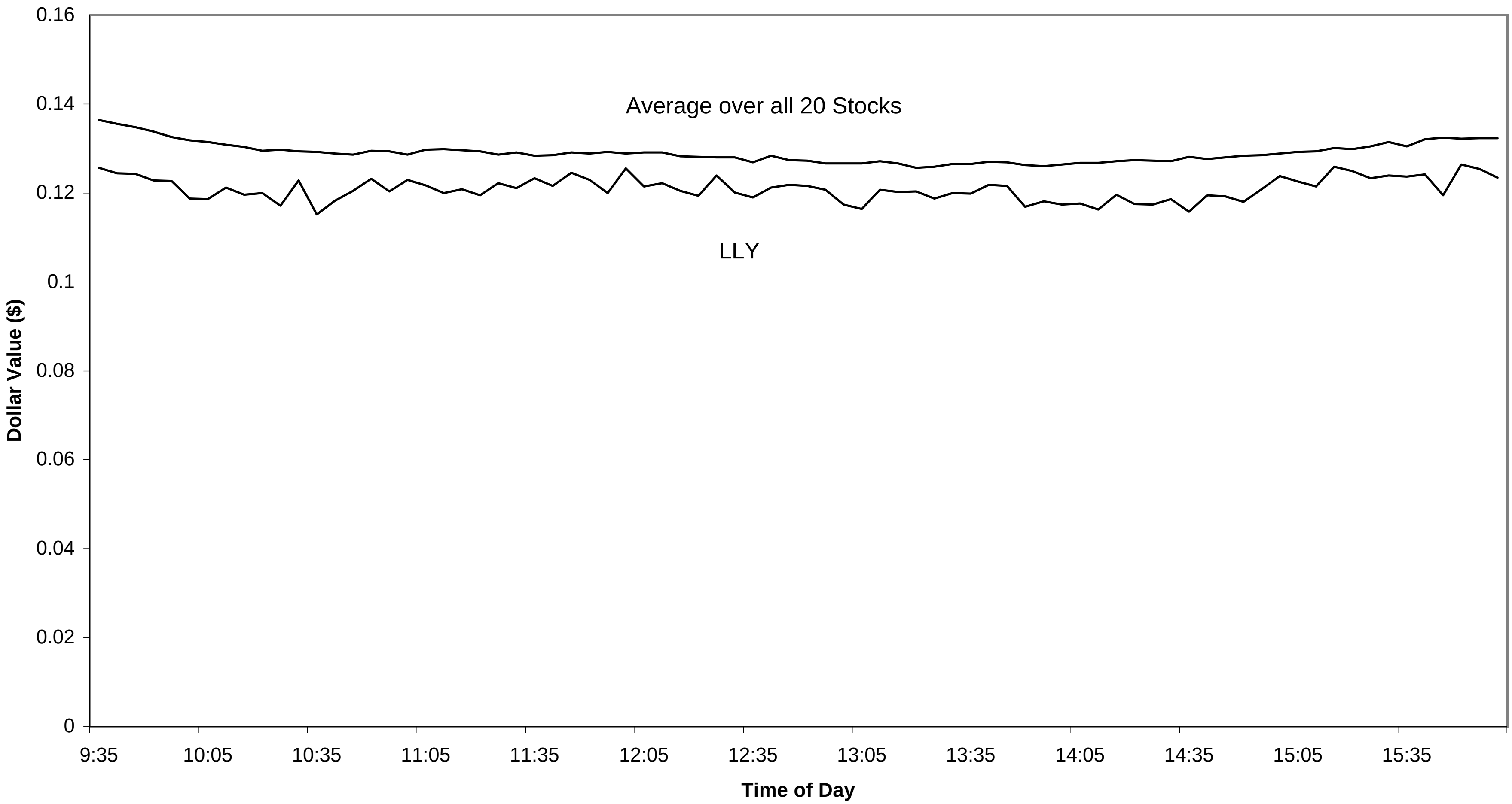

Figure 5

Dollar Value of Order Processing and Specialist Rent Components of the Effective Spread

This figure presents the dollar value of the order processing and specialist rent components of the effective bid-ask spread. The dollar value of the components are constructed by multiplying the five-minute estimate of the order processing and specialist rent components of the spread by the five-minute average effective bid-ask spread over all trades in each time interval. The average over all 20 stocks is computed as the equally weighted mean for each of the 78 five-minute intervals.

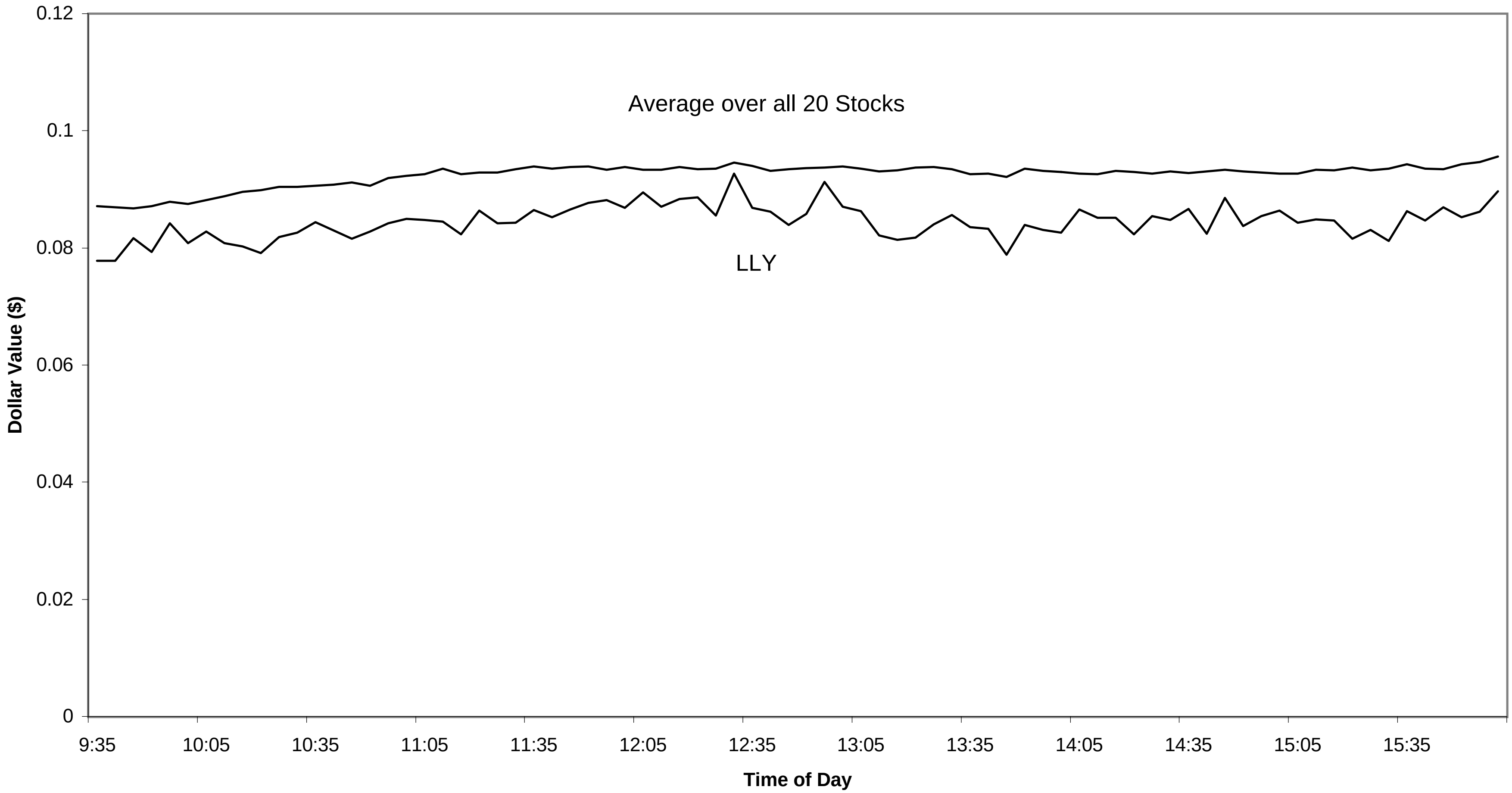

Figure 6

Intraday Pattern in the Proportion of Trades Executed Inside the Quoted Spread (Average over all 20 Stocks)

Trades executed inside the quoted spread are identified as any trade where the transaction price is either less than the quoted ask price ans greater than the quoted bid price. The proportion of all trades which are executed inside the quoted spread are calculated for each stock over 78 five-minute intervals of the trading day over all 254 trading days for each stock. Averages for each five-minute interval (presented below) are then computed as the equally weighted mean over the 20 stocks in the sample.

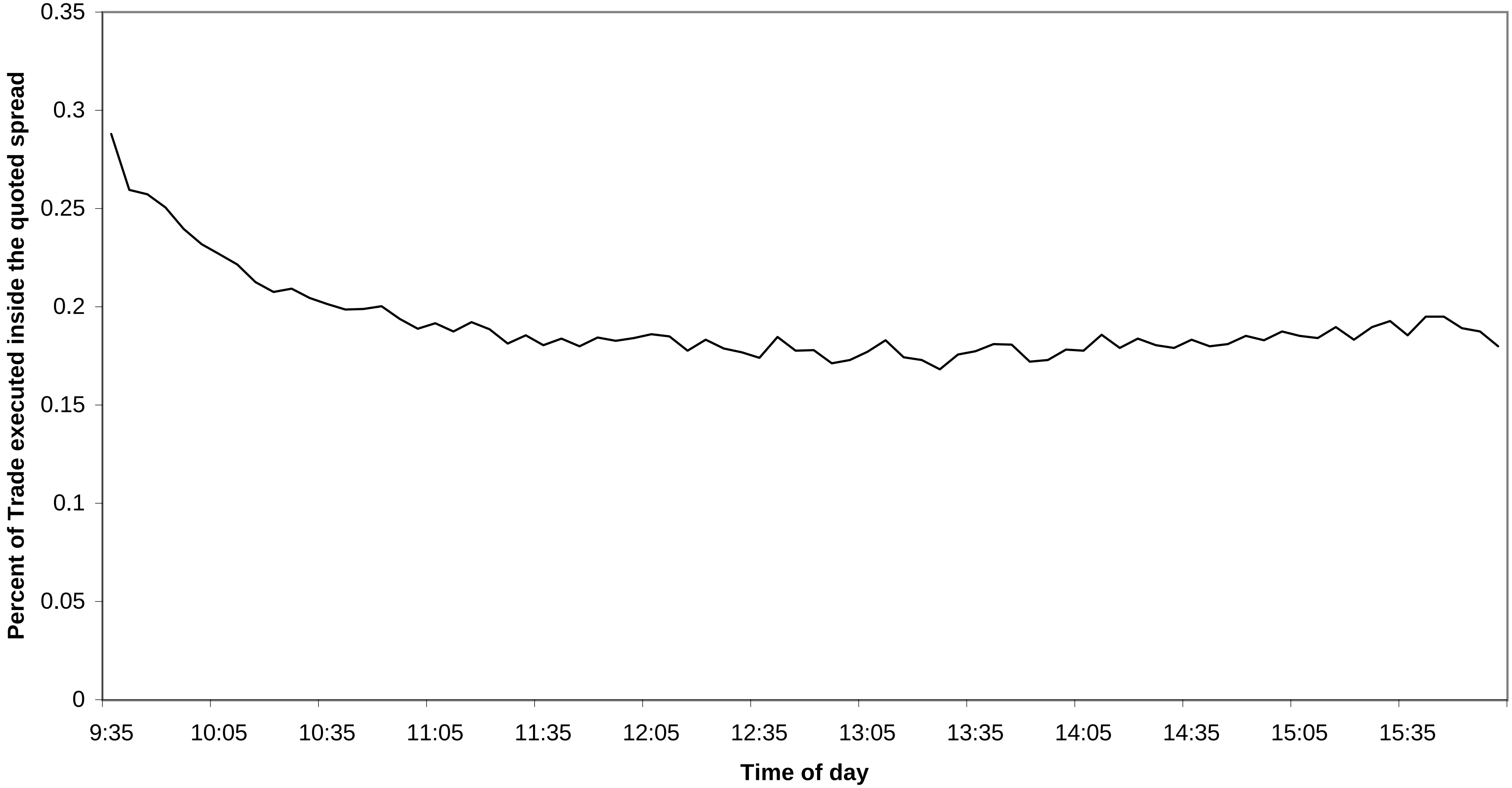

Figure 7

Intraday Patterns in Quoted Depth, Volume and Trade Size

This figure present intraday patterns in quoted depth volume and average trade size. Quoted depth is measured as the average number of shares offered at the bid and ask price over all transactions within 78 five-minute intervals. We then compute the equally weighted cross-sectional mean over the 20 stocks in our sample. Volume and trade size are similarly constructed using the total number of shares trasacted and the average transaction size in each time interval.