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ADVERSE SELECTION COSTS, TRADING ACTIVITY AND LIQUIDITY IN THE NYSE: AN EMPIRICAL ANALYSIS IN A DYNAMIC CONTEXT**

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Abstract

This paper measures the adverse selection costs associated to a given trade by estimating its permanent impact on market quotes. This estimation depends on observable trade features and market conditions, and it is given by the impulse-response function of a generalization of the Hasbrouck's (1991a,b) VAR model. It is evidenced that microstructure structural models of quote formation may introduce a downward bias in the estimation of adverse selection costs by assuming that trades only have an immediate impact on prices. Moreover, it is observed that the market behavior, in terms of liquidity and activity, in the short-term period after a trade depends on the information-asymmetry risk associated to that trade.

Keywords: Microstructure; Adverse Selection Costs, Liquidity.

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1. Introduction

Since the influential paper by Bagehot (1971), the impact of adverse selection costs in liquidity, trading activity, and price formation has become a fundamental notion of the theoretical and empirical research in market microstructure (e.g., Copeland and Galai, 1983; Kyle, 1985; Glosten and Milgrom, 1985, and O'Hara, 1995). Several papers have evaluated the relative importance of adverse selection costs over total market making costs (e.g., Stoll, 1989; Glosten and Harris, 1988; George et al., 1991; Lin et al., 1995, Madhavan et al., 1997; Huang and Stoll, 1997, among others). In all these studies adverse selection costs are characterized as the permanent impact that an unexpected trade produces on the equilibrium value of the stock. These papers usually build on structural models of price formation in which the trading process is exogenous and prices instantaneously reflect all the information conveyed by a trade. Moreover, structural models provide an estimator of the average adverse selection costs for all trades executed during the sample period studied, but are unable to measure the costs of each particular trade. This paper extends this line of research to a trade by trade dynamic framework.

Hasbrouck (1991a,b) suggest a general econometric approach to model the relationship between the trading process, endogenous in this case, and the adjustments of market quotes. The dynamic setting of the Hasbrouk's model enables trades to have lagged effects on market quotes. In this paper, we measure the information-asymmetry risk of each IBM trade executed at the NYSE from February to June 1996 by its estimated long-run impact on the stock price. This permanent impact will depend on certain observable features of the trade, like size (e.g., Easley and O'Hara, 1987) and the time elapsed since the execution of the preceding trade (e.g., Easley and O'Hara, 1992). The effect of price volatility and quoted liquidity are also considered simultaneously. The trade-specific estimator of the adverse selection costs is the impulse-response function of a generalization of the Hasbrouck's (1991a,b) vector autoregressive (VAR) model, derived by dynamic simulation.

Using the structural model suggested by Lin, Sanger and Booth (1995) we evidence that adverse selection costs do increase with the information-asymmetry risk estimated through the impulse-response function of our model. Moreover, information-asymmetry risk is not uniformly distributed along the trading session, consistently with Foster and Viswanathan (1990, 1993) and Madhavan et al. (1997), among others. More important, we show that adverse selection costs estimators based on structural models of quote formation may be biased downward because they do not take into account the lagged effects of trades.

Our procedure also provides an estimation of the period of time that quotes need to adjust to the information carried by each particular trade. It is evidenced that quotes adjust faster during the opening and closing hours of the trading session. Additionally, quote alignments after trades are progressive rather than instantaneous; this fact originates sequences of trades with a similar (but decreasing) information-asymmetry risk. Admati and Pfleiderer (1988) and Holden and Subrahmanyam (1992) suggested that the competition among informed traders increase price efficiency. We do show that the price discovery process improves after risky trades. Trading frequency augments following trades with a higher expected informational content, what suggests an increase in competition among informed traders. This fact accelerates the adjustment of the stock price to the new trade-inferred information.

In accordance with several event studies (e.g., Lee et al., 1993; Koski and Michaely, 2000, and Goldstein and Kavajecz 2000b) it is found that, during the short-term period that follows the execution of a given trade, the illiquidity and the trading activity levels increase with the estimated adverse selection costs. The sensitivity of the market conditions to our trade-specific adverse selection costs measure indicates that observable trade and market characteristics signal the presence of information motivated trades and lead to the incorporation of the new information into prices.

The paper proceeds as follows. Section 2 reviews the VAR model of Hasbrouck (1991a) and motivates the use of the impulse-response function as an estimator of the adverse selection costs. Section 3 describes the data and defines variables. Section 4 discusses the simulation procedure used to estimate the impulse-response function for each trade. Section 5 analyzes the distribution of adverse selection costs through the trading session. Section 6 studies the persistence in the adverse selection costs conditions. Section 7 measures the speed of adjustment of market quotes to the new information inferred from the trading process. Section 8 measures the relevance of adverse selection costs in total market making costs using a dynamic framework. Section 9 compares the behavior of the market after trades with different information-asymmetry risk. Finally, section 10 concludes.

2. The Hasbrouck's (1991a) VAR model and the impulse-response function

Consider the following standard model of quote formation. Let m_t be the efficient price, understood as the expected true value of the stock in some future terminal time κ (ψ_κ) conditional on the available public information set at moment t (Φ_t), $m_t \equiv E[\psi_\kappa / \Phi_t]$. This efficient price follows a random walk process

$$m_t = m_{t-1} + w_t, \tag{1}$$

where the innovation w_t is such that $E[w_t \,|\Phi_{t-1}] = 0$ and $E[w_t w_{t-i} \,|\Phi_{t-1}] = 0$, $\forall\ i\neq 0$. Non-zero values of w_t should be understood as updates of the public information set Φ_t. This new information can be inferred from the trading process or, alternatively, emanate from trade-unrelated sources (like public announcements). Let now s_t be a weakly stationary stochastic process, that is $E[s_t] = 0$, $Var[s_t] = \sigma_s^2$ and $E[s_t s_{t-k}] = \sigma_k$, $\forall k\neq 0$. The variable s_t captures the transitory deviations between the efficient price and market quotes (see (2), where q_t is the quote midpoint). This transitory component is due to market frictions, operative costs and inventory holding costs.

$$q_t = m_t + s_t. \tag{2}$$

The stationary characterization on the transitory component guarantees that any shock affecting s_t will only have a temporal effect on quotes. On the contrary, a shock that affects to w_t will have a permanent impact on quotes, because it alters the expected long-run value of the stock (m_t). As a consequence, a trade may have a permanent and a transitory impact on prices. Let x_t be the trade indicator, equal to 1 for a buyer-initiated trade and –1 for a seller-initiated trade. Denote by $\eta_t = x_t$ - E[x_t/Φ_{t-1}] to the unexpected component of a trade given the public information set, that can be characterized as an i.i.d. $(0, \sigma_\eta^2)$ process. Given that the predictable component of x_t is already incorporated into m_{t-1}, only η_t provides new information to agents. Hence, the permanent impact of a trade in prices will be given by E[w_t/η_t]. Assuming linearity, $w_t = \alpha\eta_t + u_t$, with E[$u_t\ /\eta_t$] = 0 and E[$u_t u_{t-i}/\eta_t$] = 0 $\forall\ i\neq 0$. Therefore,

$$\mathrm{E}[w_t \,|\eta_t] = \alpha\eta_t. \tag{3}$$

The parameter $\alpha>0$ measures the adverse selection costs.

Consider that the public information set in t-1 is exclusively given by the past evolution of trades and quotes, that is $\Phi_{t-1} = \{\Delta q_{t-1}, \Delta q_{t-2}, \ldots, x_{t-1}, x_{t-2}, \ldots\}$. Under this hypothesis Hasbrouck (1991a,b) introduces an econometric methodology to model the dynamic relationship between the trading process and the adjustment of market quotes. This methodology is based on a general VAR model like (4),

$$\begin{aligned} \Delta q_t &= \sum\nolimits_{i=1}^{\infty} a_i \Delta q_{t-1} + \sum\nolimits_{i=0}^{\infty} b_i x_{t-i} + v_{1,t} \\ x_t &= \sum\nolimits_{i=1}^{\infty} c_i \Delta q_{t-1} + \sum\nolimits_{i=1}^{\infty} d_i x_{t-i} + v_{2,t}. \end{aligned} \tag{4}$$

The revision in market quotes $\Delta q_t = (q_t - q_{t-1})$ represents the change in the midpoint of the bid-ask spread after a trade in t (x_t). The terms $v_{1,t}$ and $v_{2,t}$ are zero-mean mutually and serially uncorrelated and homokedastic stochastic processes. The variable $v_{1,t}$ represents new trade-unrelated information. On the contrary, $v_{2,t}$ is the unexpected component of the trade (η_t in (3)). As in the previous structural model, the VAR model assumes that causality flows from the trading process to market quotes. Under orthogonality, $\mathrm{Cov}(v_{1,t}, v_{2,t}) = 0$, the system in (4) can be efficiently estimated equation by equation using Ordinary Least Squares (OLS).

The VAR methodology turns out to be more flexible than the structural models of quote formation. First, the trading process is not exogenous to the model. Second, the information provided by a trade does not need to be incorporated instantaneously into prices. Hence, a trade may have lagged effects on prices. Finally, the VAR model does not require of a correctly specified underlying structural model; despite that, Hasbrouck (1991a) shows that the VAR model captures, as special cases, the main dynamics behind those structural models of quote formation (see also Escribano and Pascual, 2000). But the VAR model has some important drawbacks from an econometric point of view. The homokedasticity assumption in the distribution of $v_{1,t}$ and $v_{2,t}$ appears to be restrictive given the vast evidence about intraday deterministic patterns in volatility (e.g., Harris, 1986; McInish and Wood, 1990a,b; Werner and Kleidon, 1995). In any case, defining the model in trade-time should mitigate the effect of a latent heterokedasticity.[1] In addition, Escribano and Pascual (2000) show that there is an important loss of information in averaging the quote behavior through the quote midpoint. These authors propose a vector error correction model (VEC) for ask and bid prices, with the bid-ask spread as the error correction term, that generalizes the VAR model. Hasbrouck (1991a,b), Hasbrouck (1993), de Jong et al. (1995), Hasbrouck (1996), and Dufour and Engle (2000), among others, discuss other controversial aspects related to the estimation of the VAR model, like the linearity structure and the independence between $v_{1,t}$ and $v_{2,t}$.

By the Wold Theorem (e.g., Hamilton, 1994) the vector $\{\Delta q_t, x_t\}$, being weakly stationary and non-deterministic, has a vector moving average (VMA) representation like (5), maybe of

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[1] Hasbrouck (2000) introduces a model for ask and bid quotes in which the innovations in the efficient price are generated by an EGARCH model. Hausman et al. (1992) analyzes changes in prices using an ordered probit model, without forcing homokedasticity. However, in these models the trading process is endogenous.

infinite order. The $\theta_j(L)$ terms, j={1,...,4}, are polynomials in the lag operator L ($L^k y_t = y_{t-k}$).

$$\begin{bmatrix} \Delta q_t \\ x_t \end{bmatrix} = \theta(L) v_t = \begin{bmatrix} \theta_1(L) & \theta_2(L) \\ \theta_3(L) & \theta_4(L) \end{bmatrix} \begin{bmatrix} v_{1,t} \\ v_{2,t} \end{bmatrix}. \tag{5}$$

The polynomial $\theta_2(L) = (\theta_{2,0} + \theta_{2,1} L + \theta_{2,2} L^2 + \cdots)$ represents the dynamic relationship between the unexpected component of a trade ($v_{2,t}$) and the posterior adjustment of market quotes. Thus, after a unitary shock in the trading process ($v_{2,t}$=1) the long-term impact on quotes could be measured by the sum of all the coefficients of that polynomial (see (6)).

$$I_\infty(\Delta q_t / v_{2,t}) = \theta_2(1) v_{2,t} = \sum_{i=0}^{\infty} \theta_{2,i} v_{2,t}\,. \tag{6}$$

The plot of $\partial \Delta q_{t+k} / \partial v_{2,t}$ for k={0,1,2,3...} is usually known as the impulse-response function. Hasbrouck (1991b) suggest using the variance of (6) as an absolute measure of the informativeness of trades provided that $I_\infty(\Delta q_t / v_{2,t})$ is an estimator of (3).

In this paper we use a generalization of the Hasbrouck (1991a) model that, following Dufour and Engle (2000) and Escribano and Pascual (2000), is given by

$$\begin{aligned} \Delta q_t &= \sum_{i=1}^{\infty} a_i \Delta q_{t-i} + \sum_{i=0}^{\infty} \left[\alpha_i^q + \beta_i^{q\prime} MC_{t-i} + \sum_{h \neq 4} \lambda_h^q D_{t-i}^h \right] x_{t-i} + v_{1,t} \\ x_t &= \sum_{i=1}^{\infty} c_i \Delta q_{t-i} + \sum_{i=1}^{\infty} \left[\alpha_i^x + \beta_i^{x\prime} MC_{t-i} + \sum_{h \neq 4} \lambda_h^x D_{t-i}^h \right] x_{t-i} + v_{2,t}. \end{aligned} \tag{7}$$

The vector MC_t includes the set of exogenous variables that characterize the trade and its market environment. Vectors β_i^q and β_i^x have dimension kx1, where k is the number of variables in MC_t, specified latter on. The vector D_t contains dummy variables that locate the trade inside the trading session. Therefore, the public information set is now given by

$$\Phi_{t-1} = \{\Delta q_{t-1}, \Delta q_{t-2}, \ldots, x_{t-1}, x_{t-2}, \ldots, MC_{t-1}, MC_{t-2}, \ldots, D_{t-1}, D_{t-2}, \ldots\}.$$

The information-asymmetry risk associated to each trade is estimated through the impulse-response function associated to this model.

The results in the Melbroeck's (1992) insider trading research show that information-motivated trading is detected via trade-specific characteristics. Microstructure theory has identified several variables that may influence on the impact of a trade in prices. Easley and O'Hara (1987), Glosten and Harris (1988), and Hasbrouck (1988), among others, suggest that large-sized trades may hide impatient traders with a perishable informational advantage. The relevance of trade size in the VAR methodology was already evidenced by Hasbrouck (1991a). Easley and O'Hara (1992) propose a model in which less time between consecutive trades is an indicator of new information arriving at the market. Dufour and Engle (2000) test the predictions of Easley and O'Hara's model using the VAR methodology. Copeland and Galai (1983), French and Roll (1986), and Bollerslev and Melvin (1994), among others, manifest the relevance of price volatility in determining liquidity in general and market quotes in particular. In this paper volatility is introduced in the VAR model as a determinant of the impact of a trade in prices. It is measured by the implicit volatility in the change of market quotes (Δq_t), estimated using a GARCH-type model (e.g., Bollerslev, 1986). Finally, adverse selection costs and liquidity are negatively related (e.g., Glosten and Milgrom, 1985; Kyle, 1985; Huang and Stoll, 1997; Kavajecz, 1999). Following the current trend (e.g., Lee et al., 1993; Goldstein and Kavajecz, 2000a,b; Jones and Lipson, 2000, and Corwin and Lipson, 2000), in this paper liquidity is measured by both immediacy costs and depth. All these perfectly observable variables will be included in MC_t.

3. Data

The VAR model (7) is estimated for IBM using trade and quote data from the TAQ database of the NYSE. All the trading days from January to June 1996 are considered. IBM was one of the most frequently traded stocks during the sample period. This guarantees a number of observations large enough to perform the posterior empirical analysis. We only keep trades and quotes from the primary market (NYSE). Data from the regional exchanges is not considered. Trades not codified as "regular trades" have been discarded. Trades performed at the same market, at the same price, and with the same time stamp are treated as just one trade. All quote and trade registers previous to the opening quote or posterior to the 16:00, the official closing time, are dropped. The overnight changes in quotes are treated as missing values. Quotes with bid-ask spreads lower than or equal to zero or quoted depth equal to zero have also been eliminated. When prices and quotes must be considered together, the so-called "five seconds rule" (see Lee and Ready, 1991) has been applied. This rule assigns to each trade the first quote stamped at least five seconds before the trade itself.

Following previous empirical studies, a trade is classified as buyer (seller) initiated when the price is closer to the ask (bid) than to the bid (ask). From now on, first ones are called "buys" and the second ones are called "sells". The trade indicator x_t equals 1 for buys, -1 for sells, and 0 for trades with execution price equal to the quote midpoint. A change in quotes is computed as the difference between the quote associated to the trade at t+1 and the quote associated with trade at t: $\Delta q_t=(q_t - q_{t-1})$. Eight trading-time dummies are constructed: one for trades during the first half-hour of trading, five for each trading hour between 10:00 a.m. and 15:00 p.m. and, finally, the last trading hour has been divided in two half-hour intervals. This procedure isolates the opening and closing periods of the session.

Five exogenous variables are included in vector MC_t. The trade size, measured by the number of shares (V_t). The time in seconds since the previous trade (T_t). Immediacy costs, measured by the quoted bid-ask spread (S_t). Quoted depth (QD_t), computed as the average between the number of shares offered at the best ask and bid prices. Volatility (R_t), measured by the implicit volatility in the time series of Δq_t (σ_t^2), obtained using the GARCH(1,1) model (8), estimated by maximum likelihood and with the robust variance-covariance matrix of Bollerslev and Wooldridge (1992) (see Bollerslev, Chou and Kroner, 1992, and Bollerslev, Engle and Nelson, 1994 for reviews of this type of models).[2] All coefficients are statistically significant.

$$\begin{cases} \Delta q_t = (.0309)\varepsilon_{t-1} + \varepsilon_t \\ \sigma_t^2 = (2.2\text{E}-5) + (.0235)\sigma_{t-1}^2 + (.9664)\varepsilon_{t-1}^2 \end{cases} \tag{8}$$
$$Adj - R^2 : 0.001497,\ \text{Prob(F)} = 0.0000$$

Next section exposes the dynamic simulation procedure used to estimate the information-asymmetry risk associated to each IBM trade executed during the sample period analyzed.

4. Estimation of the trade-specific information-asymmetry risk

The impulse-response function of (7) is our estimator of the trade-specific adverse selection costs. The VMA representation of (7) is approximated by Monte Carlo simulation (notice that the model is non-linear). The simulated impulse-response function provides an estimation of the accumulated impact of each trade on quotes, conditional on market

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[2] This model offers the best fitting among all those tested, including ARCH and EGARCH models.

conditions and trade features. Denote this conditional accumulated impact by $I_t(\Delta q_t \mid v_{2,t}, MC_t, D_t)$. A larger expected impact should be interpreted as a higher information-asymmetry risk associated to the trade.

To perform the simulation we need to define a generating process for $MC_t' = (V_t, T_t, S_t, QD_t, R_t)$. It is assumed that each component of MC_t follows a general probabilistic process, exogenous to the model (7), approximated by a linear autoregressive model AR(p_k) like (9), where p_k, k={1,...,5}, must be determined empirically. Model (9) is estimated by GLS, and dummy variables are included to control for the deterministic intraday components.

$$\theta_p^k(L)MC_t^k = \sum_{h=1}^{8} \varphi_h^k D_t^h + u_{k,t}. \tag{9}$$

Once (7)-(9) have been estimated, the simulation procedure for each of the IBM trades will be the following:

Step #1: Use (9), k={1,...,5}, to predict the future values of MC_t needed to proceed with the simulation of (7). Assume that $u_{k,t} \sim N(\mu_k, \sigma_k^2)$, where μ_k and σ_k^2 are estimated through the mean and variance of the GLS residuals of (9). The initial conditions MC_{t-i}^k for i=1,...,p_k and $\forall$ k, correspond to the values associated to the p_k trades that precede the one simulated.

Step #2: Obtain the impulse-response function of (7), n periods into the future, using the predicted values of MC_t^k for k={1,...,5} in step #1. In order to do that, assume that every trade generates a unitary shock ($v_{2,t} = 1$) and is executed after a steady state period, defined by $x_{t-1} = \cdots = x_{t-5} = 0$ and $\Delta q_{t-1} = \ldots = \Delta q_{t-5} = 0$.[3] This simulation exercise leads to a realization of the impulse-response function for a given MC_t path. The accumulated impact $\tilde{I}_t^j(\Delta q_t \mid v_{2,t}, MC_t, D_t)$ for the case of infinite order polynomials appears in equation (10). The asterisk means a simulated value, not observed.

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[3] Obviously, trades were not generally executed after such a steady state period. However, this hypothesis allows isolating the impact associated to a trade from the impact of previous trades.

$$\tilde{I}_t^{\,j}(\Delta q_t \mid v_{2,t}, MC_t, D_t) = \sum_{y=1}^{n} a_y \left[\sum_{i=1}^{n-y} \Delta q_{t+i}^{*} \right] + \sum_{y=0}^{n} \alpha_y^q \left[\sum_{i=1}^{n-y} x_{t+i}^{*} + v_{2,t} \right] +$$

$$+ \sum_{y=0}^{n} (\beta_y^q)^T \left[\sum_{i=1}^{n-y} (MC_{t+i}^{*} + \lambda^{q\prime} D_{t+i}^{*}) x_{t+i}^{*} + (MC_t + \lambda^{q\prime} D_t) v_{2,t} \right]. \qquad (10)$$

Step #3: Repeat steps #1 and #2 10.000 times. The 10.000 estimated conditional values for each step n_j (j=1,...,n) of the impulse-response function are averaged to obtain the final impulse-response function of the trade,

$$\tilde{I}_t \ (\Delta q_t \mid v_{2,t}, MC_t, D_t) = \frac{1}{10.000} \sum_{i=1}^{10.000} \tilde{I}_t^{\,i}(\Delta q_t \mid v_{2,t}, MC_t, D_t). \qquad (11)$$

In this paper n=50, a period we will evidence to be more than enough for prices to reflect all the information impounded by a trade. The order of the autoregressive process in (9) depends on the variable considered, but it is never greater than $p_k = 5$ (likelihood ratio tests show that longer lags are not statistically significant for any MC_t^k). Moreover, following Hasbrouck (1991a,b), de Jong et al. (1995), Dufour and Engle (2000) and Escribano and Pascual (2000), the polynomials in the VAR model (7) are truncated at lag five.

Some trades in the sample period are not simulated. The expected impact of a given trade should depend on the impact of similar preceding trades. For that reason, the expected impact of the first trade in February is obtained with the VAR model (7) estimated using all trades in January (around 24.000 trades). The simulation of the second trade in February is obtained using the VAR model estimated with the data of all the trades in January but the first one and adding the formerly simulated trade, and so on. In this manner, the coefficients of the VAR model are also actualized in the midterm. This implies that trades in January are not going to be simulated. Because of the definition of the trade indicator x_t, it is not possible to simulate trades with execution price equal to the quote midpoint ($x_t = 0$). Finally, the conditional expectation of x_t has to take values in the range of possible values [-1, 1] during all the simulation steps, something that may not be the case for extreme values of MC_t. Through the simulation procedure this observations are identified and discarded from the study. At the end, nearly 80.000 trades remain.

All dummies, except the one corresponding to the 12:00-13:00 interval (D_t^4), were included initially in the estimation interacting with contemporaneous and lagged values of the trade indicator x_t. Nonetheless, preliminary F tests showed that only the dummy variables affecting to the contemporaneous value of x_t were jointly statistically significant. Moreover, only the dummy corresponding to the first trading interval (9:30-10:00 a.m.) resulted statistically significant at the 5% level. Therefore, the VAR model finally estimated is (12),

$$\begin{aligned} \Delta q_t &= \sum_{i=1}^{5} a_i \Delta q_{t-1} + \sum_{i=0}^{5} \left[\alpha_i^q + \beta_i^{q}{}' MC_{t-i}\right] x_{t-i} + \lambda_1^q D_t^1 x_t + v_{1,t} \\ x_t &= \sum_{i=1}^{5} c_i \Delta q_{t-1} + \sum_{i=1}^{5} \left[\alpha_i^x + \beta_i^{x}{}' MC_{t-i}\right] x_{t-i} + \lambda_1^x D_t^1 x_{t-1} + v_{2,t}. \end{aligned} \tag{12}$$

Table I displays the estimated coefficients of the VAR model (12) using all trades executed from January to June 1996 (both included). Results coincide with those found in previous research: a large-sized trade, executed a few seconds since the previous trade, in a period of high volatility and poor quoted liquidity has a larger expected impact on quotes, consistently with the adverse selection costs models previously referenced.

[Table I]

As an example, Figure 1 shows the estimated impulse-response function for a buy trade executed at 9:37:50 a.m., with V_t = 1.000 shares, T_t = 2 seconds, S_t = US$ 0.25, QD_t = 2.500 shares and R_t = 0,00278.

[Figure 1]

To compute the information-asymmetry risk that corresponds to a given trade (ASC_t), we first locate the step τ of the simulation that reaches the 99% of the total estimated impact. For the trade in Figure 1, this percentage is achieved at the point marked by the vertical plane (τ = 25). Notice that the variable τ will be an estimator of the time (in number of trades) required for prices to reflect all the information carried by the trade. The accumulated impact at this point is our estimation of the adverse selection costs for a particular trade. For the trade in Figure 1, ASC_t = US$ 0.1099.

Figure 2 displays the empirical distribution of the absolute value of ASC_t for all trades simulated. Using the percentiles of this distribution, trades are classified in five groups, ASC(1) to ASC(5), from lower to higher adverse selection cost. One trade belongs to ASC(1) if $|ASC_t| < P(0.25)$, to ASC(2) if $P(25) \leq |ASC_t| < P(50)$, to ASC(3) if $P(50) \leq |ASC_t| < P(75)$, to ASC(4) if $P(75) \leq |ASC_t| < P(95)$ and, finally, to ASC(5) if $|ASC_t| \geq P(95)$, where P(y) represents the value of the y% percentile. Reference values are $P(25) = 0.0503$, $P(50) =$

0.0629, $P(75) = 0.0855$ and $P(95) = 0.1292$. Therefore, the trade in Figure 1 belongs to ASC(4).

[Figure 2]

5. The intraday distribution of adverse selection costs.

Empirical evidence suggests that adverse selection costs are not uniformly distributed throughout the trading session (e.g., Wei, 1992; Foster and Viswanathan, 1993; Lin et al., 1995, and Madhavan et al., 1997). Usually, adverse selection costs decrease towards the end of the session, sometimes (see Madhavan et al., 1997) together with an increase in inventory holding costs. This result could be explained by a higher concentration of information-motivated versus liquidity-motivated trades during the initial intervals of the trading session.[4]

Figure 3 shows the empirical distribution of IBM trades by trading hour and adverse selection costs level, measured by ASC_t. The number of trades corresponding to the time intervals [9:30,10:00), [15:00,15:30) and [15:30,16:00) has been multiplied by two in order to get comparable magnitudes. Bands of the same color represent the percentage of trades belonging to ASC(j), j={1,...,5}, executed in each "hourly" interval. Thus, the eight bands of the same color sum to the 100%. The column height is the sum of all five percentages per interval; larger columns represent more intense trading periods. Figure 3 shows that the distribution of the trading activity exhibits the usual U-shaped pattern. Additionally, trades with higher expected adverse selection costs, ASC(4) and ASC(5), are concentrated at the extremities of the session: between 9:30 a.m. and 11:00 a.m. and between 3:00 p.m. and 4:00 p.m. The 61% of all trades belonging to ASC(5) were performed during the opening (47%) and closing (14%) half-hours. Similarly, the 74% of all trades classified as ASC(4) were accomplished during these extreme intervals of the session, the 44.4% during the opening and closing half-hours, and the 25.66% only during the first half-hour. The opposite occurs with those trades with the lowest expected adverse selection costs. ASC(1) trades are detected mainly in the middle of the session and only the 5.14% were executed during the first half-hour of trading.

[Figure 3]

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[4] There is also empirical evidence about regular patterns in volume and volatility (e.g., Harris, 1986; Jain and Joh, 1988; McInish and Wood, 1990a,b), and liquidity (e.g., McInish and Wood, 1992; Lee et al., 1993, Chan et al., 1995a,b) consistent with regular intraday differences in market making costs. Admati and Pfleiderer (1988), Brock and Kleidon (1992), Harris and Raviv (1993) and Handa and Schwartz (1996) offer alternative explanations for these deterministic findings.

Previous results manifest that the risk of trading with an informed agent is the highest during the opening intervals of each session (e.g., Foster and Viswanathan, 1990). The ASC(5) and ASC(4) trades represent more than the 50% of all trades observed between 9:30 a.m. and 10:00 a.m., something that does not occur in any other hourly interval. At closing high risk trades are the 32.19% of all trades executed. On the contrary, ASC(1) and ASC(2) trades represent the 25.15% of all trades during the opening period versus the 65.93% between 1:00 p.m. and 2:00 p.m.

6. Risk persistency

The statistical significance of some lagged values of the trade indicator x_t in the estimation of model (12) (see Table I) implies that all the information carried by a trade is not instantaneously incorporated into prices. On the contrary, the model predicts a progressive adjustment of market quotes.[5] If this were the case, it should be expected to find additional trades taking profits from the temporal divergence between market quotes and the efficient price. Therefore, we should observe sequences of trades with similar (but decreasing) values of ASC_t. This section studies this possible short-run persistency in the information-asymmetry risk by modeling the time series of ASC_t.

The usual unit-root tests (extended Dickey and Fuller, 1979, and Phillips and Perron, 1988) show that ASC_t is an I(0) process. Moreover, the autocorrelation and partial autocorrelation functions indicate that ASC_t can be modeled as an autoregressive process of finite order (AR(p)), with p at least equal to 3. The information inferred from the trading process and the possible transitory deviation between m_t and q_t are both expected to increase with ASC(j), j={1,...,5}. Thus, our intuition is that the magnitude of the autoregressive coefficients of the AR(p) model should also increase with the estimated adverse selection costs level for the trade at time t. We proceed with the estimation of the truncated AR(5) model (13) for the time series of ASC_t using the Generalized Least Squares (GLS) method. This model includes the dummy variables Q_t^j, j={1,...,5}, such that Q_t^j equals 1 if $ASC_t \in ASC(j)$ and 0 otherwise.[6] These dummy variables define five thresholds in the autoregressive structure of ASC_t. The variable u_t is the error term of the model. Table II summarizes the estimation.

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[5] Hasbrouck (1996) remarks that NYSE specialists are obliged to avoid large variations in the stock price, which forces them to adjust the market quotes in a gradual manner.

[6] We have also considered an alternative specification for (13) using the dummy variables D_t instead of Q_t to truncate the AR(5) structure. This alternative model would capture differences in the AR(5) coefficients per trading hour. The statistical tests performed do not allow us to reject the null hypothesis of an equal AR(5) structure across trading hours. Therefore, we conclude that the results in Table II do are due to differences in adverse selection costs and are not biased by any intraday regular pattern.

$$ASC_t = \sum_{j=1}^{5}\left(\sum_{p=1}^{5}\phi_p^j ASC_{t-p}\right)D_t^j + u_t \qquad (13)$$

[Table II]

Table II reveals significant differences in the autocorrelation structure of the time series ASC_t across the five levels of adverse selection costs previously defined. Using the Wald test (e.g., Davidson and MacKinnon, 1993) we reject (at the 5% level) the null hypothesis that the sums of the autoregressive coefficients corresponding to each pair ASC(j) and ASC(k), with $j \neq k$, are equal. The sum of the autoregressive coefficients increases with ASC(j), $j=\{1,\ldots 5\}$, meaning that trades with a high information-asymmetry risk (high ASC_t value) are followed by similar risky trades more likely than trades with low information-asymmetry risk (low ASC_t value) are followed by akin trades. In summary, Table II shows that the information-asymmetry risk persists after the execution of a risky trade. Risk persistency does augment with the adverse selection costs associated to the reference trade at time t.[7]

7. How fast do market quotes reflect the information inferred from trades?

The simulation of the VAR model (12) produces two outputs: a trade-specific adverse selection costs measure (ASC_t) and an estimation of the time (in number of events) that quotes require to incorporate all the information provided by a particular trade (τ_t). This last estimation of the time needed for quote adjustment has been transformed into real time using the distance in seconds between the time stamp of the simulated trade and the time stamp of the τth trade executed afterwards. Denote $D(\tau)_t$ to the series formed by the real-time distances obtained for all the IBM trades simulated. This section studies whether this time of adjustment depends on the market conditions and the particular characteristics (MC_t) of the corresponding trades. Table III summarizes the results of estimating the regression equation (14) using OLS robust to general heterokedasticity and autocorrelation in the error terms (Newey and West, 1987).

$$D(\tau)_t = \delta_0 + \delta_1' MC_t + \sum_{\substack{j=1 \\ j\neq 4}}^{8}\gamma_j D_t^j + u_t\,. \qquad (14)$$

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[7] Risk persistency could also be evaluated by applying the extended Dickey-Fuller unit roots test to each threshold in (13). However, the t statistics of such a test are neither standard nor currently tabulated. It should be necessary to obtain the critic values by simulation, something that is out of the scope of this paper.

For simplicity, we assume linearity in the specification. In order to control for the regular patterns in trading frequency evidenced in previous section, we include the dummy variables D_t^h (12:00-13:00 is the control interval).

[Table III]

As expected, the duration of the process of quote accommodation to the information revealed by a trade depends on the moment of execution. During the less frequently traded hours (between 12:00 and 14:00), the period of quote adjustment could go on around 12 minutes ($\delta_0/60$). However, if the trade is executed during the first half-hour of the trading session, this time is reduced to 7.5 minutes ($(\delta_0+\gamma_1)/60$), approximately. Moreover, Table III shows that the adjustment period shortens with trade size and volatility; on the contrary, it lengthens with liquidity and the time since the execution of the preceding trade. Collectively, the higher the expected adverse selection costs, the shorter the adjustment period.

We hypothesize that this last finding is due to an increase in the trading intensity following trades with high information-asymmetry risk, what accelerates the process of price discovery. The increase in the trading intensity may reflect the sequential reaction of the market to the same informative signal, the imitative behavior by other agents in the market, or even order-splitting by the same agent (see Easley and O'Hara, 1987; Biais et al., 1995, and He and Wang, 1995). As the results in the previous section suggest, the temporal disagreement between quoted prices and the efficient price may induce competition among traders. Admati and Pfleiderer (1988), Easley and O'Hara (1992), and Holden and Subrahmanyam (1992) develop alternative models in which competition among informed traders favors price efficiency, specially if these traders' activity is based on the same informative signal. Our results imply that prices respond more quickly after a trade when adverse selection costs increase, which is consistent with this competitive argument and also with insider trading research findings (e.g., Holthausen et al., 1990, and Lin and Rozeff, 1995). Section 9 will provide additional evidence that supports this hypothesis of "market acceleration" after an informative trade.

Huang and Stoll (1996) measured the impact of a trade at time *t* by $(q_{t+\tau^*} - q_t)x_t$, where $q_{t+\tau^*}$ is the quote midpoint associated to the first trade executed (at least) τ^* minutes later. The value of τ^* is the same for all trades and arbitrarily fixed. Huang and Stoll (1996) used this measure to compare the adverse selection costs of a matched sample of NYSE and Nasdaq listed stocks. The evidence in this section indicates that the results of Huang and Stoll (1996) are biased because the value of τ^* depends on the moment of execution, the concrete characteristics of the trade and the specific market conditions. Moreover, the value of τ_t for a given trade may differ under different microstructures, which seems an interesting topic for future research.

8. The relevance of adverse selection costs in a dynamic context

A very prolific and successful line of research in microstructure has focused on the evaluation of the relative importance of the different market making costs: operative costs (see, Demsetz, 1968, and Roll, 1984), inventory holding costs (see Amihud and Mendelson, 1980; Ho and Stoll, 1981 and 1983) and adverse selection costs. Several researchers have proposed alternative procedures to separate the also called immediacy costs (e.g., Stoll, 2000) in their theoretical components (e.g., Glosten and Harris, 1988; Stoll, 1989; George et al., 1991; Madhavan et al., 1997, and Huang and Stoll, 1997, among others). The basic principle behind all these studies is that adverse selection costs can be estimated through the revision in the expectations about the true value of the stock after each new transaction (see also Glosten and Milgrom, 1985). This is, precisely, what founds the use of the impulse-response function (10) as a trade-specific measure of adverse selection costs. Most of the studies previously referenced are based on structural models that explain the process of price discovery, where the trading process causes permanent and transitory effects in market prices. In these models it is assumed that all the information carried by a trade is incorporated instantaneously into prices. Therefore, trades have no lagged effects on prices. However, the results in previous sections suggest that market quotes adjust progressively, because the initial impact of the trade does not reflect all the new information. Using the procedure suggested by Lin et al. (1995), we show that rejecting the existence of these lagged effects downward biases the estimation of the adverse selection costs component using structural models.[8] Equation (15) summarizes the method proposed by Lin et al. (1995),

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[8] We choose Lin et al. (1995) because it is one of the most used models (e.g., Brockman and Chung, 1999). Moreover, this method does not require the estimation of a dynamic equation; so, our estimation results will be less affected by the elimination of those trades that could not be simulated (see section 4). As far as we know, there is no study making a "horse race" with all these methods, something that is really surprising given that the empirical results of all these models are quite inconsistent. Considering all trades executed from January to June 1996, we obtain that, in average, adverse selection costs represent the 7,66% of all market making costs using Madhavan et al. (1997), 16% using Lin et al. (1995), 21% using Glosten and Harris (1988) and almost negligible using Huang and Stoll (1997). Although Huang and Stoll (1997) is, probably, the most general model, its main advantage lies in the fact that it allows to distinguish between inventory holding and operative costs. Our interest, however, is focused on adverse selection costs only. Finally, the parametric simplicity of the Lin et al.'s (1995) model facilitates to perform certain extensions directed to control for several factors.

$$(q_t - q_{t-1}) = \delta(P_t - q_{t-1}) + e_t, \tag{15}$$

where P_t represents the execution price of the trade, e_t is the error term and $|P_t - q_{t-1}|$ is the half-effective spread. The parameter δ measures adverse selection costs; notice that δ is the percentage of the effective spread that is not realized due to the immediate change in the midpoint of the bid-ask spread after the trade. Under the assumption that trades incorporate at once the information revealed by the trade, this immediate change equals the total impact of the trade. Using the sample of all trades previously simulated, equation (15) is estimated by OLS robust to any potential heterokedasticity and autocorrelation of unknown form in the error terms (Newey and West, 1987). According to the Lin et al.'s (1995) model, adverse selection costs for the sample of simulated trades supposes the δ = 26.3% of the full immediacy costs.

The first column of coefficients in Table IV shows the results of the estimation of equation (16) using again the Newey and West (1987) method. This model is a generalization of (15) that controls for several regularities: the trading interval (by means of the dummy variables D_t^h, h={1,...,8}) and the risk of asymmetric information (by the dummy variables Q_t^j, where Q_t^j equals 1 if $ASC_t \in ASC(j)$, j={1,...,5}, and 0 otherwise). The variable u_t is the error term.

$$\Delta q_t = \delta_0(P_t - q_{t-1}) + \sum_{j=2}^{5}\left[\delta_Q^j(P_t - q_{t-1})\right]Q_t^j + \sum_{\substack{h=1\\h\neq 4}}^{8}\left[\delta_D^h(P_t - q_{t-1})\right]D_t^h + u_t \tag{16}$$

Table IV shows that the percentage of total immediacy costs due to adverse selection costs significantly augments with ASC(j), from the 15,97% for ASC(1) trades to the 29,95% for ASC(5) trades. Only one intraday effect becomes statistically significant: for trades executed during the first half-hour of trading the percentage of market making costs due to adverse selection costs increases in 2,55 percentage points. We replicate the previous estimation exercise using the results of our simulation exercise. The second column of coefficients in Table IV contains the estimation of (16) but replacing the dependent variable Δq_t by the initial impact of the trade obtained from the simulation of the VAR model (12). Again, adverse selection costs increase from the 16.14% for ASC(1) trades to the 26,28% for ASC(5) trades. These percentages are much the same as those obtained with the observed data. With the simulated initial impacts, the percentage of immediacy costs due to adverse selection costs increases for trades accomplished during the initial and final hourly intervals of the session. If only the initial impact of the trade is considered, adverse selection costs represent, in average terms, no more than the 30-32% of the effective spread.

However, as previous simulation and estimation results indicated, the total impact of a trade is more than the initial adjustment of quotes. There are significant lagged effects, probably linked with a progressive adjustment of market quotes to the new information. For each trade, we compute the ratio of the total impact obtained by the simulation of (12) to the half-effective spread,

$$\tilde{I}_t^{\tau}(\Delta q_t / v_{2,t}, MC_t, D_t)/|P_t - q_{t-1}|.$$

In medians, the simulated total impact represents the 66% of the effective spread for ASC(1) trades, the 80% for ASC(3) trades and more than the 100% for ASC(5) trades. This result manifests that adverse selection costs in a dynamic framework are more important than what the current structural model's estimators would suggest. The quoted spread for a frequently traded stock like IBM (most of the time equal to the tick, US$ 1/8 in 1996) does not compensate the costs of providing liquidity to high expected adverse selection costs trades.

9. Adverse selection costs and market behavior

This section focuses on the market behavior during the short-term period that comes after the execution of a trade. We analyze whether this behavior depends on the adverse selection costs expected for that trade. There is a lot of empirical evidence about unusual market patterns around localized informative events. The quoted liquidity, the market activity and the volatility of prices experiment anomalous behaviors around profit (e.g., Lee et al., 1993, and Krinsky and Lee, 1996), corporate takeovers (Foster and Viswanathan, 1994) and dividend (e.g., Venkatesh and Chiang, 1986, and Koski and Michaely, 2000) announcements. Recently, similar behaviors have been evidenced around trading halts (Corwin and Lipson, 2000, and Goldstein and Kavajezc, 2000b) and changes in monetary policy (Kavajecz, 1999). These unusual patterns generally consist on increased trading activity, volatility and illiquidity (in terms of wider spreads and smaller depth) both before and after the event. The pre-event behavior is attributed to the enlargement of the information asymmetries between informed an uninformed traders generated by the anticipation of the informative shock (e.g., Kim and Verrecchia, 1991, and Seppi, 1992). Post-event behavior is more difficult to interpret. If the public announcement resolves the information asymmetry, the market should return to its non-event behavior. Nonetheless, Kim and Verrecchia (1994) suggest a model in which certain traders are able to make superior judgments from earning announcements than others. This situation increases information asymmetry after the announcements and produces less liquidity and the possibility of more trading activity and volatility.

We consider the fifteen minutes interval that follows the execution of each particular trade.[9] We focus on market behavior during the post-event period because the adverse selection costs estimator (ASC_t) measures the permanent impact of the unexpected (and therefore not anticipated) component of a given trade. The market behavior prior to the trade cannot be attributed to that trade. Our null hypothesis is that, after a trade, the trading activity, the price volatility and the illiquidity of the stock increase with the adverse selection costs estimated for that trade. In this study, any unusual post-event market behavior may be imputed to the greater information content of high-ASC_t trades and the progressive adjustment of market quotes to that information (both already evidenced in previous sections).

Event studies compare the periods surrounding the events under analysis with a benchmark that is not influenced by such (or other) informational events. Such a methodology is not workable in our case because our events (trades) are not isolated from other similar events. Hence, the behavior of the market after a specific trade should depend not only on its information-asymmetry risk but also on the risk of the subsequent trades. It has been evidenced in previous sections that trades are usually followed by additional trades with a similar risk of being motivated by new information. This phenomenon produces clusters of trades that can be differentiated by the average level of adverse selection costs. Clusters of trades with a similar ASC(j) level, of equal sign and that are close in time can be associated to the same informational event. So, we proceed by filtering the sample in order to avoid possible biases in posterior tests induced by the presence of these groups of trades linked to the same informational signal. When we observe a sequence of buys or sells with the same ASC(j) level that are very close one to the others, only the first trade of the sequence is included in the subsequent tests.[10]

Market behavior is represented by means of three dimensions: activity, volatility and liquidity. The number of trades executed and the accumulated volume (in number of shares)

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[9] We consider 15 minutes because the results in Table III indicate that the impact of a trade can take around 12 minutes, in average, to be negligible.

[10] In order to determine when successive trades are "very close in time" we compute the median of the seconds between two consecutive trades belonging to the same ASC(j) level, with j={1,...,5}. These medians are 30 for ASC(1) trades, 24 for ASC(2) and ASC(3) trades, 17 for ASC(4) trades and 13 for ASC(5) trades. If the time between to consecutive trades of the same type is less than the corresponding median, these trades are considered as originated by the same informative event. The analysis has been repeated using other criterions to filter the

measure market activity. Volatility is characterized by the variability of the ask (bid) price after buys (sells). Liquidity is measured in terms of both quoted spread and quoted depth. For each minute $m=\{1,...,15\}$ that comes after a trade time-stamped at t we compute the following variables: (a) the number of shares transacted (Vol_{t+m}). (b) The number of trades reported (NT_{t+m}). (c) The standard deviation of the ask/bid price (VA_{t+m}). (d) The average bid-ask spread (SPT_{t+m}) and (e) the average quoted depth (DPT_{t+m}) both weighted by time.[11]

We use the non-parametric rank test of Krustal and Wallis (1952) for equality of means to compare the previous variables in minutes. Trades are grouped according to the corresponding adverse selection costs level (ASC(j), j={1,...,5}). Activity, liquidity and volatility indicators usually show intraday regular patterns and, as was shown in section 5, adverse selection costs are not uniformly distributed throughout the trading session. Therefore, we also separate trades according to the moment of execution and test for differences in medians between those trades accomplished during the same hourly interval. Comparisons are performed minute by minute. The variables are standardized by hourly interval.[12] Main findings are reported in the Appendix. The tables show the means of each variable by trading period and adverse selection costs level. The Kruskal-Wallis' test is realized against the alternative hypothesis of differences in means and also against the alternative hypothesis of mean of ASC(k) > mean of ASC(z), for k > z, k={2,...,5} and k={1,...,4}. Bold format implies that means are significantly different (at least) at the 5% level in the sense that the mean of ASC(k) > mean of ASC(z), k > z.

Table A.I and Table A.II in the Appendix evidence important differences in trading activity as the risk due to asymmetric information increases. As was suggested in section 7, trades with an high expected information content drive to an increase in the trading intensity, probably due to the successive reaction of the market to the new information and the competition among traders. As a consequence, the trading frequency and the traded volume augment. In most of the hourly intervals analyzed the significant differences extend across the 15 minutes considered, mainly during the first half-hour of the trading session. Differences in

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sample and even using all trades in the sample. The main implications of the findings are equivalent in all cases.

[11] For trades stamped during the last quarter-hour of the trading session (15:45-16:00 h.) the values of all these variables are treated as missing for those minutes that include or exceed the official closing hour (16:00 h.).

[12] The standardization method is robust to outliers. For example, consider the observation that corresponds to the accumulated volume of the fifth minute after a trade time-stamped at 9:58:00 ($Vol_{10:02:00-10:02:59}$). To standardize it, we subtract the median of Vol for all the minutes traded in the period 10:00 a.m. to 11:00 a.m. during all the sample period. This difference is divided by the interquartile range of Vol.

volatility, on the contrary, are much less important. Table A.III shows the average standard deviation of the ask price after buys.[13] Means are increasing with ASC(j), implying that trades with greater adverse selection costs tend to increment the uncertainty about the true value of the stock. But in few cases these differences are statistically significant. Therefore, in a trade by trade basis, we do not found the volatility of quotes during a given interval of the session to depend on the information-asymmetry risk attached to the last trade executed.

Table A.IV in the Appendix evidences that immediacy costs are increasing in adverse selection costs. For most of the trading intervals, the average quoted spread for each adverse selection costs level is statistically different during the 15 minutes analyzed. Wider quoted spreads are the result of the combination of a consumption effect caused by the increase in trading activity and a greater protectionism by liquidity providers facing an increase in adverse selection costs. Regarding the quoted depth, although ASC(5) (ASC(1)) trades are located in periods of higher (lower) depth than the other trades, there is not a strict increasing relationship between the quoted depth and ASC(j). But, it is observed that, during the 15 minutes period, quoted depth tends to increase with less intensity (or even decrease) the higher the risk of asymmetric information assigned to the trade (see Table A.V in the Appendix).[14] Therefore, quoted liquidity after a trade is characterized by higher immediacy costs and a depth level that reverts to its initial level at a more leisurely pace as we rise the adverse selection costs assigned to the trade.

Globally, these findings suggest that agents in the market do base the evaluation of the informational content of trades on observable features (like trade size and time since the previous trade) and in the market situation (like price volatility and liquidity). Afterwards, agents react accordingly to their evaluation, altering (at least) the liquidity of the stock and the intensity of trading. This behavior is independent of the moment of the session.

10. Conclusions

This paper has evaluated the information-asymmetry risk of each IBM trade performed in the NYSE from February to June 1996. The trade-specific estimator of adverse selection costs is the impulse-response function associated to the VAR model introduced by Hasbrouck (1991a): the higher the estimated permanent impact on market quotes for a particular trade the

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[13] Results using the variability of the bid price after sells and the variability of the midpoint of the bid-ask spread after any trade are similar.

[14] Depth quoted at the bid price after sells shows a similar behavior. This table does not report the results of the Krustal-Wallis tests because the casuistic is too much broad.

higher the adverse selection costs. The Hasbrouk's model has been extended to allow conditioning the impact on the simultaneous effect of several trade characteristics and market conditions. This procedure differs from those currently in the literature in several aspects:

(a) It is possible to characterize the adverse selection costs of a particular trade as a function of several variables (like trade size, time since the previous trade performed, liquidity and volatility) acting simultaneously. These variables had been considered independently so far. Thus, the estimated impact of a large-sized trade will be different depending on the quoted spread and depth, the time since the previous trade executed etc.

(b) Current methods that measure adverse selection costs, based on structural models of quote formation, provide an average value for all trades executed during a given sample period, but are not able to obtain a trade-specific estimation. This paper has shown that risky trades are not uniformly distributed throughout the trading session.

(c) Structural models (e.g., Stoll, 1989; Glosten and Milgrom, 1988; Madhavan et al., 1997; Huang and Stoll, 1997) only take into account the instantaneous impact of a trade in prices. On the contrary, the Hasbrouck's (1991a,b) VAR model sets a dynamic framework that makes possible to capture also the lagged effects of trades. Thus, this paper has shown that structural models like Lin et al. (1995) undervalue the relevance of adverse selection costs. Adverse selection costs estimations based on structural models may be biased downward because they do not consider the lagged effects of trades on prices.

(d) The simulation of the VAR model also provides an estimation of the time (in number of events) that quotes require in order to incorporate all the information carried by a particular trade. It has been shown that as the risk of asymmetric information increases the trading activity also augments and this accelerates the process of price discovery.

Finally, this paper has evidenced that the market behavior in the short-term period that comes after a trade depends on the information-asymmetry risk associated to that trade. Differences are especially relevant in terms of activity and liquidity: the 15 minutes that come after a trade are more active and less liquid as the risk of information asymmetries associated to the trade increases. Trade-specific characteristics lead to the market's recognition of informed trading.

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TABLE I

Estimation of the VAR model

This table reports the GLS coefficients of the VAR model in (12) using all IBM trades from January to June 1996 V_t = trade size (in number of shares). T_t = time (in seconds) since the preceding trade. S_t = bid-ask spread. QD_t = quoted depth (average between depth at the ask and depth at the bid prices) R_t = volatility (implicit volatility of Δq_t estimated with a GARCH (1,1) model) q_t = quote midpoint, x_t = 1 for buys, −1 for sells and zero otherwise.

(Coef.x1000)[†]	Δq_t	x_t	(Coef.x1000)	Δq_t	x_t
Δq_{t-1}	**-27.2**	**-4174.8**	$x_t R_t$	**509.9**	
Δq_{t-2}	**22.5**	**296.8**	$x_{t-1} R_{t-1}$	-18.5	**13905**
Δq_{t-3}	**24.8**	**590.8**	$x_{t-2} R_{t-2}$	98.8	**-7018.6**
Δq_{t-4}	**16.3**	**383.8**	$x_{t-3} R_{t-3}$	-36.6	-2871.3
Δq_{t-5}	**13.7**	**383.8**	$x_{t-4} R_{t-4}$	-43.2	**-8484.2**
x_t	-0.7408		$x_{t-5} R_{t-5}$	**237.9**	2427.3
x_{t-1}	**2.4121**	**301.2**	$x_t S_t$	**116.8**	
x_{t-2}	0.2684	**127.7**	$x_{t-1} S_{t-1}$	**17.6**	**853.7**
x_{t-3}	-0.5438	**48.5**	$x_{t-2} S_{t-2}$	**-7.25**	**-102.7**
x_{t-4}	-0.6255	**55.5**	$x_{t-3} S_{t-3}$	**-5.72**	-83.7
x_{t-5}	**-1.7085**	**44.4**	$x_{t-4} S_{t-4}$	-3.9	-51.6
$x_t V_t$	**0.000884**		$x_{t-5} S_{t-5}$	**-10.8**	**-118.4**
$x_{t-1} V_{t-1}$	**0.000299**	**0.0023**	$x_t QD_t$	**-0.0329**	
$x_{t-2} V_{t-2}$	**0.0000353**	**-0.0021**	$x_{t-1} QD_{t-1}$	-0.0026	**0.3559**
$x_{t-3} V_{t-3}$	-0.0000343	**-0.0018**	$x_{t-2} QD_{t-2}$	**0.0072**	**0.0849**
$x_{t-4} V_{t-4}$	0.0000272	**-0.0014**	$x_{t-3} QD_{t-3}$	0.0053	**0.1871**
$x_{t-5} V_{t-5}$	**0.0000623**	**-0.0022**	$x_{t-4} QD_{t-4}$	0.0013	0.0344
$x_t T_t$	**-0.0607**		$x_{t-5} QD_{t-5}$	**0.0035**	-0.0186
$x_{t-1} T_{t-1}$	**-0.0189**	0.0101	$x_t D_t^1$	**1.642**	
$x_{t-2} T_{t-2}$	0.0004	**-0.231**	$x_{t-1} D_{t-1}^1$		**34.2**
$x_{t-3} T_{t-3}$	-0.0024	**-0.265**	Adj-R^2:	0.2001	
$x_{t-4} T_{t-4}$	0.0005	**-0.1674**	Nº obs.:	125164	
$x_{t-5} T_{t-5}$	**0.0094**	-0.1246	F(42,125164):	746.58	Prob>F: 0.0000

[†] Format in bold means significant (at least) at the 5% level.

TABLE II

Risk persistency

This table shows the estimated GLS coefficients of the truncated AR(5) model in (13). The time series ASC_t is built with the estimated adverse selection costs corresponding to all IBM trades executed from February to June 1996. A trade belongs to the set ASC(1) if $|ASC_t| <$ P(0.25), to ASC(2) if P(25)$\leq |ASC_t| <$ P(50), to ASC(3) if P(50)$\leq |ASC_t| <$ P(75), to ASC(4) if P(75)$\leq |ASC_t| <$ P(95) and, finally, to ASC(5) if $|ASC_t| \geq$ P(95), where P(y) represents the value of the y% percentile of the empirical distribution of ASC_t. The dummy Q_t^j equals 1 if $ASC_t \in ASC$(j), j={1,...,5}, and 0 otherwise.

Coefficient*	Q_t^1 : ASC(1)	Q_t^2 : ASC(2)	Q_t^3 : ASC(3)	Q_t^4 : ASC(4)	Q_t^5 : ASC(5)
ϕ_1^j	**0.3333**	**0.4082**	**0.5896**	**0.7427**	**0.8964**
ϕ_2^j	**0.1279**	**0.1229**	**0.1191**	**0.0755**	-0.0285
ϕ_3^j	**0.1222**	**0.0907**	**0.0436**	0.0257	0.0719
ϕ_4^j	**0.1007**	**0.0918**	**0.0729**	**0.0421**	0.0153
ϕ_5^j	**0.1513**	**0.1693**	**0.1298**	**0.1402**	**0.1291**

Adj-R^2 = 0.9497, Prob>F = 0.0000.

* Format in bold means statistically significant at least to the 5% level.

TABLE III

Speed of adjustment of quotes to the information inferred from trades.

This table summarizes the estimation of (14) by OLS robust to heterokedasticity and autocorrelation (Newey and West, 1987). The variable τ is an estimation of the time (in number of events) that quotes need to capture all the information provided by a given trade. This τ comes from the simulation of the VAR model (12) for all IBM trades, and it is stock-specific. $Z(\tau)_t$ is the series formed with all τ_t expressed in real time (seconds). V_t = trade size (in number of shares). T_t = time (in seconds) since the preceding trade. S_t = bid-ask spread. QD_t = quoted depth (average between depth at the ask and depth at the bid prices). R_t = volatility (implicit volatility of Δq_t estimated with a GARCH (1,1) model), and D_t^j, j={1,...,8} are dummy variables that control for deterministic intraday patterns.

Variable		Coefficient*
δ_0	(const.)	**721.41**
V_t	(δ_1)	**-0.0051**
T_t	(δ_2)	**2.1679**
R_t	(δ_3)	**-26495.11**
S_t	(δ_4)	**-424.72**
QD_t	(δ_5)	**0.4391**
D_t^1	[9:30 10:00)	**-263.98**
D_t^2	[10:00 11:00)	**-232.71**
D_t^3	[11:00 12:00)	**-108.26**
D_t^5	[13:00 14:00)	7.6262
D_t^6	[14:00 15:00)	**-123.29**
D_t^7	[15:00 15:30)	**-225.56**
D_t^8	[15:30 16:00)	**-276.85**
Adj.-R^2:		0.2346
Prob > F		0.0000

* Format in bold means statistically significant, at least, at the 5% level.

TABLE IV

Adverse selection costs over the total immediacy costs

This table summarizes the results of estimating the percentage of the effective spread that is due to adverse selection costs. The Lin et al.'s (1995) model has been extended in order to control for intraday effects and the risk level due to information asymmetries, see equation (16). The model is estimated by theNewey and West's (1987) method. Two alternative dependent variables have been used: the observed change in the midpoint of the bid ask spread (the original variable in Lin et al., 1995) and the initial (first-step) impact estimated by the simulation of the VAR model in (12).

Coefficient (x100)*	Δq_t	Initial impact (simulation)
δ_0	**15.9793**	**16.1386**
δ_Q^2	**5.1832**	**2.8813**
δ_Q^3	**10.5893**	**5.1355**
δ_Q^4	**12.2063**	**6.4202**
δ_Q^5	**13.9802**	**10.1475**
δ_D^1 [9:30 10:00)	**2.5499**	**1.9521**
δ_D^2 [10:00 11:00)	1.2797	**1.0046**
δ_D^3 [11:00 12:00)	0.7079	0.2678
δ_D^5 [13:00 14:00)	0.5919	0.0478
δ_D^6 [14:00 15:00)	0.6355	0.0242
δ_D^7 [15:00 15:30)	1.2583	**0.7867**
δ_D^8 [15:30 16:00)	0.6813	**0.7202**
	Adj.-R^2(NW): 0.2055	Adj.-R^2 (NW): 0.2121

* Format in bold means significant, at least, at the 5% level.

FIGURE 1

The impact of a buyer initiated trade on the quote midpoint (simulation).

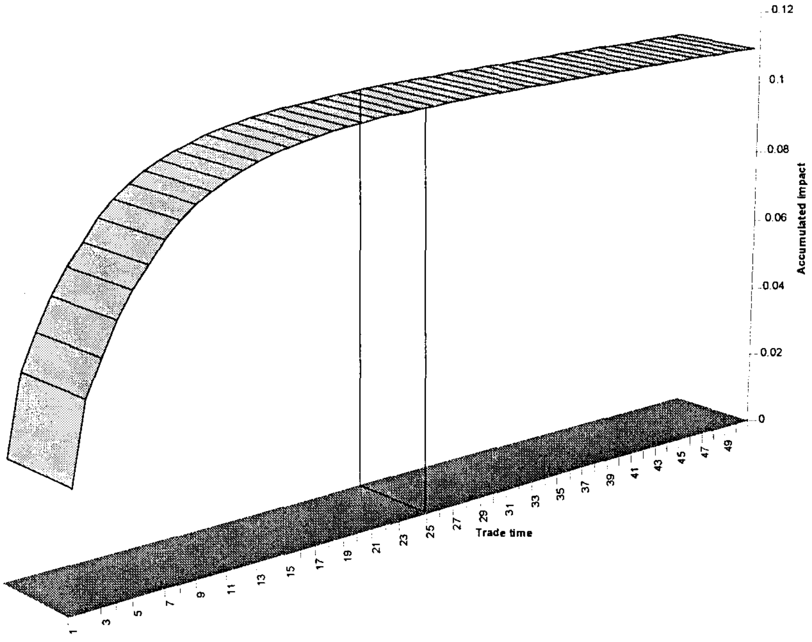


FIGURE 2

Empirical distribution of $|ASC_i|$

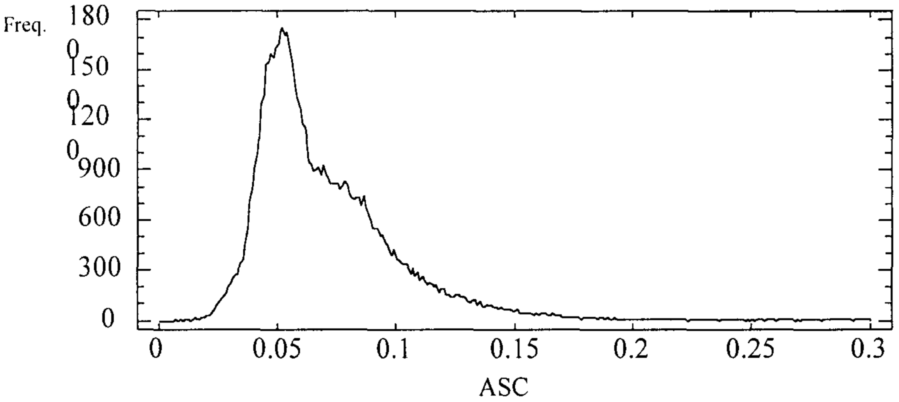
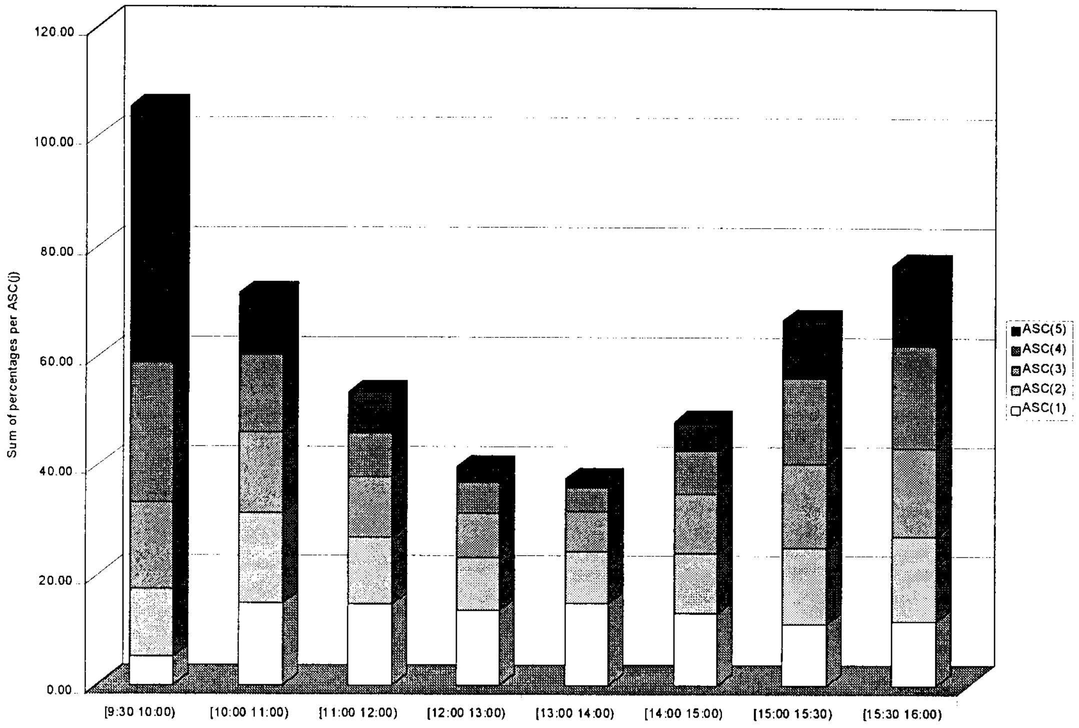


FIGURE 3

Intraday distribution of the information-asymmetry risk



APPENDIX

Means by minute and risk of asymmetric information

A.I: Accumulated volume

9:30 -10	t+1	t+2	t+3	t+4	t+5	t+6	t+7	t+8	t+9	t+10	t+11	t+12	t+13	t+14	t+15
ASC(1)[†]	**8738.48**	**9523.33**	**9891.82**	**9439.70**	**9814.24**	**9853.64**	**10400.00**	**8923.03**	**9430.91**	**9213.64**	**10096.97**	**8664.85**	**9834.24**	**10081.82**	**8966.67**
ASC(2)[†]	**10339.29**	**10074.79**	**10508.05**	**10505.09**	**9703.08**	**10146.27**	**9949.11**	**10317.28**	**10035.15**	**10478.23**	**9274.44**	**9835.74**	**9597.99**	**9750.18**	**9160.83**
ASC(3)[†]	**14156.17**	**13314.74**	**13504.72**	**12757.71**	**13010.21**	**12133.33**	**12228.04**	**12729.00**	**11893.35**	**11870.91**	**11768.02**	**11624.28**	**12939.50**	**12379.77**	12093.64
ASC(4)[‡]	**15562.73**	**14806.94**	**14669.24**	**14474.18**	**14609.01**	**14316.95**	**14537.48**	**13960.37**	**13932.33**	**14163.88**	**14110.94**	**13663.16**	**13025.82**	**13241.77**	**13122.46**
ASC(5)	16872.73	17855.72	17614.81	17587.10	18102.05	16530.06	16575.51	16542.08	15463.34	16470.67	16077.71	16093.11	16492.52	15297.95	16019.06
10 -11	t+1	t+2	t+3	t+4	t+5	t+6	t+7	t+8	t+9	t+10	t+11	t+12	t+13	t+14	t+15
ASC(1)	**7747.74**	**7899.84**	**7997.24**	**8159.27**	**7858.68**	**7882.37**	**8082.42**	**7923.90**	**7697.66**	**7250.77**	**8046.52**	**7684.81**	**7704.41**	**7319.60**	**7528.25**
ASC(2)	**9439.66**	**9523.24**	**9137.15**	**9519.43**	**9376.45**	**9193.76**	**9251.10**	**9391.34**	**9376.40**	**8989.41**	**9031.72**	**8697.08**	**9135.26**	**8666.62**	**9322.52**
ASC(3)	**11787.51**	**11537.53**	**11295.97**	**10910.92**	**11015.54**	**11037.04**	**10520.22**	**10343.63**	**10387.26**	**10763.55**	**9658.44**	**10067.73**	**9705.46**	**9675.16**	**9353.37**
ASC(4)	**14677.65**	**14241.36**	**13302.47**	**13084.94**	**13699.63**	**13412.59**	**13867.72**	**13152.65**	**13370.19**	**12816.61**	**12271.11**	**12297.53**	**12204.07**	**11241.54**	**11866.85**
ASC(5)	21014.95	20511.69	21694.84	21795.11	21361.69	18953.26	18152.72	17567.12	18618.48	17176.63	15568.48	17161.41	16749.46	19173.10	17579.89
11 -12	t+1	t+2	t+3	t+4	t+5	t+6	t+7	t+8	t+9	t+10	t+11	t+12	t+13	t+14	t+15
ASC(1)	**6168.29**	**6060.08**	**6132.71**	**5954.58**	**5663.18**	**5780.32**	**5834.29**	**6398.95**	**6107.98**	**6041.26**	**5895.37**	**6223.69**	**6401.34**	**5914.33**	**5486.72**
ASC(2)	**7465.27**	**7233.15**	**7160.01**	**6855.94**	**6821.98**	**6543.41**	**6576.45**	**6793.22**	**6604.02**	**7034.78**	**6592.51**	**6732.39**	**6803.31**	**6953.07**	**6777.05**
ASC(3)	**8573.29**	**7721.09**	**7781.97**	**8084.05**	**8001.28**	**7582.52**	**7273.96**	**7460.27**	**7189.49**	**7403.48**	**7188.26**	**7648.29**	**7382.82**	**7425.86**	**7350.61**
ASC(4)	**10656.05**	**10407.48**	**10858.71**	**10127.05**	**10700.00**	**10226.84**	**10580.53**	**9627.36**	**10449.08**	**9250.31**	**9828.38**	**9507.68**	**9405.84**	**9669.57**	**9280.02**
ASC(5)	18989.61	17999.13	18056.28	16159.74	16352.81	17753.68	17376.62	15823.81	16106.49	16181.39	14063.20	14902.17	14148.05	14889.61	14288.75
12 -13	t+1	t+2	t+3	t+4	t+5	t+6	t+7	t+8	t+9	t+10	t+11	t+12	t+13	t+14	t+15
ASC(1)	**5401.03**	**5180.15**	**4885.60**	**5035.22**	**4796.40**	**4732.34**	**4696.30**	**4862.31**	**4694.34**	**4563.86**	**4514.55**	**4540.93**	**4790.08**	**5045.50**	**4908.95**
ASC(2)	**6794.95**	**6723.39**	**5633.01**	**6366.92**	**6205.61**	**5790.66**	**5912.73**	**5706.78**	**5586.57**	**5861.25**	**5587.20**	**5337.51**	**5160.62**	**5608.93**	**5494.53**
ASC(3)	**7244.72**	**7038.06**	**6290.43**	**6007.58**	**6403.91**	**6979.10**	**6344.26**	**6109.57**	**6403.98**	**6236.45**	**6726.65**	**5832.47**	**5796.17**	**6270.21**	**5958.65**
ASC(4)	**9761.22**	**9079.59**	**8847.61**	**8539.94**	**8453.69**	**8121.13**	**8582.92**	**8337.63**	**7543.56**	**7991.90**	**7937.92**	**7965.12**	**6913.89**	**7523.44**	**7244.43**
ASC(5)	22986.60	15871.13	26021.65	17380.41	15579.38	10712.37	16025.77	20267.01	17055.67	15061.86	12618.56	13106.19	15839.18	12460.83	12638.14
13 -14	t+1	t+2	t+3	t+4	t+5	t+6	t+7	t+8	t+9	t+10	t+11	t+12	t+13	t+14	t+15
ASC(1)	**5173.13**	**4920.88**	**5128.85**	**5204.01**	**5121.36**	**4889.95**	**5277.24**	**5162.98**	**5299.28**	**5179.94**	**5156.98**	**5045.77**	**4969.45**	**5103.96**	**5182.31**
ASC(2)	**6823.10**	**6471.28**	**6380.20**	**5904.63**	**5893.82**	**6553.72**	**6019.38**	**6125.56**	**5661.52**	**6411.80**	**6134.62**	**5924.09**	**5920.79**	**6183.99**	**6285.67**
ASC(3)	**7619.37**	**6526.29**	**6666.61**	**6827.52**	6707.10	**6984.57**	**6983.35**	**6291.85**	**6398.33**	**6630.15**	**6820.33**	**7354.60**	**6658.37**	**6686.59**	**6669.76**
ASC(4)	**9521.70**	9764.41	9481.25	8839.58	**7830.21**	**7614.76**	**8229.51**	**7955.90**	8516.15	8822.22	7705.21	8198.44	7789.41	8122.92	8372.40
ASC(5)	13481.54	7009.23	16901.54	6740.00	21283.08	10829.23	12116.92	8550.77	8552.31	6823.08	6347.69	9710.77	14543.08	9643.08	12740.00
14 -15	t+1	t+2	t+3	t+4	t+5	t+6	t+7	t+8	t+9	t+10	t+11	t+12	t+13	t+14	t+15
ASC(1)	**6267.99**	**6180.64**	**6793.01**	**6344.72**	**6671.23**	**6959.35**	**6741.20**	**6481.41**	**7145.21**	**6939.38**	**7156.82**	**6860.12**	**7578.33**	**7107.54**	**7432.18**
ASC(2)	**8766.81**	**7666.87**	**7928.65**	**7705.22**	**7808.08**	**7660.22**	**7577.87**	**7586.14**	**8333.37**	**8387.69**	**8009.76**	**8877.44**	**8630.45**	**8167.37**	**8500.25**
ASC(3)	**8544.57**	**8194.67**	**8668.61**	8328.69	9273.08	8536.79	**8355.86**	**9202.21**	**8864.87**	**8894.30**	**8547.70**	**8751.87**	**8845.68**	**8788.66**	**8758.37**
ASC(4)	**9738.45**	**9559.69**	**9119.08**	9509.49	9138.16	9369.28	9938.55	10030.53	9428.87	10332.39	9347.16	9421.43	9961.35	9786.20	9654.99
ASC(5)	12556.12	13638.78	12205.10	10083.16	9604.59	9954.59	10239.29	10273.98	9521.43	12047.96	11097.96	10643.88	10264.80	10384.69	10729.59
15 -15:30	t+1	t+2	t+3	t+4	t+5	t+6	t+7	T+8	t+9	t+10	t+11	t+12	t+13	t+14	t+15
ASC(1)	**7854.50**	**8392.35**	**8117.99**	**8126.98**	**8037.58**	**8370.87**	**7982.82**	**8446.44**	**8044.56**	**8576.38**	**9101.48**	**8075.30**	**8403.89**	**7510.20**	**8204.83**
ASC(2)	**9797.80**	**9107.97**	**9344.76**	**9410.59**	**9298.95**	**8403.14**	**8539.73**	**9475.47**	**8167.19**	**8485.85**	**8460.06**	**8603.77**	**8382.60**	**8724.42**	**8054.09**
ASC(3)	**11605.51**	**11030.37**	**10920.84**	**10341.03**	**10887.38**	**10450.84**	10764.11	**10079.07**	**9692.06**	**10502.62**	**10257.48**	**11114.30**	**10845.70**	**9913.46**	10860.00
ASC(4)	**13222.52**	**12420.42**	**11916.12**	11968.54	**11706.95**	12139.63	11080.57	**11997.90**	**11632.78**	11369.43	11567.22	11544.48	11560.82	11232.45	11276.82
ASC(5)	18397.69	17333.53	16806.94	14296.53	13413.87	15658.38	14899.42	16175.72	15452.60	14430.06	13238.73	15288.44	14502.31	14825.43	12958.38
15:30 -16	t+1	t+2	t+3	t+4	t+5	t+6	t+7	T+8	t+9	t+10	t+11	t+12	t+13	t+14	t+15
ASC(1)	**7581.39**	**8399.58**	**8361.57**	**8141.90**	**7869.23**	**9458.86**	**7637.52**	**8547.84**	**8363.95**	**8615.48**	**8327.73**	**7533.26**	**8577.96**	**8645.00**	**8927.11**
ASC(2)	**8957.03**	**8236.21**	**8754.93**	**8602.90**	**8746.53**	**7944.23**	**7976.96**	**8101.35**	**7751.34**	**8730.92**	**8450.54**	**8390.02**	**8775.00**	**9358.70**	**8200.00**
ASC(3)	**9980.07**	10182.77	10912.49	**11146.82**	10479.22	10904.55	11945.98	10527.96	11094.22	11331.09	10562.12	11312.92	11623.17	11054.76	11694.56
ASC(4)	**11921.37**	**11422.13**	**11517.88**	**12697.20**	**11476.44**	**10922.45**	**12169.87**	**12283.16**	**11876.06**	**11879.59**	**12070.29**	**11522.81**	**12581.85**	**12934.06**	**13214.68**
ASC(5)	27828.33	23908.29	26377.23	29627.89	29899.44	27354.76	24135.26	22889.33	27444.44	26068.61	23597.64	26140.17	35745.28	21279.61	28244.44

[†] Format in bold implies a statistical difference in means with respect to ASC(4) (ASC(j)<ASC(4)) to (al least) the 5%. level

[‡] Format in bold implies a statistical difference in means with respect to ASC(5) (ASC(4)<ASC(5)) to (al least) the 5% level.

APPENDIX (Cont.)

A.II: Number of trades

9:30 –10	t+1	t+2	t+3	t+4	t+5	t+6	t+7	t+8	t+9	t+10	t+11	t+12	t+13	t+14	t+15
ASC(1)	**3.121**	**3.309**	**3.142**	**3.279**	**3.167**	**3.212**	**3.373**	**3.227**	**3.173**	**3.188**	**3.164**	**3.230**	**3.173**	**3.167**	**3.185**
ASC(2)	**3.562**	**3.507**	**3.469**	**3.343**	**3.344**	**3.250**	**3.367**	**3.335**	**3.239**	**3.236**	**3.142**	**3.175**	**3.098**	**3.200**	**3.044**
ASC(3)	**3.979**	**4.029**	**3.909**	**3.858**	**3.863**	**3.877**	**3.798**	**3.730**	**3.779**	**3.665**	**3.719**	**3.634**	**3.663**	**3.680**	**3.676**
ASC(4)	**4.452**	**4.355**	**4.274**	**4.232**	**4.295**	**4.228**	**4.196**	**4.115**	**4.108**	**4.104**	**4.117**	**4.054**	**3.985**	**3.959**	**3.941**
ASC(5)	4.630	4.720	4.694	4.674	4.576	4.588	4.482	4.540	4.258	4.350	4.408	4.372	4.384	4.227	4.243
10 –11	t+1	t+2	t+3	t+4	t+5	t+6	t+7	t+8	t+9	t+10	t+11	t+12	t+13	t+14	t+15
ASC(1)	**2.905**	**2.844**	**2.807**	**2.775**	**2.776**	**2.741**	**2.721**	**2.645**	**2.730**	**2.661**	**2.689**	**2.711**	**2.665**	**2.599**	**2.642**
ASC(2)	**3.304**	**3.183**	**3.075**	**3.090**	**3.063**	**3.042**	**3.013**	**3.004**	**2.981**	**2.932**	**2.974**	**2.921**	**2.949**	**2.922**	**3.017**
ASC(3)	**3.705**	**3.623**	**3.480**	**3.392**	**3.370**	**3.448**	**3.330**	**3.282**	**3.278**	**3.256**	**3.234**	**3.244**	**3.199**	**3.154**	**3.246**
ASC(4)	**3.990**	**3.898**	**3.848**	**3.834**	**3.709**	**3.722**	**3.681**	**3.647**	**3.702**	**3.604**	**3.529**	**3.448**	**3.477**	**3.359**	**3.446**
ASC(5)	4.457	4.595	4.332	4.389	4.394	4.264	4.095	4.261	4.242	3.905	3.845	4.005	3.565	3.644	3.886
11 –12	t+1	t+2	t+3	t+4	t+5	t+6	t+7	t+8	t+9	t+10	t+11	t+12	t+13	t+14	t+15
ASC(1)	**2.343**	**2.297**	**2.302**	**2.243**	**2.231**	**2.250**	**2.234**	**2.252**	**2.223**	**2.219**	**2.208**	**2.228**	**2.170**	**2.171**	**2.198**
ASC(2)	**2.762**	**2.655**	**2.593**	**2.563**	**2.528**	**2.536**	**2.396**	**2.383**	**2.405**	**2.466**	**2.365**	**2.391**	**2.354**	**2.374**	**2.294**
ASC(3)	**2.937**	**2.877**	**2.767**	**2.724**	**2.741**	**2.739**	**2.635**	**2.631**	**2.594**	**2.579**	**2.490**	**2.632**	**2.573**	**2.494**	**2.454**
ASC(4)	**3.376**	**3.406**	**3.314**	**3.107**	**3.183**	**3.138**	**3.127**	**3.186**	**3.186**	**3.024**	**3.035**	**3.149**	**3.047**	**3.055**	**2.997**
ASC(5)	3.931	4.022	4.017	4.087	4.212	4.022	3.892	3.983	3.987	4.022	4.069	3.771	3.827	3.810	3.797
12 –13	t+1	t+2	t+3	t+4	t+5	t+6	t+7	t+8	t+9	t+10	t+11	t+12	t+13	t+14	t+15
ASC(1)	**2.104**	**2.030**	**1.962**	**1.989**	**1.990**	**1.929**	**1.999**	**1.959**	**1.879**	**5.000**	**1.864**	**1.870**	**1.928**	**1.929**	**1.870**
ASC(2)	**2.437**	**2.377**	**2.217**	**2.221**	**2.209**	**2.183**	**2.143**	**2.082**	**2.077**	**2.092**	**2.061**	**2.067**	**2.037**	**2.042**	**1.959**
ASC(3)	**2.541**	**2.420**	**2.312**	**2.328**	**2.254**	**2.329**	**2.177**	**2.248**	**2.234**	**2.276**	**2.213**	**2.204**	**2.221**	**2.175**	**2.158**
ASC(4)	**2.916**	**2.793**	**2.753**	**2.734**	2.661	**2.690**	**2.621**	**2.679**	**2.592**	**2.540**	**2.508**	**2.608**	**2.492**	**2.563**	**2.553**
ASC(5)	3.443	3.701	3.639	3.289	3.072	3.258	3.454	3.309	3.082	3.433	3.278	3.649	3.577	3.526	3.433
13 –14	t+1	t+2	t+3	t+4	t+5	t+6	t+7	t+8	t+9	t+10	t+11	t+12	t+13	t+14	t+15
ASC(1)	**1.986**	**1.966**	**1.951**	**1.937**	**1.900**	**1.872**	**1.928**	**1.892**	**1.916**	**1.914**	**1.952**	**1.933**	**1.837**	**1.955**	**1.948**
ASC(2)	**2.400**	**2.326**	**2.234**	**2.140**	**2.144**	**2.129**	**2.217**	**2.147**	**2.127**	**2.139**	**2.146**	**2.098**	**2.103**	**2.148**	**2.188**
ASC(3)	**2.471**	**2.406**	**2.368**	**2.245**	**2.410**	**2.365**	**2.270**	**2.174**	**2.274**	**2.291**	**2.196**	**2.314**	**2.213**	**2.197**	**2.205**
ASC(4)	**2.905**	**2.832**	**2.875**	**2.714**	**2.667**	**2.575**	**2.538**	**2.500**	**2.514**	**2.550**	**2.509**	**2.569**	**2.516**	**2.493**	**2.505**
ASC(5)	2.908	2.354	3.108	2.954	3.323	2.954	3.431	3.446	2.985	2.477	2.308	2.723	2.831	2.846	2.969
14 –15	t+1	t+2	t+3	t+4	t+5	t+6	t+7	t+8	t+9	t+10	t+11	t+12	t+13	t+14	t+15
ASC(1)	**2.398**	**2.333**	**2.381**	**2.336**	**2.331**	**2.336**	**2.313**	**2.278**	**2.337**	**2.409**	**2.405**	**2.404**	**2.475**	**2.462**	**2.523**
ASC(2)	**2.874**	**2.684**	**2.605**	**2.565**	**2.527**	**2.522**	**2.523**	**2.539**	**2.520**	**2.567**	**2.597**	**2.661**	**2.697**	**2.606**	**2.704**
ASC(3)	**3.000**	**2.866**	**2.825**	**2.826**	2.850	**2.788**	**2.842**	**2.855**	**2.853**	**2.949**	2.799	2.910	2.883	2.938	2.953
ASC(4)	**3.161**	**3.134**	**3.070**	**3.072**	3.068	3.039	3.171	3.091	3.124	3.164	3.083	3.035	3.158	3.207	3.121
ASC(5)	3.541	3.551	3.622	3.561	3.408	3.270	3.474	3.260	3.378	3.566	3.500	3.372	3.276	3.133	3.418
15 –15:30	t+1	t+2	t+3	t+4	t+5	t+6	t+7	t+8	t+9	t+10	t+11	t+12	t+13	t+14	t+15
ASC(1)	**2.902**	**2.881**	**2.937**	**2.954**	**2.862**	**2.856**	**2.878**	**2.995**	**2.952**	**2.907**	**3.055**	**2.961**	**3.004**	**2.889**	**3.003**
ASC(2)	**3.320**	**3.066**	**3.031**	**3.134**	**3.081**	**2.966**	**3.023**	**3.108**	**2.978**	**2.991**	**3.056**	**3.000**	**2.962**	**3.121**	**3.028**
ASC(3)	**3.564**	**3.480**	**3.421**	**3.410**	3.429	**3.383**	**3.427**	**3.550**	**3.371**	**3.287**	3.393	3.373	3.394	3.321	3.425
ASC(4)	**3.919**	**3.861**	**3.760**	**3.600**	**3.617**	3.745	3.700	**3.792**	**3.780**	3.714	**3.606**	**3.787**	**3.629**	**3.544**	3.564
ASC(5)	4.353	4.439	4.214	4.139	4.092	3.913	3.971	4.422	4.514	3.827	4.173	4.150	4.214	4.208	3.919
15:30 –16	t+1	t+2	t+3	t+4	t+5	t+6	t+7	t+8	t+9	t+10	t+11	t+12	t+13	t+14	t+15
ASC(1)	**3.136**	**3.213**	**3.236**	**3.256**	**3.193**	**3.330**	**3.148**	**3.112**	**3.021**	**3.127**	**3.002**	**3.000**	**3.125**	**3.080**	**3.087**
ASC(2)	**3.235**	**3.151**	**3.243**	**3.298**	**3.282**	**3.240**	**3.225**	**3.170**	**3.180**	**3.143**	**3.258**	**3.105**	**3.298**	**3.459**	**3.313**
ASC(3)	**3.554**	**3.530**	3.590	**3.569**	**3.517**	**3.471**	**3.467**	**3.486**	**3.413**	**3.374**	**3.427**	**3.517**	3.615	3.445	**3.555**
ASC(4)	**3.968**	**3.816**	**3.801**	**3.831**	**3.698**	**3.712**	**3.762**	**3.692**	**3.746**	**3.925**	**3.862**	**3.769**	**3.759**	4.004	**3.924**
ASC(5)	4.837	4.899	4.965	4.837	4.853	4.827	4.506	4.633	4.618	4.686	4.520	4.368	4.689	4.000	4.576

APPENDIX (Cont.)

A.III: Standard deviation of the ask price after buys

9:30 –10	t+1	t+2	t+3	t+4	t+5	t+6	t+7	t+8	t+9	t+10	t+11	t+12	t+13	t+14	t+15
ASC(1)	0.0286	**0.0338**	**0.0317**	**0.0405**	**0.0321**	**0.0294**	**0.0374**	**0.0373**	**0.0329**	**0.0348**	**0.0359**	**0.0362**	**0.0319**	**0.0325**	**0.0329**
ASC(2)	**0.0300**	**0.0346**	**0.0378**	**0.0400**	**0.0333**	**0.0331**	**0.0326**	**0.0368**	**0.0345**	**0.0325**	**0.0327**	**0.0324**	**0.0371**	**0.0319**	**0.0338**
ASC(3)	0.0431	0.0468	0.0466	0 0467	**0.0407**	**0.0395**	**0.0435**	**0.0409**	**0.0424**	**0.0389**	**0.0403**	0.0387	0.0423	0.0414	**0.0384**
ASC(4)	0.0459	0.0530	0.0544	0.0542	0.0507	**0.0490**	0.0493	0.0509	**0.0503**	0.0468	**0.0480**	**0.0508**	**0.0444**	0.0456	**0.0458**
ASC(5)	0.0500	0.0612	0.0615	0 0630	0.0594	0.0575	0.0540	0.0556	0.0574	0.0578	0.0579	0.0575	0.0517	0.0458	0.0523
10 –11	t+1	t+2	t+3	t+4	t+5	t+6	t+7	t+8	t+9	t+10	t+11	t+12	t+13	t+14	t+15
ASC(1)	**0.0195**	**0.0247**	**0.0263**	**0.0247**	**0.0251**	**0.0257**	0.0259	**0.0254**	**0.0224**	**0.0260**	**0.0256**	0.0251	0.0248	**0.0241**	0.0236
ASC(2)	0.0257	0.0300	0.0313	0.0302	0.0324	0.0284	0.0308	0.0290	0.0283	0.0281	0.0287	0.0291	0.0285	0.0278	0.0289
ASC(3)	0.0319	0.0375	0.0369	0.0382	0.0350	0.0364	0.0381	0.0341	0.0368	0.0365	0.0361	0.0344	0.0364	0.0340	0.0332
ASC(4)	0.0370	0.0452	0.0441	0.0468	0.0423	0.0455	0.0412	0.0405	0.0425	0.0418	0.0397	0.0391	0.0381	0.0391	0.0396
ASC(5)	0.0471	0.0606	0.0566	0.0561	0.0555	0.0554	0.0485	0.0511	0.0498	0.0499	0.0505	0.0464	0.0511	0.0432	0.0462
11 –12	t+1	t+2	t+3	t+4	t+5	t+6	t+7	t+8	t+9	t+10	t+11	t+12	t+13	t+14	t+15
ASC(1)	**0.0124**	**0.0184**	0.0202	**0.0184**	**0.0180**	**0.0208**	**0.0206**	0.0191	0.0218	0.0209	0.0195	0.0202	0.0190	0.0240	0.0205
ASC(2)	**0.0226**	**0.0253**	**0.0239**	**0.0264**	**0.0266**	**0.0248**	**0.0231**	**0.0230**	**0.0222**	**0.0236**	**0.0236**	**0.0221**	**0.0227**	**0.0233**	**0.0237**
ASC(3)	**0.0282**	**0.0319**	**0.0290**	**0.0286**	**0.0295**	**0.0276**	**0.0300**	**0.0264**	**0.0277**	**0.0274**	**0.0262**	**0.0266**	**0.0267**	**0.0245**	**0.0273**
ASC(4)	**0.0334**	**0.0395**	**0.0361**	**0.0371**	**0.0385**	**0.0401**	**0.0353**	**0.0328**	**0.0379**	**0.0346**	**0.0370**	**0.0321**	**0.0337**	**0.0309**	**0.0348**
ASC(5)	0.0454	0.0555	0.0451	0.0451	0.0458	0.0592	0.0476	0.0587	0.0496	0.0440	0.0528	0.0478	0.0441	0.0410	0.0526
12 –13	t+1	t+2	t+3	t+4	t+5	t+6	t+7	t+8	t+9	t+10	t+11	t+12	t+13	t+14	t+15
ASC(1)	**0.0142**	0.0167	0.0172	0.0189	0.0188	**0.0175**	0.0173	0.0194	**0.0172**	0.0174	0.0168	0.0177	0.0175	0.0183	0.0192
ASC(2)	0.0192	0.0252	0.0199	0.0240	0.0227	**0.0216**	0.0251	0.0241	**0.0214**	**0.0210**	0.0234	0.0234	0.0224	0.0206	0.0197
ASC(3)	**0.0219**	**0.0246**	**0.0243**	**0.0262**	**0.0238**	**0.0245**	**0.0255**	**0.0255**	**0.0224**	**0.0241**	0.0255	**0.0248**	**0.0245**	0.0234	**0.0222**
ASC(4)	**0.0256**	0.0315	0.0306	**0.0321**	**0.0259**	**0.0301**	**0.0311**	**0.0262**	0.0316	**0.0294**	**0.0266**	**0.0289**	**0.0261**	**0.0235**	**0.0234**
ASC(5)	0.0349	0.0380	0.0345	0.0309	0.0467	0.0394	0.0268	0.0369	0.0241	0.0334	0.0327	0.0464	0.0512	0.0304	0.0346
13 –14	t+1	t+2	t+3	t+4	t+5	t+6	t+7	t+8	t+9	t+10	t+11	t+12	t+13	t+14	t+15
ASC(1)	**0.0119**	**0.0163**	**0.0183**	**0.0194**	**0.0165**	**0.0175**	0.0192	**0.0188**	**0.0177**	0.0175	**0.0188**	0.0196	0.0193	0.0191	0.0225
ASC(2)	**0.0209**	**0.0228**	**0.0236**	**0.0223**	**0.0193**	**0.0226**	**0.0206**	**0.0230**	**0.0234**	**0.0200**	**0.0233**	**0.0207**	**0.0216**	**0.0201**	**0.0206**
ASC(3)	**0.0212**	**0.0281**	0.0269	0.0264	0.0263	**0.0261**	0.0252	0.0269	0.0260	0.0265	0.0285	0.0267	0.0273	0.0270	0.0243
ASC(4)	0.0274	0.0357	0.0304	0.0326	0.0319	0.0360	0.0313	0.0320	0.0328	0.0270	0.0334	0.0306	0.0295	0.0296	0.0342
ASC(5)	0.0351	0.0417	0.0324	0.0352	0.0298	0.0341	0.0496	0.0304	0.0328	0.0329	0.0265	0.0129	0.0233	0.0340	0.0236
14 –15	t+1	t+2	t+3	t+4	t+5	t+6	t+7	t+8	t+9	t+10	t+11	t+12	t+13	t+14	t+15
ASC(1)	**0.0178**	**0.0217**	**0.0249**	**0.0248**	**0.0227**	**0.0248**	**0.0223**	**0.0224**	**0.0241**	**0.0260**	**0.0255**	**0.0235**	**0.0240**	**0.0257**	**0.0273**
ASC(2)	0.1219	0.0275	0.0292	0.0746	0.0733	0.0298	0.0268	0.0296	0.0697	0.0740	0.0275	0.0271	0.0293	0.0281	0.0301
ASC(3)	0.1208	0.0335	0.0340	0.0788	0.0793	0.0321	0.0338	0.0328	0.1257	0.0792	0.0329	0.0309	0.0776	0.0319	0.0355
ASC(4)	0.0279	0.0377	0.0355	0.0374	0.0343	0.0320	0.0402	0.0391	0.0378	0.0364	0.0375	0.0350	0.0343	0.0350	0.0374
ASC(5)	0.0390	0.0409	0.0444	0.0395	0.0348	0.0291	0.0364	0.0462	0.0312	0.0434	0.0357	0.0336	0.0322	0.0284	0.0291
15 –15:30	t+1	t+2	t+3	t+4	t+5	t+6	t+7	t+8	t+9	t+10	t+11	t+12	t+13	t+14	t+15
ASC(1)	**0.0221**	**0.0310**	**0.0318**	**0.0294**	**0.0307**	**0.0281**	**0.0311**	**0.0308**	**0.0336**	**0.0337**	**0.0306**	**0.0333**	**0.0335**	**0.0314**	**0.0310**
ASC(2)	**0.0280**	0.0335	**0.0295**	0.0327	**0.0323**	0.0353	**0.0343**	**0.0321**	**0.0293**	**0.0338**	**0.0321**	**0.0355**	**0.0310**	**0.0309**	**0.0378**
ASC(3)	0.0354	0.0393	0.0377	0.0384	0.0422	0.0403	0.0399	0.0391	0.0410	0.0408	0.0391	0.0393	0.0420	0.0397	0.0449
ASC(4)	0.0401	0.0427	0.0442	0.0443	0.0443	0.0428	0.0464	0.0421	0.0419	0.0441	0.0416	0.0444	0.0452	0.0435	0.0397
ASC(5)	0.0435	0.0453	0.0493	0.0376	0.0439	0.0499	0.0445	0.0473	0.0532	0.0415	0.0462	0.0536	0.0491	0.0506	0.0489
15:30 –16	t+1	t+2	t+3	t+4	t+5	t+6	t+7	t+8	t+9	t+10	t+11	t+12	t+13	t+14	t+15
ASC(1)	**0.0205**	**0.0291**	0.0320	0.0313	0.0358	0.0376	0.0312	0.0327	0.0304	0.0328	**0.0225**	0.0345	**0.0287**	0.0320	**0.0252**
ASC(2)	0.0282	0.0337	0.0329	0.0335	0.0361	0.0379	0.0307	0.0380	0.0291	0.0339	0.0340	0.0323	0.0333	0.0353	0.0328
ASC(3)	0.0322	0.0368	0.0363	0.0410	0.0385	**0.0405**	0.0368	0.0404	**0.0395**	0.0381	0.0356	0.0371	0.0379	0.0375	**0.0382**
ASC(4)	0.0347	**0.0444**	**0.0396**	**0.0400**	0.0374	0.0403	0.0406	**0.0418**	0.0410	0.0434	0.0401	0.0430	0.0418	0.0382	0.0426
ASC(5)	0.0422	0.0584	0.0669	0.0552	0.0469	0.0476	0.0582	0.0592	0.0482	0.0507	0.0553	0.0531	0.0445	0.0446	0.0491

APPENDIX (Cont.)

A.IV: Quoted spread

9:30 –10	t+1	t+2	t+3	t+4	t+5	t+6	t+7	t+8	t+9	t+10	t+11	t+12	t+13	t+14	t+15
ASC(1)	**0.1426**	**0.1718**	**0.1706**	**0.1716**	**0.1748**	**0.1706**	**0.1727**	**0.1680**	**0.1682**	**0.1720**	**0.1732**	**0.1692**	**0.1667**	**0.1714**	**0.1753**
ASC(2)	**0.1481**	0.1726	0.1781	0.1767	**0.1743**	**0.1742**	**0.1769**	**0.1789**	**0.1775**	**0.1741**	**0.1785**	**0.1776**	**0.1798**	**0.1803**	**0.1792**
ASC(3)	**0.1616**	**0.1831**	**0.1853**	**0.1852**	**0.1820**	**0.1821**	**0.1815**	**0.1822**	**0.1848**	**0.1848**	**0.1871**	**0.1868**	**0.1877**	**0.1888**	**0.1878**
ASC(4)	**0.2033**	0.2022	**0.1990**	**0.1964**	**0.1976**	**0.1994**	**0.1990**	**0.1994**	**0.1980**	**0.2022**	**0.2013**	**0.2027**	**0.2019**	**0.2018**	**0.2004**
ASC(5)	0.2552	0.2243	0.2204	0.2206	0.2195	0.2168	0.2180	0.2165	0.2208	0.2210	0.2231	0.2233	0.2231	0.2190	0.2226
10 –11	t+1	t+2	t+3	t+4	t+5	t+6	t+7	t+8	t+9	t+10	t+11	t+12	t+13	t+14	t+15
ASC(1)	**0.1364**	**0.1556**	**0.1626**	**0.1647**	**0.1661**	**0.1682**	**0.1685**	**0.1698**	**0.1709**	**0.1696**	**0.1695**	**0.1697**	**0.1667**	**0.1668**	**0.1685**
ASC(2)	**0.1426**	**0.1647**	**0.1715**	**0.1736**	**0.1753**	**0.1728**	**0.1753**	**0.1736**	**0.1732**	**0.1720**	**0.1731**	**0.1728**	**0.1713**	**0.1732**	**0.1737**
ASC(3)	**0.1698**	**0.1812**	**0.1858**	**0.1850**	**0.1860**	**0.1844**	**0.1833**	**0.1827**	**0.1826**	**0.1851**	**0.1841**	**0.1825**	**0.1822**	**0.1822**	**0.1818**
ASC(4)	**0.2181**	**0.2059**	**0.1999**	**0.1970**	**0.1957**	**0.1951**	**0.1929**	**0.1920**	**0.1923**	**0.1916**	**0.1942**	0.1937	0.1906	0.1913	**0.1902**
ASC(5)	0.2628	0.2178	0.2092	0.2078	0.2091	0.2077	0.2073	0.2027	0.2017	0.2083	0.2077	0.2151	0.2143	0.2124	0.2051
11 –12	t+1	t+2	t+3	t+4	t+5	t+6	t+7	t+8	t+9	t+10	t+11	t+12	t+13	t+14	t+15
ASC(1)	**0.1332**	**0.1510**	**0.1578**	**0.1619**	**0.1649**	**0.1658**	**0.1677**	**0.1686**	**0.1669**	**0.1677**	**0.1688**	**0.1697**	**0.1726**	**0.1708**	**0.1692**
ASC(2)	**0.1404**	**0.1611**	**0.1675**	**0.1684**	**0.1719**	**0.1718**	**0.1713**	**0.1715**	**0.1703**	**0.1720**	**0.1725**	**0.1730**	**0.1733**	**0.1716**	**0.1714**
ASC(3)	**0.1700**	**0.1785**	**0.1792**	**0.1782**	**0.1784**	**0.1783**	**0.1799**	**0.1813**	**0.1796**	**0.1792**	**0.1789**	**0.1789**	**0.1794**	**0.1784**	**0.1799**
ASC(4)	**0.2243**	**0.2056**	**0.1988**	**0.1946**	**0.1939**	**0.1920**	**0.1883**	**0.1905**	**0.1895**	**0.1853**	**0.1863**	**0.1847**	**0.1889**	0.1890	0.1872
ASC(5)	0.2773	0.2350	0.2181	0.2029	0.2062	0.2030	0.2149	0.2086	0.2010	0.2078	0.2064	0.2006	0.1991	0.1984	0.1956
12 –13	t+1	t+2	t+3	t+4	t+5	t+6	t+7	t+8	t+9	t+10	t+11	t+12	t+13	t+14	t+15
ASC(1)	**0.1340**	**0.1484**	**0.1569**	**0.1635**	**0.1662**	**0.1677**	**0.1681**	**0.1692**	**0.1696**	**0.1690**	**0.1723**	**0.1700**	**0.1707**	**0.1702**	**0.1692**
ASC(2)	**0.1407**	**0.1611**	**0.1685**	**0.1736**	**0.1729**	**0.1708**	**0.1718**	**0.1700**	**0.1709**	**0.1688**	**0.1741**	**0.1735**	**0.1729**	**0.1721**	**0.1712**
ASC(3)	**0.1711**	**0.1760**	**0.1765**	**0.1756**	**0.1762**	**0.1746**	**0.1783**	**0.1747**	**0.1748**	**0.1754**	0.1772	**0.1763**	**0.1740**	**0.1736**	0.1763
ASC(4)	**0.2212**	**0.2026**	0.1932	0.1899	**0.1883**	0.1867	0.1876	0.1825	0.1815	**0.1835**	**0.1826**	**0.1861**	**0.1824**	**0.1808**	**0.1812**
ASC(5)	0.2602	0.2195	0.1955	0.1965	0.2028	0.1963	0.1832	0.1899	0.1924	0.1900	0.1861	0.1927	0.1970	0.2011	0.2039
13 –14	t+1	t+2	t+3	t+4	t+5	t+6	t+7	t+8	t+9	t+10	t+11	t+12	t+13	t+14	t+15
ASC(1)	**0.1325**	**0.1464**	**0.1528**	**0.1578**	**0.1604**	**0.1629**	**0.1615**	**0.1625**	**0.1636**	**0.1647**	**0.1649**	**0.1637**	**0.1645**	**0.1655**	**0.1646**
ASC(2)	**0.1397**	**0.1587**	**0.1637**	**0.1663**	**0.1664**	**0.1677**	**0.1690**	**0.1694**	**0.1722**	**0.1716**	**0.1722**	**0.1728**	**0.1714**	**0.1708**	**0.1730**
ASC(3)	**0.1752**	**0.1799**	**0.1789**	**0.1776**	**0.1781**	**0.1772**	**0.1784**	**0.1787**	**0.1762**	**0.1762**	**0.1773**	**0.1775**	0.1801	0.1788	**0.1775**
ASC(4)	**0.2260**	**0.2045**	0.1941	0.1901	0.1875	**0.1868**	**0.1864**	**0.1887**	**0.1848**	**0.1847**	**0.1831**	0.1871	0.1852	0.1864	**0.1849**
ASC(5)	0.2657	0.2295	0.2026	0.1930	0.1912	0.1996	0.2000	0.2095	0.1997	0.1980	0.1977	0.1903	0.1833	0.1869	0.2024
14 –15	t+1	t+2	t+3	t+4	t+5	t+6	t+7	t+8	t+9	t+10	t+11	t+12	t+13	t+14	t+15
ASC(1)	**0.1344**	**0.1538**	**0.1633**	**0.1697**	**0.1706**	**0.1731**	**0.1722**	**0.1733**	**0.1738**	**0.1759**	**0.1737**	**0.1751**	**0.1771**	**0.1770**	**0.1775**
ASC(2)	**0.1426**	**0.1642**	**0.1716**	**0.1768**	**0.1789**	**0.1784**	**0.1775**	**0.1781**	**0.1798**	0.1815	**0.1819**	**0.1793**	0.1785	0.1789	0.1815
ASC(3)	**0.1749**	**0.1816**	**0.1850**	**0.1859**	**0.1860**	**0.1851**	**0.1849**	**0.1854**	**0.1850**	0.1865	**0.1873**	**0.1840**	0.1877	0.1879	0.1875
ASC(4)	**0.2186**	**0.2025**	**0.1953**	0.1931	**0.1919**	**0.1940**	0.1907	0.1901	0.1909	0.1904	0.1913	0.1906	**0.1891**	0.1893	0.1890
ASC(5)	0.2686	0.2254	0.2125	0.1995	0.2035	0.1973	0.1967	0.1967	0.2005	0.1919	0.1906	0.1932	0.1928	0.1913	0.1911
15 –15:30	t+1	t+2	t+3	t+4	t+5	t+6	t+7	t+8	t+9	t+10	t+11	t+12	t+13	t+14	t+15
ASC(1)	**0.1418**	**0.1648**	**0.1709**	**0.1781**	**0.1805**	**0.1810**	**0.1793**	**0.1793**	**0.1819**	**0.1808**	**0.1809**	**0.1787**	**0.1815**	**0.1805**	**0.1799**
ASC(2)	**0.1424**	**0.1687**	**0.1738**	**0.1790**	**0.1851**	**0.1816**	0.1796	**0.1786**	**0.1810**	0.1797	**0.1796**	0.1784	0.1803	0.1807	**0.1781**
ASC(3)	**0.1754**	**0.1858**	**0.1867**	**0.1855**	**0.1882**	**0.1898**	0.1893	**0.1877**	**0.1905**	0.1917	**0.1901**	0.1896	0.1898	0.1886	**0.1870**
ASC(4)	**0.2137**	**0.2009**	**0.1974**	**0.1947**	**0.1929**	**0.1940**	0.1913	**0.1939**	**0.1943**	0.1941	0.1957	0.1920	0.1933	0.1926	0.1914
ASC(5)	0.2658	0.2202	0.2096	0.2147	0.2073	0.2006	0.1967	0.2064	0.2074	0.2003	0.1995	0.2019	0.1973	0.1978	0.1952
15:30 –16	t+1	t+2	t+3	t+4	t+5	t+6	t+7	t+8	t+9	t+10	t+11	t+12	t+13	t+14	t+15
ASC(1)	**0.1410**	**0.1659**	**0.1704**	**0.1755**	**0.1787**	**0.1796**	**0.1795**	**0.1746**	**0.1785**	**0.1790**	**0.1753**	**0.1791**	**0.1790**	**0.1791**	**0.1822**
ASC(2)	**0.1438**	**0.1657**	**0.1742**	**0.1795**	**0.1824**	**0.1796**	**0.1792**	**0.1804**	**0.1792**	**0.1799**	**0.1797**	**0.1846**	0.1839	0.1840	**0.1843**
ASC(3)	**0.1755**	**0.1856**	**0.1878**	0.1919	0.1946	**0.1904**	**0.1900**	**0.1915**	**0.1916**	0.1917	0.1902	0.1910	0.1903	0.1910	**0.1889**
ASC(4)	**0.2189**	**0.2069**	**0.1983**	**0.1962**	**0.1948**	**0.1975**	**0.1985**	**0.1966**	**0.1970**	**0.1945**	**0.1936**	**0.1931**	**0.1912**	0.1951	0.1997
ASC(5)	0.2681	0.2226	0.2162	0.2135	0.2124	0.2181	0.2166	0.2157	0.2131	0.2116	0.2184	0.2054	0.2033	0.2047	0.2121

APPENDIX (Cont.)

A.V: Depth quoted at the ask price after buys

9:30 -10	t+1	t+2	t+3	t+4	t+5	t+6	t+7	t+8	t+9	t+10	t+11	t+12	t+13	t+14	t+15
ASC(1)	70.94	78.60	92.06	100.85	110.34	116.05	123.25	117.86	113.53	115.26	120.11	117.42	112.08	122.37	118.39
ASC(2)	72.11	83.39	93.31	94.50	99.55	107.00	108.01	104.29	103.26	113.53	116.20	112.91	112.86	110.39	113.70
ASC(3)	83.18	98.38	103.19	105.24	105.25	112.98	118.65	121.51	127.96	130.36	136.72	137.89	131.46	132.24	134.59
ASC(4)	69.96	75.81	83.06	89.35	91.72	90.40	93.18	103.11	105.57	102.09	99.72	99.31	99.98	110.00	109.54
ASC(5)	79.29	74.30	76.98	88.02	95.27	98.12	91.82	94.03	92.27	95.10	87.71	91.08	91.61	87.34	97.75
10 - 11	t+1	t+2	t+3	t+4	t+5	t+6	t+7	t+8	t+9	t+10	t+11	t+12	t+13	t+14	t+15
ASC(1)	71.70	88.72	97.19	97.91	103.45	106.35	110.19	111.56	111.64	113.15	111.13	114.85	112.73	111.14	116.48
ASC(2)	84.03	97.86	100.03	104.32	109.76	110.79	114.33	112.77	113.94	115.40	119.05	116.57	112.65	110.50	111.44
ASC(3)	78.18	83.16	86.35	91.53	93.87	97.51	96.64	94.53	97.47	98.58	98.93	98.14	100.00	101.09	101.99
ASC(4)	79.63	80.83	84.51	87.04	91.80	89.13	91.11	91.23	87.84	88.56	91.16	97.41	98.51	96.83	96.60
ASC(5)	107.00	82.29	89.13	93.12	103.26	99.76	92.90	105.27	101.03	92.71	108.71	117.95	115.42	109.53	104.96
11 -12	t+1	t+2	t+3	t+4	t+5	t+6	t+7	t+8	t+9	t+10	t+11	t+12	t+13	t+14	t+15
ASC(1)	73.45	86.20	91.57	93.19	96.61	99.81	100.98	102.22	104.86	104.72	103.79	107.65	111.87	110.09	108.10
ASC(2)	81.11	89.06	92.43	97.10	98.78	100.14	102.59	106.14	107.07	104.47	102.97	106.85	104.32	107.43	105.06
ASC(3)	77.18	81.83	84.75	90.03	94.11	101.55	100.87	102.34	101.29	104.19	105.48	103.77	103.11	106.73	102.40
ASC(4)	78.81	73.80	79.76	78.94	86.97	83.70	88.06	91.44	91.36	89.03	88.15	86.17	90.37	92.51	98.56
ASC(5)	138.09	111.17	104.75	116.44	116.03	90.33	80.55	84.90	98.68	96.25	108.71	118.46	107.64	97.80	94.03
12 -13	t+1	t+2	t+3	t+4	t+5	t+6	t+7	t+8	t+9	t+10	t+11	t+12	t+13	t+14	t+15
ASC(1)	71.74	80.03	89.34	94.78	101.56	102.60	104.43	108.01	109.49	111.00	110.63	116.06	121.68	121.78	122.43
ASC(2)	87.83	93.77	96.26	102.10	108.63	109.01	112.99	105.85	107.86	113.92	120.71	120.96	123.28	124.05	123.41
ASC(3)	96.80	102.66	102.52	103.11	103.53	102.14	104.85	104.23	107.09	111.13	113.73	110.46	112.06	116.01	110.99
ASC(4)	98.32	101.69	101.44	100.24	101.73	95.12	95.84	95.56	97.49	101.81	101.34	104.03	107.43	108.50	113.62
ASC(5)	205.59	164.69	154.22	126.73	120.74	136.19	155.22	140.71	160.94	158.14	140.82	117.84	103.84	110.84	137.44
13 -14	t+1	t+2	t+3	t+4	t+5	t+6	t+7	t+8	t+9	t+10	t+11	t+12	t+13	t+14	t+15
ASC(1)	74.06	81.93	90.27	96.91	97.02	101.71	103.09	99.64	102.08	101.48	105.44	104.36	103.78	101.77	103.85
ASC(2)	86.27	92.81	100.16	105.13	105.91	110.92	110.72	111.25	118.00	113.59	111.65	114.59	123.22	120.16	122.73
ASC(3)	81.37	82.66	85.62	86.59	88.38	89.15	88.74	92.58	93.24	89.14	91.67	92.63	99.07	97.48	98.62
ASC(4)	96.33	93.97	92.27	95.60	101.49	99.93	91.68	100.53	100.96	104.72	107.89	102.49	102.64	101.78	99.69
ASC(5)	146.03	144.42	147.17	172.94	127.28	125.34	119.58	95.60	107.19	106.24	142.68	101.71	95.89	93.26	114.02
14 -15	t+1	t+2	t+3	t+4	t+5	t+6	t+7	t+8	t+9	t+10	t+11	t+12	t+13	t+14	t+15
ASC(1)	72.14	84.29	91.77	97.30	101.86	103.57	101.06	101.14	107.06	108.59	107.28	109.29	115.60	118.06	118.92
ASC(2)	76.71	85.02	90.79	97.33	102.45	102.07	103.38	104.71	107.73	107.44	105.15	102.74	106.12	107.25	107.66
ASC(3)	77.74	83.00	88.31	88.51	87.51	89.15	89.20	92.55	89.87	90.79	88.35	88.73	91.80	90.71	88.05
ASC(4)	82.56	80.04	77.16	85.29	88.69	91.24	93.09	89.44	85.65	88.18	88.83	90.18	92.31	92.17	88.64
ASC(5)	143.32	117.11	104.31	106.60	103.72	118.51	116.72	103.06	92.34	91.91	78.90	82.20	92.28	88.13	87.93
15 -15:30	t+1	t+2	t+3	t+4	t+5	t+6	t+7	t+8	t+9	t+10	t+11	t+12	t+13	t+14	t+15
ASC(1)	61.24	77.08	82.54	86.86	88.36	96.69	101.48	101.99	99.77	98.37	99.11	99.44	97.90	101.84	101.07
ASC(2)	77.28	83.97	93.53	93.55	92.56	97.28	97.64	98.55	97.33	96.85	94.11	95.81	95.04	95.16	94.83
ASC(3)	73.86	85.68	88.80	82.24	88.52	93.95	88.46	88.31	86.77	92.19	92.08	98.89	99.03	91.26	87.78
ASC(4)	73.92	77.61	76.25	78.57	80.90	84.56	80.44	81.40	83.00	85.39	81.16	82.59	83.28	80.11	83.39
ASC(5)	84.32	79.53	80.84	79.71	86.93	85.77	73.09	72.80	65.54	70.63	73.73	80.45	88.20	81.37	83.97
15:30 -16	t+1	t+2	t+3	t+4	t+5	t+6	t+7	t+8	t+9	t+10	t+11	t+12	t+13	t+14	t+15
ASC(1)	62.52	75.02	82.48	86.43	95.43	101.28	99.87	110.07	128.91	118.41	120.75	120.35	106.06	108.24	119.64
ASC(2)	82.78	91.68	101.14	106.56	115.91	115.34	106.56	105.89	104.70	103.76	110.00	117.06	113.67	118.84	125.57
ASC(3)	83.32	93.29	97.79	100.25	99.90	97.76	96.73	89.46	92.24	95.43	90.83	94.15	94.43	98.42	104.94
ASC(4)	74.11	77.95	80.59	87.03	89.24	94.95	94.47	89.43	81.20	84.35	99.98	100.84	99.44	91.98	88.00
ASC(5)	137.21	101.10	90.40	97.21	97.38	107.41	114.54	118.82	103.07	110.12	88.28	104.05	106.44	93.70	88.75

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