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PRICE EFFECTS OF TRADING AND COMPONENTS OF THE BID-ASK SPREAD ON THE PARIS BOURSE

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Price effects of trading and components of the bid-ask spread on the Paris Bourse

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Abstract

In this paper we estimate price effects of trading and components of the bid-ask spread on the Paris Bourse. We compare the outcomes of several well-known estimators of bid-ask spread components. First, we estimate components of the bid-ask spread by the Glosten-Harris (1988) model. The estimation results show that the processing cost is lower for large transactions than for small ones. In line with theoretical predictions, the adverse selection cost increases with trade size, and is estimated between 25% and 40% of total spread. We then use a reduced form approach based on a Vector Auto Regression. Using the long run price effect as a measure of the adverse selection cost, we estimate that between 50% (for small transactions) and 80% (for large transactions) of the spread is due to asymmetric information. There is no reversal of the direction of trade, which suggests that inventory control is unlikely to be important on the Paris Bourse. Finally, we check the robustness of these results by less restrictive, direct estimates of long-run price effects.

Keywords: microstructure, asymmetric information, VAR, persistence, robustness.

Introduction.

There is by now a large literature that analyses transactions data for financial markets. Among the issues in this literature are the dynamic properties of transaction prices, and in particular the price effect of trading. Closely related to this work is the issue of estimating the components of the bid-ask spread. Much of the empirical literature in this area is based on theoretical models, although more reduced form approaches are also popular. In this paper, we analyse price effects of trading and the components of the bid-ask spread on a new data set from the Paris Bourse. The Bourse operates a fully automated order processing system (the CAC system) which gives very high quality limit order and transactions data.

We take several different approaches to estimating spread components. The two main models that we use are the Glosten and Harris (1988) model and the VAR model pioneered in market microstructure work by Hasbrouck (1991a,1991b,1993). The former model is closely linked to market microstructure theory, whereas the latter adopts a more agnostic, reduced form approach. We show that these models yield very different component estimates. Moreover, we show that there is an important difference between the effects of trading on mid-quotes and on transaction prices.

A methodological innovation in this paper is a test of the robustness of the VAR approach. We propose a direct estimate of expected price changes due to a transaction, and compare these estimates to the price effects implied by the VAR model. We show that most conclusions of the VAR model stand up against this test, although the VAR tends to overestimate the precision of the results.

This paper extends the analysis in De Jong et al. (1993), where we estimated transaction costs in Paris and compared these with costs on a competing exchange, SEAQ International in London. In the present paper we present a decomposition of the realised spread in Paris into cost components and consider price effects of trading.

The setup of the paper is as follows. In Section 1 we discuss the institutional structure of the Bourse and the data. In Section 2 we briefly discuss the theoretical background of the bid-ask spread decomposition. In Section 3 we analyse the price effects of trading using structural models of transaction prices. In Section 4 we apply the reduced form methodology developed by Hasbrouck (1991a, 1991b, 1993) to estimate of the price effects of trading. In Section 5 we check the robustness of the results. In Section 6 we conclude.

1. Institutional background and data.

In this section we briefly describe the trading structure on the Paris Bourse and the data. The Bourse is a continuous auction market and uses a centralised electronic system for displaying and processing orders, the Cotation Assistée en Continu (CAC) system. This system, based on the Toronto Stock Exchange's CATS (Computer Assisted Trading System), was first implemented in Paris in 1986. Since then, trading in nearly all securities has been transferred from the floor of the exchange onto the CAC system. All the most actively traded French equities are traded on a monthly settlement basis in round lots of 5 to 100 shares set by the Société des Bourses Françaises (SBF) to reflect their unit price. The SBF itself acts as a clearing house for buyers and sellers, providing guarantees against counterparty default. There are no specialists or professional market makers. Instead, liquidity is provided by the public limit order book.

Every morning at 10 a.m. the trading day opens with a batch auction where all eligible orders are filled at a common market clearing price. Nowadays the batch auction is relatively unimportant, accounting for no more than 10 to 15% of trading volume. Its role is to establish an equilibrium price before continuous trading starts. Continuous trading takes place from 10 a.m. to 5 p.m.

In the continuous trading session there are two types of orders possible, limit orders and market orders. Limit orders specify the quantity to be bought or sold, a required price and a date for automatic withdrawal if not executed by then, unless the limit order is good till cancelled ("à révocation"). Limit orders cannot be issued at arbitrary prices because there is a minimum "tick" size of FF 0.1 for stock prices less than FF 500, and FF 1 for higher prices. More than one limit order may be issued at the same price. To these orders, strict time priority for execution applies.

Market orders only specify the quantity to be traded and are executed immediately "au prix du marché", i.e. at the best price available. If the total quantity of the limit orders at this best price do not suffice to fill the whole market order, the remaining part of the market order is transformed into a limit order at the transaction price (for a detailed description of this system see Biais et al. (1992)). Hence, market orders do not automatically walk up the limit order book, and do not always provide immediate execution of the whole order[1].

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[1] A trader who wants to trade a certain quantity immediately can circumvent this mechanism by placing a *limit order* at a very unfavourable price. This limit order will then be executed against existing orders on the other side of the market that show a more favourable price.

After the opening, traders linked up to the CAC system will see an onscreen display of the "market by price". For both the bid side and the ask side of the market, the five best limit order prices are displayed together with the quantity of shares available at that price and the number of individual orders involved. The difference between the best bid and ask price is known as the "fourchette". Brokers can scroll down to further pages of the screen to view limit orders available beyond the five best prices. In addition, some information concerning the recent history of trading is given: time, price, quantity and buyer and seller identification codes for the five last transactions, the cumulative quantity and value of all transactions since the opening, and the price change from the previous day's close to the latest transaction.

The member firms of the Bourse (the "Sociétés de Bourse") key orders directly into the CAC system via a local terminal. All market participants can contribute to liquidity by putting limit orders on display. There is some scope for negotiated deals if the limit order book is insufficiently deep. A financial intermediary can negotiate a deal directly with a client at a price lying within the current fourchette, provided that the deal is immediately reported to the CAC system as a "cross order". For trades at prices outside the fourchette, the member firm acting as a principal is obliged to fill all central market limit orders displaying a better price than the negotiated price within five minutes.

Our data set is a transcription of all changes in the trading screen information for all shares on the CAC system for 44 trading days in the summer of 1991, starting May 25 and ending July 25. We have available a complete record of the total limit order quantity at the five best prices on both the bid side and the ask side of the market and all transactions. Due to the automated trading system, the data are relatively clean. The time stamps indicate exactly the time of the transaction or quote change. Also, quote and trade information has the correct sequence, so that it is possible to exactly find out who initiated the trade, the buyer or the seller, by comparing the transaction price with the previous mid-quote, i.e. the average of best buy and sell limit order prices.

Concerning transactions, there is an indicator showing whether the transaction is a "cross" negotiated outside the CAC system. Cross transactions need not be reported immediately to the exchange, so that there may be errors in the reported times of these transactions. We also have available broker identification codes of the buying and selling parties, which allow us to identify series of small transactions that were initiated by the same person as part of one large transaction. The transaction price per share for such transactions is defined as the quantity weighted average of the price of the small transactions that together make up the larger one.

In this paper, we use a sample of transactions in the shares of ten large firms, with 4000 to 11,000 observations per stock. Most transactions involve a limit order, so that it can exactly be determined who initiated the trade, buyer or seller. For the "crosses", which are negotiated outside the CAC system, we use the simple rule that transactions with a price above the mid-quote[2] are deemed to be buyer initiated, and below the mid-quote seller initiated. Transactions exactly at the mid-quote are not classified. The size of the transaction is the number of shares traded, divided by the so-called Normal Market Size (NMS), which is a transaction size set by the authorities on London's SEAQ International market, and roughly corresponds to the median transaction size in that stock. For the Paris market, 1 NMS corresponds to the 99th percentile of the transaction size distribution.

French shares are also traded on other exchanges, especially London's SEAQ International. It would appear natural to analyse transactions data from both markets simultaneously. There are good reasons not to include London data into the analysis, however. Transactions in London are negotiated between traders and market makers by telephone and are not publicly reported, so that other traders cannot see that they have taken place. The trading process in London is not very visible to outsiders; only the market makers' quotes are publicly observable, but these are often adjusted slowly and do not give a good indication of actual transaction prices. Therefore, we decided to analyse only the transactions from the Paris Bourse.

2. Theoretical background.

In the market microstructure literature broadly three components of the bid-ask spread are distinguished. The first component of the bid-ask spread is the processing cost. This includes the pure cost of processing an order and the compensation for the services of a dealer, i.e. the compensation for being in the market and providing liquidity to traders. The processing cost only has an instantaneous effect on the transaction price. Future prices are not influenced by the presence of a processing cost component in the bid-ask spread.

The second component of the spread is due to asymmetric information between the market maker and the public. Traders with superior information will have an

2 The mid-quote is defined as the average between the best bid and the best ask price available.

incentive to trade on one side of the market only. For example, a trader who knows that the quoted price is lower than the stock's true value will have an incentive to buy. A trade at the ask, initiated by a buyer, therefore gives the market maker a signal that his quoted prices are too low, and he will revise his quotes upward[3]. Because new information is revealed to the market with a transaction, this price effect will be permanent.

The third component of the spread is due to inventory control. The literature in this area[4] usually considers a dealership market where professional market makers provide liquidity and absorb order imbalances. All trades are assumed to be executed through the market makers, whose position in the stock (inventory) in general deviates from their desired inventory level. Therefore, the market makers pose bid and ask quotes to encourage trades that will restore their inventory to the desired level. For example, starting out from a balanced inventory, after a large sale to a market maker (at the bid), his inventory will be higher than desired, and the market maker will revise his quotes downward to encourage purchases by the public. As a result, the price is moved in the direction of the trade. This price effect is temporary, because in the long run the market maker is expected to rebalance his inventory.

3. Estimating spread components by a structural models of transaction prices.

There is a growing literature on estimation of the components of the bid-ask spread. The early empirical papers concentrate on processing costs and one of the other cost components. Ho and Macris (1984) estimate a model for the options exchange with an inventory control component. Glosten and Harris (1988) specify a model with adverse selection costs due to asymmetric information between market participants. Both studies find that trading influences future prices. It is unclear however, which effect is more important, inventory control or adverse selection. Stoll (1989) was one of the first papers to address this question explicitly. Stoll develops an estimator of all three spread components that is based on the covariances between quote changes. This estimator has several disadvantages, however. First, it is inefficient in cases where direct information

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3 Moreover, informed traders have an incentive to trade large quantities, in order to maximise the benefits of trading on perishable asymmetric information, cf. Glosten and Harris (1988) and Easley and O'Hara (1987). Therefore, there is also adverse selection in the size of the transaction: large trades are more likely to be initiated by informed traders than small trades. This theory predicts that large trades will have bigger price effects than small trades.

4 See for example Ho and Stoll (1981).

on the side of the market initiating the transaction is available. In such cases, a regression based estimator such as developed in De Jong et al. (1993) is more efficient. A second disadvantage of Stoll's analysis is that it only considers the effect of a transaction one period ahead, and disregards the long run price effects. This is important because it probably takes more than one transaction for the market maker to rebalance his inventory. Madhavan and Smidt (1991) present an elegant model for transaction prices. In their model, the market maker poses bid and ask quotes based on his best guess of the true value of the stock and on his current inventory. His expectation of the value of the stock after a transaction is updated using Bayes' rule.

Estimation of the Madhavan-Smidt model requires data on the inventories of market makers. However, for the Paris Bourse such data are not directly available. We also cannot construct inventory levels because we do not observe all transactions. For example, we do not know who trades in London or on the inter-dealer market. Therefore, we base our empirical work on the Glosten and Harris (1988) model, which does not distinguish an inventory control component. But in contrast to Glosten and Harris we do estimate both a constant and a trade size dependent part to both the order processing cost and the adverse selection effect.

We shall now present a short derivation of the Glosten and Harris (1988) model along the lines of Madhavan and Smidt (1991). The main purpose of this exercise is to show that there is an interaction between the processing cost and the adverse selection effect. Define the following variables:

p_t = transaction price
Q_t = 'sign' of the transaction[5]
z_t = signed size (number of shares traded)
y_t = expected value of the stock *before* the transaction
μ_t = expected value of the stock *after* the transaction
e_t = publicly observed change in the value of the stock

The first equation of the model states that the transaction price is equal to the expected value of the stock *after* the transaction, plus the processing cost which may depend on the transaction size. We add a random pricing error, u_t, that captures other influences on the transaction price, such as price discreteness and other factors that are not modelled. We assume that u_t is uncorrelated with the other variables in the price equation. Thus, the pricing equation becomes

5 The *sign* is defined as follows: +1 if the transaction is initiated by the buyer (at the ask) and -1 if the transaction is initiated by the seller (at the bid).

$$(1) \qquad p_t = \mu_t + \beta z_t + \psi Q_t + u_t,$$

The expected value after the transaction, μ_t, is based on all publicly available information after the transaction, and includes the adverse selection price effect. The 'posterior' mean μ_t is obtained by taking a weighted average of the 'prior' mean (the expected value before the transaction) and the 'excess demand' for shares

$$(2) \qquad \mu_t = \pi y_t + (1-\pi)[p_t + z_t/\alpha].$$

The parameter π reflects the degree of information asymmetry between the market maker and the public; if there is no asymmetry then $\pi=1$. The parameter α is related to the slope of the demand function for shares. To close the model, it is supposed that the expected value before the transaction, y_t, is equal to the expected value after the previous transaction plus the publicly observed rise in the value of the shares between the two transactions

$$(3) \qquad y_t = \mu_{t-1} + e_t.$$

Together, (1)-(3) constitute the model. Substituting (2) in (1), one obtains the transaction price as a function of the expected value before the transaction plus the price effects of a transaction

$$(4) \qquad p_t = y_t + (\lambda + \beta/\pi)z_t + (\psi/\pi)Q_t + u_t,$$

where $\lambda=(\frac{1-\pi}{\pi})\frac{1}{\alpha}$. The quoted spread for size $|z|$ therefore is

$$(5) \qquad S(z) = 2(\psi/\pi + (\lambda + \beta/\pi)|z|)$$

The decomposition of the half-spread into cost components is as follows:

Processing cost	$\psi + \beta\|z\|$
Adverse selection cost	$\psi^* + (\lambda + \beta^*)\|z\|$

where $\psi^*=(\frac{1-\pi}{\pi})\psi$ and $\beta^*=(\frac{1-\pi}{\pi})\beta$. From this decomposition it is clear that the presence of a processing cost component strengthens the adverse selection effect. Glosten (1987) provides an intuitive argument for this: if there are other transaction costs besides adverse selection costs, noise traders are less likely to trade (compared with the situation where there are no other costs) and therefore transactions that do take place give stronger signals about the true value of the shares. Substituting out the latent mid-price y_t from (4) yields the following regression equation:

(6) $$\Delta p_t = (\lambda+\beta/\pi)z_t - \beta z_{t-1} + (\psi/\pi)Q_t - \psi Q_{t-1} + \xi_t.$$

where $\xi_t \equiv e_t + \Delta u_t$. The components of the spread in the Glosten-Harris model can be estimated directly by the following re-parametrisation of (6)

(7) $$\Delta p_t = (\lambda+\beta^*)z_t + \beta\Delta z_t + \psi^* Q_t + \psi\Delta Q_t + \xi_t.$$

The permanent effects, attributed to adverse selection, are measured by the coefficients of the level variables, whereas the transitory processing cost is measured by the coefficients of the variables in first differences.

A number of econometric issues concerning the estimation of equation (7) require special attention. Following Harris (1986) and Hasbrouck (1991b), who argue that observed covariance patterns in transaction returns are more consistent with transaction time than with calendar time, we assume that the relevant 'clock' is transaction time. We include a constant term in the model to capture the average return between transactions (i.e. a non-zero mean of e_t). The variance of the errors is unspecified by the model. For several reasons, it is likely that the errors are heteroskedastic. For example, the variance may depend on the time of day, and the variance may depend on the trade size. Moreover, due to the presence of the pricing error u_t, ξ_t has an MA(1) serial correlation pattern. With this error structure, OLS gives consistent point estimates, but the usual standard error formula is incorrect. We compute heteroskedasticity and autocorrelation consistent (HAC) standard errors by the method of Newey and West (1987). The size of the transaction is censored at 2 times NMS, which corresponds roughly to the 99.5 percentile of the size distribution, so that 5 out of every 1000 transactions are affected. The reason for censoring is to mitigate the effect of very large trades on the estimates, see also Hausman, Lo and MacKinlay (1992). In the estimation, the dependent variable is the percentage change in transaction prices, so that the parameter estimates can be interpreted as relative (percentage) price effects. Overnight returns and opening prices are excluded from the sample.

In Table 1 the estimates of the Glosten-Harris model are presented. The table shows that the fixed processing cost per transaction, ψ, is always highly significant, but varies quite a lot, from 0.06% for Elf-Aquitaine to 0.17% for UAP. The proportional processing cost, β, is negative in all cases but one (Axa-Midi) where it is positive but insignificant. The highly significant estimates of ψ^* indicate that the adverse selection cost has a fixed, size-independent component for all series. This result strongly contradicts the findings of Glosten and Harris (1988), who report no significant fixed adverse selection cost[6]. Only in four cases the proportional part of adverse selection cost is significantly positive. In the other cases the proportional adverse selection cost is not significant. The weight of the prior mid-price in the new mid-price, π, is estimated close to 0.75 for all series, which is slightly higher than the average of 2/3 reported by Madhavan and Smidt (1991).

Together, the processing cost and adverse selection cost make up the bid-ask spread. Table 1 also shows estimates of the bid-ask spread for a very small transaction and a transaction of NMS. The estimates suggest that usually the spread is declining in trade size, the cause being that the declining processing cost dominates the increasing adverse selection cost. In only two cases does the spread increase with trade size. The estimated spreads are comparable to the results reported in De Jong et al. (1993). Table 1 also reports the proportion of the spread that can be attributed to adverse selection. For the smallest size, about 25% of the spread is due to adverse selection. Because of the decreasing processing cost and increasing adverse selection cost, the adverse selection component at NMS is usually much larger, about 40% of the spread.

4. Simultaneous analysis of prices and transactions.

The structural model of the previous section gives direct estimates of spread components. The structural approach has some disadvantages, however. First, the estimates assume that the model is correctly specified. For example, it is assumed that all asymmetric information is revealed immediately after the transaction so that there is only an immediate price effect of trading and no lagged effects. Second, it assumes that the pattern of trading is exogenous. If so, it is not

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6 In their empirical work, Glosten and Harris found that only the fixed part of the processing cost and the part of the adverse selection cost that is proportional to trade size were significant.

possible to identify an inventory control component if, as in our case, inventory data are not available.

In this section we take a reduced form approach, based on the dynamic price effects of trading. By explicitly separating temporary from permanent price effects the inventory control component can under some additional assumptions be identified. Moreover, the price reaction to trades is interesting in itself. Kyle (1985) mentions 'resiliency' as one of the aspects of the quality of a stock market. Fast recovery to the new equilibrium value after a transaction will reduce average realised transaction costs (measured as the difference between transaction prices and equilibrium prices). The pattern of price adjustment can be used to construct such an alternative measure of the cost of trading.

In the literature, several components estimators based on the above ideas have been developed. Stoll (1989) proposes an estimator based on the auto-covariances of quote changes and transaction price changes. This estimator has several disadvantages, however. First, it is inefficient in cases where direct information on the side of the market where the transaction took place is available. In such cases, a regression based estimator such as developed in De Jong et al. (1993) is more efficient. A second disadvantage of Stoll's analysis is that it only considers the effect of a transaction one period ahead, which disregards the long run price effects. This is important because it probably takes more than one transaction for the market maker's inventory to rebalance.

We prefer the Vector Auto Regressive (VAR) model of price changes and transaction characteristics developed by Hasbrouck (1991a,1991b,1993). From the VAR estimates, the complete pattern of price reaction to trades is easily computed. The joint price and trade dynamics are modelled by the following Vector Auto Regression (VAR):

$$(8)\qquad \begin{pmatrix} 1 & -b_0 \\ 0 & I \end{pmatrix} \begin{pmatrix} \Delta p_t \\ x_t \end{pmatrix} = \begin{pmatrix} a(L) & b(L) \\ c(L) & d(L) \end{pmatrix} \begin{pmatrix} r_{t-1} \\ x_{t-1} \end{pmatrix} + \begin{pmatrix} e_{1t} \\ e_{2t} \end{pmatrix}, \quad V\begin{pmatrix} e_{1t} \\ e_{2t} \end{pmatrix} = \begin{pmatrix} \sigma^2 & 0 \\ 0 & \Omega \end{pmatrix}.$$

where Δp_t denotes the price change and x_t is a vector of trade 'attributes', which for our purposes includes the trade sign (Q_t) and size (z_t). The trade characteristics vector, x_t, is included in the equation for Δp_t, so that for identification the error terms e_{1t} and e_{2t} are supposed to be uncorrelated. The leading coefficient b_0 measures the instantaneous effect of x_t on the transaction price, and may be used as a measure of the realised bid-ask spread. This model allows a very general dependence of price changes and trade sign and size on the past, without the assumption that the trade pattern is exogenous[7].

Although some of the coefficients of the VAR are interesting in themselves, the effects of shocks on future returns and other variables are more interesting for the purposes of this paper. In particular, we are interested in the expected value of the stock price τ periods after a shock, given that the system initially is in the 'steady state':

$$\text{(9)} \quad \begin{aligned} pe_1(\tau) &\equiv E(p_{t+\tau}-y_t | e_{1t}=1,\ e_{2t}=0,\ \Delta p_{t-1}=0,\ \ldots\ x_{t-1}=0,\ \ldots) \\ pe_2(\tau) &\equiv E(p_{t+\tau}-y_t | e_{1t}=0,\ e_{2t}=1,\ \Delta p_{t-1}=0,\ \ldots\ x_{t-1}=0,\ \ldots)^{8} \end{aligned}$$

Sims (1980) popularized the idea to compute such price effects from the *impulse responses* of the VAR model, which can be computed by inverting the VAR to the following Vector Moving Average (VMA) representation:

$$\text{(10)} \quad \begin{pmatrix} \Delta p_t \\ x_t \end{pmatrix} = \begin{pmatrix} \alpha(L) & \beta(L) \\ \gamma(L) & \delta(L) \end{pmatrix} \begin{pmatrix} e_{1t} \\ e_{2t} \end{pmatrix}.$$

To illustrate the usefulness of the VMA form, consider the equation for the price changes in more detail

$$\text{(11)} \quad \Delta p_t = \Sigma_{k=0}^{\infty} \alpha_k e_{1,t-k} + \Sigma_{k=0}^{\infty} \beta_k e_{2,t-k}.$$

In words, the price differences are infinite sums of past innovations in the price equation (e_{1t}) and the transaction equation (e_{2t}). The effect of unit price and trade innovations on the price *change* τ periods ahead are measured by α_τ and β_τ, respectively. Thus, the coefficients of the VMA are exactly the desired impulse responses. The effects of a unit shock on the price *level* τ periods ahead is measured by partial sums of the impulse responses:

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7 Such an assumption was made by Glosten and Harris (1986), Hasbrouck (1988) and Stoll (1989).

8 This equation is for the case that x_t and e_{2t} are scalar. In the case of a multi-dimensional trade vector, the impulse responses need to be calculated from a VAR model with orthogonal innovations. In our work, this is achieved by adding the sign Q_t as an explanatory variable in the equation for the size z_t to obtain orthogonal errors.

(12) $pe_1(\tau) = \Sigma_{k=0}^{\tau}\alpha_k, \quad pe_2(\tau) = \Sigma_{k=0}^{\tau}\beta_k.$

The pattern of price adjustment following an unexpected shock gives all the necessary information to identify the three components of the bid-ask spread. The bid-ask spread itself is equal to the instantaneous price effect $pe_2(0)$ of a transaction. A close look at the VAR reveals that this equals the impact multiplier β_0, which is equal to the leading coefficient b_0 of the VAR representation. Hence, $2b_0$ is used as the estimator of the bid-ask spread. The processing cost is strictly transitory, in the sense that the costs are paid by the initiator of a transaction to the counterparty, but it does not affect future prices at all. The price effects of inventory control probably last for more periods, but eventually vanish because it is expected that in the long run the market maker will rebalance his inventory. The long run price effects provide a measure of the adverse selection cost. The long run effects of shocks are easily determined as the limits of the partial sums as $\tau \Rightarrow \infty$:

(13) $pe_1(\infty) = \Sigma_{k=0}^{\infty}\alpha_k \equiv \alpha(1), \quad pe_2(\infty) = \Sigma_{k=0}^{\infty}\beta_k \equiv \beta(1).$

Cochrane (1988) notes that this definition of the long run effects of innovations is unique and independent of any particular decomposition of the price process in permanent and transitory parts. Under the assumption that the full effect of adverse selection is realised immediately after the transaction, any deviations of the subsequent transaction price from the efficient price are due to inventory control. Thus, the inventory control component can be estimated by subtracting the long run effect $\beta(1)$ from the initial effect, β_1.

Although for our analysis of price reactions to trades the partial sums of impulse responses provide all necessary information, it is also interesting to calculate explicitly the transitory component of the stock price and its variance, which may serve as a measure of implicit transaction costs (cf. Hasbrouck, 1993). Given our assumption that the prices and transactions are generated by a bivariate VAR, the natural decomposition of the observed price, p_t, into a random walk component, μ_t, and stationary deviations around the random walk, s_t, is given by Beveridge and Nelson (1981)[9]. The decomposition is as follows

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[9] Other decompositions of the stock price in permanent and transitory components are also possible. However, these all lead to vector ARMA models for the price-trade process, whereas we assume from the start a VAR model. Hasbrouck (1993) shows that the Beveridge-Nelson decomposition give a lower bound for the variance of the stationary price part among all possible decompositions.

$$(14)\qquad p_t = \mu_t + s_t,$$

$$\mu_t = \mu_{t-1} + \left(\Sigma_{k=0}^{\infty}\alpha_k\right)e_{1t} + \left(\Sigma_{k=0}^{\infty}\beta_k\right)e_{2t},$$

$$s_t = \Sigma_{k=0}^{\infty}\alpha_k^* e_{1,t-k} + \Sigma_{k=0}^{\infty}\beta_k^* e_{2,t-k},\quad \alpha_k^* \equiv \Sigma_{j=k+1}^{\infty}\alpha_j,\quad \beta_k^* \equiv \Sigma_{j=k+1}^{\infty}\beta_j.$$

This decomposition is achieved by subtracting the long run price effects of the innovations, given by equation (13), from equation (11). The natural economic interpretation of the random walk component μ_t is that it is the underlying equilibrium price of the stock, in which all public information is reflected[10]. The stationary part, s_t, measures the deviations of the actual transaction price from the efficient price. Hasbrouck (1993) proposes to use the standard deviation of the stationary part, σ_s, as a summary measure the quality of a security market. Intuitively, σ_s reflects how closely the transaction price tracks the efficient price on average. This 'dynamic' measure of transaction costs can be seen as a generalisation of Roll's (1984) estimator. Under Roll's special assumptions, σ_s is equal to half the realised bid-ask spread.

In actual empirical application of the VAR methodology, several econometric points deserve attention. Including the sign of the transaction in a simultaneous dynamic model creates some problems for estimation and computing dynamic effects. Because Q_t is a limited dependent variable that can only take the values -1 and +1, the first equation of the VAR cannot be a conditional expectation of Q_t for all values of $\Delta p_{t-i} \in \mathbb{R}$ if the coefficients of Δp_{t-i} are non-zero. However, for moderate values of Δp_{t-i} the linear equation may be a good approximation of the true conditional expectation, and the bias in OLS estimates is probably not too serious. Using Q_t as an explanatory variable in the equation for Δp_t causes no problems, because the errors of the return equation and the other equations of the VAR are uncorrelated, see Heckman (1978). Five lags[11] in the VAR are sufficient given the general absence of residual serial correlation in the estimated equations. Overnight returns and opening trades are excluded from the analysis. All reported standard errors are heteroskedasticity consistent estimates.

We first estimate the VAR using *mid-quotes* instead of transaction prices. An example (for the Accor series) of the impulse responses of the mid-quote to an unexpected shock in the sign and the trade size is graphed in Figure 1. The figure

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10 Although equilibrium returns are probably correlated over longer horizons, see Conrad and Kaul (1989) and Lo and MacKinlay (1988), for the analysis of transactions data a good working hypothesis is that the efficient price changes are serially uncorrelated.

11 This follows Hasbrouck (1991a).

shows the typical increasing pattern of the mid-quotes after a shock, very similar to the pattern that Hasbrouck (1991a) reports for mid-quotes on the NYSE. Table 2 summarises the estimates of the initial and long run effects of shocks on the mid-quotes for all series. The main result is that the long run effect of trading on mid-quotes is larger than the short run effect, which confirms the graphical analysis. Probably, this pattern is caused by the strong positive serial correlation in the transaction sign and size. Figure 2 shows the estimated autocorrelation function of the trade sign (Q_t) for the same example. For the other series, the first order autocorrelation is also high, about 0.3, and decays only slowly to zero. Hasbrouck (1991a) also reports estimates of serial correlation in the trade sign of the same order of magnitude.

A possible explanation for this pattern is that asymmetric information is revealed only slowly to the market in a series of transactions, rather than immediately after the trade[12]. Another explanation could be the presence of 'lame duck' limit orders. Many transactions on the Bourse involve one or more limit orders. If prices of limit orders adjust only slowly to new information, probably because of costly monitoring and changing of existing orders, there will from time to time be orders which are either too cheap or too expensive. If so, a number of trades will take place on the same side of the market, causing positive serial correlation in transaction sign and increasing price effects. Berkman (1992) reports similar findings for the European Options Exchange in Amsterdam, which also has a public limit order book.

However, all these explanations refer to the behaviour of *transaction prices*, rather than mid-quotes. Therefore, in the sequel we present results of the VAR analysis on transaction price differences (returns). Figure 3 graphs the impulse responses of transaction prices of our example series. In sharp contrast to the result for mid-quotes, the effect of a trade on subsequent transaction prices is virtually the same for all horizons. This pattern is similar to the results of Holthausen, Leftwich and Mayers (1990), who found that the speed of adjustment to the new equilibrium value after block trades on the NYSE was very fast (less than 3 trades). Table 3 confirms these results for the other series. For all series. the short run price effects is almost equal to the long run effect. A remarkable result is also that the estimates of the long run effects are very similar to the

12 Another popular explanation for positive correlation is that a large transaction is split up into a series of small transactions on the same side of the market. However, in the construction of the data we aggregated a series of transaction by the same broker in the same minute to one large transaction. Despite this adjustment, there still is a very strong serial correlation in Q_t.

estimates obtained by the VAR on mid-quotes. There is also a marked difference in the price effects of small and large transactions[13], the latter being uniformly bigger.

The cause of the apparent conflict between the estimates on mid-quotes and transaction prices must be found in the strong positive serial correlation in trade sign and size. To see how serial correlation affects the price effects measures, suppose that the transaction price p_t is a markup on the mid-quote, y_t (cf. equation (4)):

$$(15) \qquad p_t = y_t + \delta Q_t + u_t.$$

In this simple model, the impulse response of $p_{t+\tau}$ to Q_t will be a factor $\delta \cdot Cov(Q_{t+\tau}, Q_t)$ larger than the impulse response of $y_{t+\tau}$. Apparently, the positive serial correlation in Q_t exactly cancels out the slow adjustment of the mid-quotes to their new equilibrium value. Because Q_t and $Q_{t+\tau}$ are almost uncorrelated for large τ, this model also explains why the estimates of the long run price effects are the same whether one uses mid-quotes or transaction prices.

Table 4 reports the estimated bid-ask spread and the breakup into components. The spread estimates are very similar to the estimates obtained from the Glosten-Milgrom model in Table 1. The standard deviation of the stationary part of the price, reported in Table 5, also gives nearly the same estimate. This is not very surprising given the immediate adjustment of prices to their new equilibrium values. The adverse selection component for small transactions is about half of the total spread. For large transactions, the adverse selection cost estimates run as high as 80%. These estimates of the adverse selection cost component are much larger than the estimates obtained from the Glosten-Milgrom model.

There is no evidence of an inventory control effect. The estimates are all around zero, and often negative. The pattern of serial correlations in sign and size also indicate that there is no strong inventory control mechanism at work. At the most intuitive level, inventory control causes so-called reversal of sign and size, i.e. negative serial correlations. These are not present in the data at all. Evidence in the literature for the inventory control effect is at best weak. Madhavan and Smidt (1992) and Hasbrouck and Sofianos (1992) estimate inventory control models on samples of data from the NYSE. In particular, they test for mean

13 A large transaction is defined here as a transaction of Normal Market Size. The price effects of large transactions were computed by adding the impulse responses of the sign and the size. The effects of a small transaction are equal to the impulse responses of a shock in the sign.

reversion in the inventory levels of specialists. Both papers are only able to find mean reversion in the inventory levels if they allow for speculative shifts in the desired inventory level. Moreover, the estimated reversion to the desired level is very slow, and takes a number of days. Therefore, for analysing intra-day price effects, inventory control is perhaps not so relevant.

The last empirical results from the VAR analysis concern the sources of shocks to transaction prices. Equation (12) shows that there are two sources of changes in the efficient price: shocks to the return equation and shocks to the trade attributes. The former are due to publicly available information that is unrelated to trades, whereas the latter reflect information that is revealed by the trading process. Hasbrouck (1991b) proposes to use the proportion of the variance in the efficient price changes due to trading as a summary statistic for the informativeness of trades. In the table, this proportion is denoted by $R^2_{w,x}$. In line with the results in Hasbrouck (1991b), we find that between 30% and 40% of the variance of w_t is explained by trading. The remainder is attributable to public information that is unrelated to the trading process. This result has to be interpreted with some caution. Recall that the regression error e_{2t} includes the linearisation error of the discrete sign Q_t, and is therefore a combination of innovations in the trade process and measurement errors. Hence, the variance of e_{2t} is larger than the variance of information revealed by trading.

5. Robust measures of price effects.

Measuring dynamic effects of trading by a VAR model is an elegant approach, but imposes strong restrictions on the pattern of impulse responses. Moreover, the estimated coefficients are dominated by the covariance structure on low order lags; the long run effects are essentially determined by extrapolating the short run pattern of correlations. Campbell and Deaton (1989) and Cochrane (1988) convincingly argue that small changes in the VAR specification can lead to substantial changes in the estimates of long run effects. To check the robustness of the VAR results, we adopt a more direct approach to estimating longer run price effects. Although this could be achieved by specifying a general non-parametric regression function, we restrict ourselves to a simple linear parameterisation[14]:

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14 Several authors, e.g. Holthausen et al. (1990), Keim and Madhavan (1992) and Chan and Lakonishok (1993), report that the price response to buyer and seller initiated transactions on the US stock market is asymmetric. We assume linearity and hence symmetry here to facilitate comparison of the results with the results of parametric models, where the asymmetry is not easily included.

(16) $$pe_2(\tau) = E(p_{t+\tau}-y_t|Q_t,z_t) = \beta_0^\tau + \beta_1^\tau Q_t + \beta_2^\tau z_t.$$

The coefficients β_1^τ and β_2^τ measure precisely the price effects of current trade sign and size. For $\tau=0$, estimates of the realised bid-ask spread are obtained.

This measure is not exactly equal to the impulse responses calculated before because we do not condition on past values of sign and size. This conditioning can be achieved by adding more lags to (16):

(17) $$pe_2(\tau) = E(p_{t+\tau}-y_t|I_t) = \beta_0^\tau + \beta_1^\tau Q_t + \beta_2^\tau z_t + \Sigma_{i=1}^{p}[\gamma_i^\tau Q_{t-1} + \delta_i^\tau z_{t-1}].$$

where I_t denotes the information set consisting of all past and current trade sign and size. The coefficients can be estimated by simple linear regression. To increase efficiency we use overlapping observation intervals if $\tau>1$.

Figure 4 graphs the estimated price effects of trading for the Accor series, obtained from regression model (16) with two additional lags for horizons up to 20 transactions. The figure shows the point estimates for the Accor price series of β_1^τ and $\beta_1^\tau+\beta_2^\tau$, which are the price effects of a small and large transaction, respectively. The patterns for a small transaction are very close to the estimates obtained by the VAR. The price effects of a large transaction are almost always larger than the price effects of small transaction, but usually very different from the VAR estimates[15]. The graphs of the other stocks show broadly the same pattern, and confirm the conclusion that a large fraction of the initial price effect of a transaction persists. As before, this result implies that asymmetric information is important and there is little evidence for inventory control.

6. Conclusions.

In this paper we analysed the intra-day price effects of trading on the Paris Bourse. Special attention was paid to estimating components of the bid-ask spread: processing cost, inventory control cost and adverse selection cost due to asymmetric information.

One remarkable result of the analysis is the difference in components estimates from structural models and from a decomposition of the price into transitory and permanent components. More specifically, the Glosten and Harris

15 How significant these differences are is difficult to determine; a formal Hausman test would be complicated because one needs explicit expressions for the standard errors of the VAR impulse responses, which are rather complicated, see Lütkepohl (1989).

(1988) model estimates adverse selection cost comprises between 25% and 40% of the quoted bid-ask spread for small and large transactions respectively. The estimates based on a VAR model for transaction prices suggest that from 50% (for small transactions) up to 80% (for large transactions) of the bid-ask spread is attributable to adverse selection. These numbers are larger than the estimates obtained from the structural models, and indeed they exceed many of the numbers reported in the literature (e.g. Stoll (1989)).

All estimates imply that processing costs decrease with transaction size, which explains the finding in De Jong et al. (1993) that the bid-ask spread is sometimes decreasing with trade size. In line with theoretical predictions, the adverse selection costs increase with size. We do not find any evidence of an inventory control effect. To the most general level, inventory control theory predicts a reversal of trade sign and prices. In marked contrast, the empirical results point at a strong positive serial correlation in trade sign (and size), which cannot be explained by inventory control. Furthermore, the point estimates of the inventory control cost are around zero and very imprecise.

References.

Bagehot, Walter (pseud.) (1971), "The only game in town", *Financial Analysts Journal* **22**, 12-14.

Beveridge and Nelson (1981), "A new approach to decomposition of economic time series into permanent and transitory components with particular attention to measurement of the 'business cycle'", *Journal of Monetary Economics* **7**, 151-174.

Biais, Bruno, Pierre Hillion and Chester Spatt (1992), "An empirical analysis of the limit order book and the order flow in the Paris Bourse", paper presented at CEPR workshop on Market Microstructure, 3-4 April 1992, Konstanz.

Campbell, John and Angus Deaton (1989), "Why is consumption so smooth?", *Review of Economic Studies* **56**, 357-374.

Chan, Louis and Josef Lakonishok (1993), "Institutional trades and intraday stock price behavior", *Journal of Financial Economics* **33**, 173-199.

Cochrane, John (1988), "How big is the random walk in GNP?", *Journal of Political Economy* **96**, 893-920.

Conrad, Jennifer and Gautam Kaul (1989), "Mean reversion in short horizon expected returns", *Review of Financial Studies* **2**, 225-240.

DeJong, Frank, Theo Nijman and Ailsa Röell (1993), "A comparison of the cost of trading French shares on the Paris Bourse and on SEAQ International", CentER Discussion Paper 9329, Tilburg University.

Easley, David and Maureen O'Hara (1987), "Price, trade size and information in securities markets", *Journal of Financial Economics* **19**, 69-90.

George, Thomas, Gautam Kaul and M. Nimalendran (1991), "Estimation of the bid-ask spread and its components: A new approach", *Review of Financial Studies* **4**, 623-656.

Glosten, Lawrence, and Lawrence Harris (1988), "Estimating the components of the bid/ask spread", *Journal of Financial Economics* **21**, 123-142.

Glosten, Lawrence and Paul Milgrom (1985), "Bid, ask and transaction prices in a specialist market with heterogeneously informed traders", *Journal of Financial Economics* **14**, 71-100.

Harris, Lawrence (1986), "A transaction data study of weekly and intra-daily patterns in stock returns", *Journal of Financial Economics* **16**, 99-117.

Hasbrouck, Joel (1988), "Trades, quotes, inventories and information", *Journal of Financial Economics* **22**, 229-252.

Hasbrouck, Joel (1991a), "Measuring the information content of stock trades", *Journal of Finance* **46**, 179-207.

Hasbrouck, Joel (1991b), "The summary informativeness of stock trades: An econometric analysis", *Review of Financial Studies* **4**, 571-595.

Hasbrouck, Joel (1993), "Assessing the quality of a security market: A new approach to transaction cost measurement", *Review of Financial Studies* **6**, 191-212.

Hasbrouck, Joel and George Sofianos (1992), "The trades of market makers: An analysis of NYSE specialists", *mimeo*.

Hausman, Jerry, Andrew Lo and A. Craig MacKinlay (1992), "An ordered probit analysis of transaction stock prices", *Journal of Financial Economics* **31**, 319-379.

Heckman, James J. (1978), "Dummy endogenous variables in a simultaneous equation system", *Econometrica* **46**, 931-959.

Ho, Thomas and Richard Macris (1984), "Dealer bid-ask quotes and transaction prices: An empirical study of some AMEX options", *Journal of Finance* **39**, 23-45.

Ho, Thomas and Hans Stoll (1981), "Optimal dealer pricing under transactions and return uncertainty", *Journal of Financial Economics* **9**, 47-73.

Holthausen, Robert, Richard Leftwich and David Mayers (1990), "Large-block transactions, the speed of response, and temporary and permanent stock-price effects", *Journal of Financial Economics* **26**, 71-95.

Keim, Donald and Ananth Madhavan (1992), "The upstairs market for large-block transactions: Analysis and measurement of price effects", working paper 21-92, Rodney L. White Center for Financial Research, Wharton School, University of Pennsylvania.

Kyle, Pete (1985), "Continuous auctions and insider trading", *Econometrica* **53**, 13-32.

Lo, Andrew and A. Craig MacKinlay (1988), "Stock prices do not follow random walks: Evidence from a simple specification test", *Review of Financial Studies*, **1**, 41-66.

Lütkepohl, Helmut (1989), "A note on the asymptotic distribution of impulse response functions of estimated VAR models with orthogonal residuals", *Journal of Econometrics* **42**, 371-376.

Madhavan, Ananth and Seymour Smidt (1991), "A Bayesian model of intraday specialist pricing", *Journal of Financial Economics* **30**, 99-134.

Madhavan, Ananth and Seymour Smidt (1992), "An analysis of daily changes in specialist inventories and quotations", *mimeo*.

Newey, Whitney and Kenneth West (1987), "A simple, positive semi-definite, heteroskedasticity and autocorrelation consistent covariance matrix", *Econometrica* **55**, 703-708.

Roll, Richard (1984), "A simple implicit measure of the effective bid-ask spread in an efficient market", *Journal of Finance* **39**, 1127-1139.

Sims, Christopher (1980), "Macroeconomics and reality", *Econometrica* **48**, 1-48.

Stoll, Hans (1989), "Inferring the components of the bid-ask spread: Theory and empirical tests", *Journal of Finance* **44**, 115-134.

Table 1. Estimates of the Extended Glosten-Harris model (7).

$$\Delta p_t = \kappa + (\lambda+\beta^*)z_t + \beta\Delta z_t + \psi^* Q_t + \psi\Delta Q_t + \xi_t$$

	κ	$\lambda+\beta^*$	β	ψ^*	ψ	π	S(0)	S(1)
AC	0.0036	-0.0219	-0.0040	0.0302	0.0816	0.73	0.2234	0.1876
	[2.53]	[1.65]	[0.35]	[11.26]	[31.22]		(0.27)	(0.09)
AQ	0.0046	0.0157	-0.0227	0.0208	0.0590	0.74	0.1595	0.1453
	[6.60]	[3.51]	[3.79]	[15.32]	[43.19]		(0.26)	(0.50)
BN	0.0045	0.0196	-0.0103	0.0163	0.0653	0.80	0.1631	0.1817
	[7.57]	[3.52]	[2.03]	[14.84]	[62.62]		(0.20)	(0.40)
CA	0.0015	0.0211	-0.0212	0.0181	0.0779	0.83	0.1919	0.1919
	[1.80]	[4.04]	[4.54]	[11.40]	[46.31]		(0.19)	(0.41)
CS	0.0152	0.0255	0.0059	0.0425	0.1227	0.74	0.3304	0.3932
	[5.45]	[1.52]	[0.42]	[9.66]	[30.19]		(0.26)	(0.35)
EX	0.0029	0.0079	-0.0101	0.0179	0.0496	0.74	0.1350	0.1306
	[4.38]	[2.13]	[2.98]	[13.08]	[36.36]		(0.27)	(0.40)
OR	0.0068	0.0011	-0.0139	0.0344	0.1051	0.75	0.2790	0.2533
	[5.16]	[0.08]	[1.19]	[13.39]	[41.26]		(0.25)	(0.28)
RI	0.0135	-0.0027	-0.0311	0.0484	0.1195	0.71	0.3358	0.2681
	[4.56]	[0.13]	[1.59]	[9.69]	[23.95]		(0.29)	(0.34)
SE	0.0029	-0.0048	-0.0254	0.0370	0.1178	0.76	0.3097	0.2495
	[1.61]	[0.30]	[1.85]	[11.55]	[33.80]		(0.24)	(0.26)
UAP	0.0120	-0.0083	-0.0431	0.0642	0.1672	0.74	0.4629	0.3600
	[4.93]	[0.60]	[3.39]	[13.15]	[33.16]		(0.28)	(0.31)

Notes: dependent variable is percentage change in transaction price; model estimated by OLS, overnight returns omitted; size (z) censored at 2 NMS; sample 24-5-91 to 31-6-91. Newey-West (1987) t-values in square brackets. S(0) is the spread for z=0, S(1) is spread for z=NMS with the fraction of S attributed to adverse selection in parentheses.

Table 2. Mid-quote effects of shocks.

	small		large	
	initial	long run	initial	long run
Accor	.0331	.0572	.0634	.1014
Elf-Aquitaine	.0307	.0522	.0476	.0862
BSN	.0219	.0285	.0582	.0836
Carrefour	.0269	.0449	.0466	.0760
Axa-Midi	.0544	.0825	.1217	.1788
Genarale des Eaux	.0198	.0315	.0295	.0506
l'Oreal	.0461	.0650	.0653	.1462
Ricard	.0521	.0769	.0816	.1140
Schneider	.0553	.0837	.0795	.1210
UAP	.0631	.1040	.0882	.1470

Notes: The table shows the percentage price effects of a transaction by the VAR model estimated on mid-quote changes, sign and size. The first two columns show the initial price effect of a very small transaction and a transaction of unit size (NMS), respectively. The second pair of columns shows the corresponding long run price effects (i.e. after 20 transactions).

Table 3. Transaction price effects of shocks.

	small		large	
	initial	long run	initial	long run
Accor	.0553	.0559	.0796	.0874
Elf-Aquitaine	.0445	.0498	.0646	.0786
BSN	.0344	.0283	.0738	.0834
Carrefour	.0497	.0397	.0708	.0710
Axa-Midi	.0831	.0771	.1401	.1656
Genarale des Eaux	.0337	.0314	.0479	.0510
l'Oreal	.0686	.0644	.1119	.1443
Ricard	.0879	.0726	.1104	.0844
Schneider	.0925	.0765	.0779	.0887
UAP	.1049	.1087	.1175	.1167

Notes: The table shows the percentage price effects of a transaction by the VAR model estimated on transaction price changes, sign and size. The first two columns show the initial price effect of a very small transaction and a transaction of unit size (NMS), respectively. The second pair of columns shows the corresponding long run price effects (i.e. after 20 transactions).

Table 4. Components of the realised bid-ask spread.

	small				large			
	spread	PC	AI	IC	spread	PC	AI	IC
Accor	.215	49	52	0	.244	35	72	-6
Elf-Aquitaine	.167	47	60	-6	.157	17	100	-18
BSN	.169	59	33	7	.199	26	84	-10
Carrefour	.183	46	43	11	.182	22	78	0
Axa-Midi	.333	50	46	4	.393	29	84	-13
Genarale des Eaux	.123	45	51	4	.128	25	80	-5
l'Oreal	.287	52	45	3	.285	22	101	-23
Ricard	.308	43	47	10	.291	24	58	18
Schneider	.317	42	48	10	.245	36	72	-9
UAP	.400	48	54	-2	.318	26	73	0

A small transaction is a hypothetical transaction of size 0, whereas a large transaction is of Normal Market Size.
The "spread" column shows the estimated realised bid-ask spread, derived from the leading coefficient b_0 of the VAR model estimated on transaction prices. The other columns show the decomposition of the spread in Processing Cost (PC), Adverse Selection cost (AI) and Inventory Control cost (IC), as a percentage of the total spread.

Table 5. Variance decompositions.

	σ_s	σ_w	$R^2_{w,x}$
Accor	0.1038	0.0815	0.40
Elf-Aquitaine	0.0823	0.0682	0.45
BSN	0.0780	0.0483	0.34
Carrefour	0.0931	0.0700	0.28
Axa-Midi	0.1662	0.1214	0.35
Genarale des Eaux	0.0620	0.0473	0.38
l'Oreal	0.1371	0.1013	0.36
Ricard	0.1519	0.1118	0.34
Schneider	0.1514	0.1141	0.36
UAP	0.1827	0.1398	0.49

The σ_s column shows the variance of the stationary part of the transaction price (in percent of the price), which is a measure of half the bid-ask spread.
The σ_w column shows the variance of the innovations in the efficient price.
The $R^2_{w,x}$ column shows the proportion of the variance of the efficient price explained by trading.

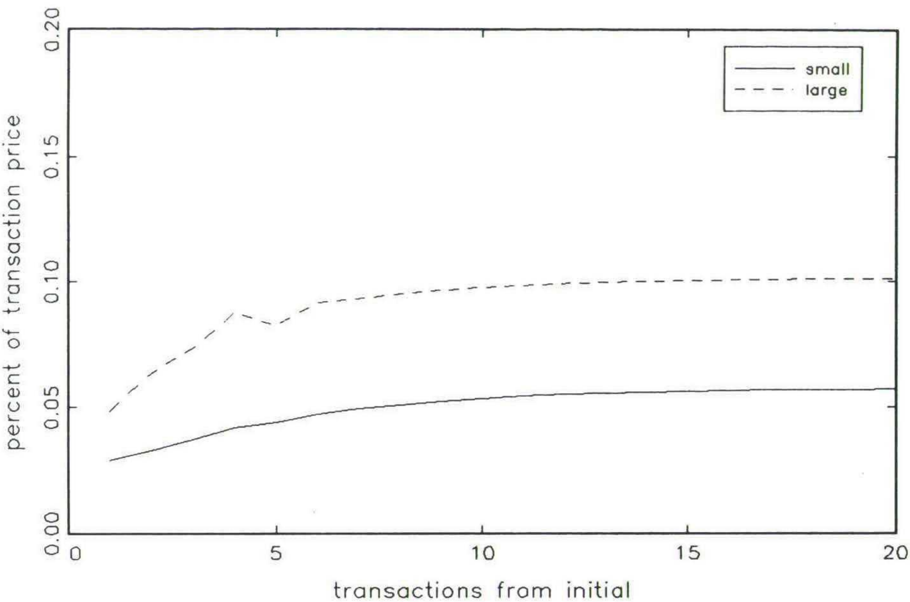

Figure 1. Impulse responses of mid-quotes; Accor.

The solid line graphs the effect on mid-quotes of a shock in the sign equation, and the dotted line graphs the effect of a shock in both the sign and the size equation. The estimation results are obtained from the VAR model, described in section 4.

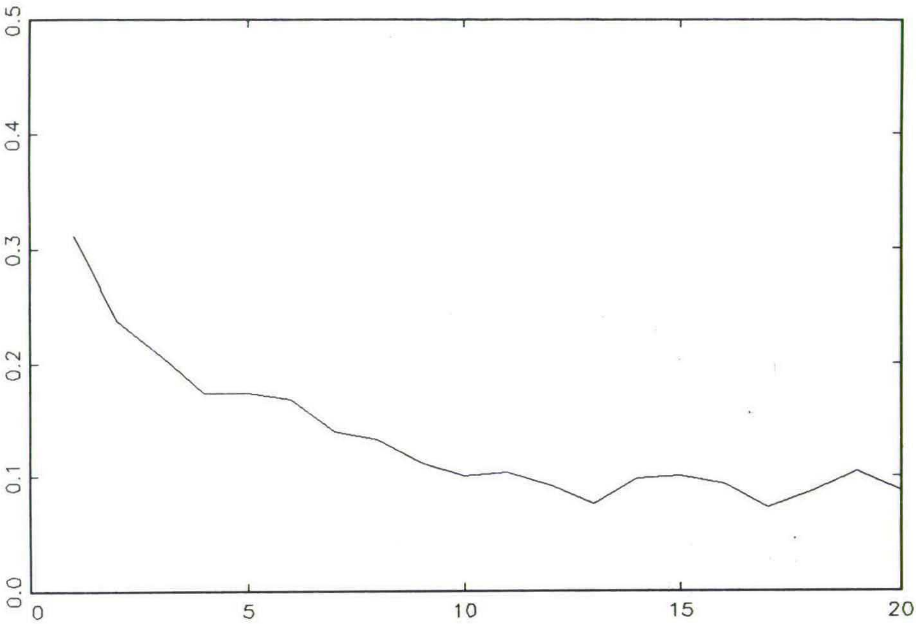

Figure 2. Autocorrelation function of transaction sign Q_t; Accor.

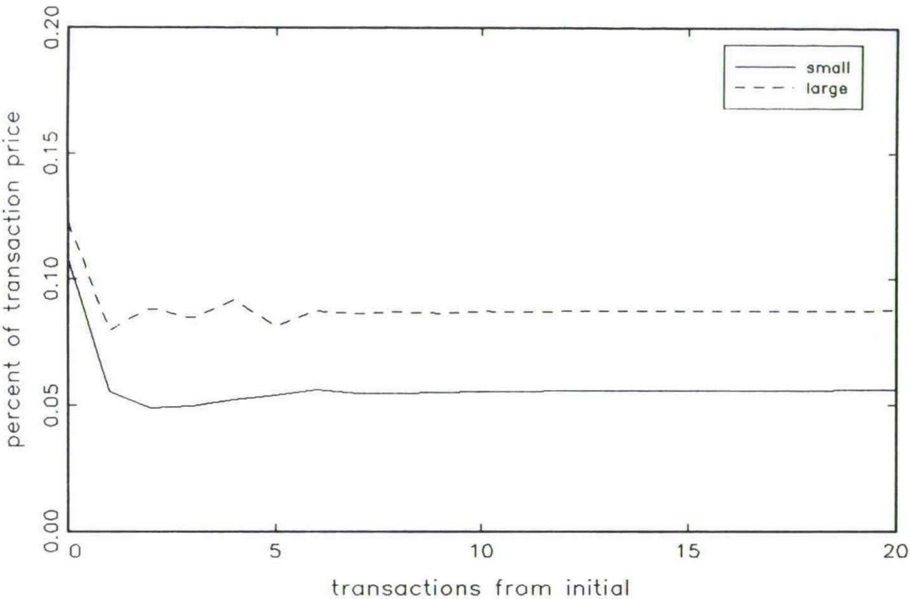

Figure 3. Impulse responses of transaction prices; Accor.

The solid line graphs the effect on transaction prices of a shock in the sign equation, and the dotted line graphs the effect of a shock in both the sign and the size equation.

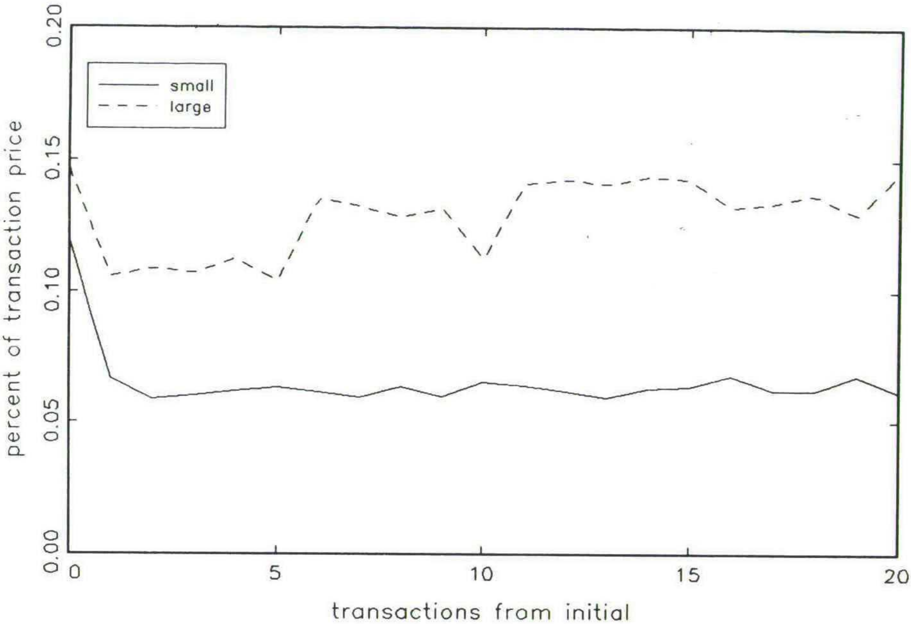

Figure 4. Robust estimates of price effects of trading; Accor.

The solid line graphs the effect on mid-quotes of a shock in the sign, and the dotted line graphs the effect of a shock in both sign and size. The estimation results are obtained from regression equation (17).

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