The microstructure of the UK gilt market

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Abstract

This paper examines the role of trades in price formation in the gilt market. The main findings are that there is apparently no information revealed by the trading process, and that even large trades do not permanently affect the price level. There is little indication that inventory adjustment plays a significant role either. Possibly as a result, spreads are decreasing in trade size. There is also bunching of trade volumes at times of day and week, casting doubt on models that explain such phenomena using adverse selection.

1. Introduction

Empirical studies of financial market microstructure have become one of the major growth areas in financial economics. However, this burgeoning literature has focused almost exclusively on equity markets and, in particular, there has not, to our knowledge, been any detailed analysis of transactions in any major bond market, despite the fact that turnover in bond markets far outstrips equities (in the UK for example, turnover in the gilt market is some three times greater than in the whole equity market). The reasons for this are probably twofold. First, bond markets tend not to be organised around a single exchange and so transactions data can be hard to come by. Second, models of adverse selection, which have become the workhorse of equity microstructure models, do not seem to be so applicable to bond markets where highly homogenous instruments are trading largely on the basis of publicly available information.

Fortunately for the UK gilt market, the London Stock Exchange maintains a full transactions database of official trades in gilts. Using this database, this paper aims to test a number of predictions of microstructure models that have been applied to equity markets in the case of government bonds. In particular, we focus on the issue of adverse selection to establish if it is indeed the case that asymmetric models do not apply to bond markets.

This paper is divided into two main sections. Section 2 begins with an introduction to the composition and structure of the gilt market, continues with a description of the data and finishes with the derivation of some stylised facts about intertemporal patterns of trading in the gilt market. Section 3 examines the role played by order flow in the formation of prices. The final section outlines some conclusions.

2. The structure of the gilt market

The gilt market is a quote-driven market in which trades are intermediated by 21 officially designated gilt-edged market-makers (GEMMs), who quote continuous bid-ask prices in all market conditions, normally between 8.30 am and 4.30 pm. In return, GEMMs receive certain benefits, such as the right to borrow stock from specialised intermediaries, the Stock Exchange money brokers (SEMBs) and access to quotes from the Inter-Dealer Brokers (IDBs). There are also broker dealers who intermediate trades between customers and market-makers. Unlike some markets, trading in the gilt market has no official starting or closing time, nor are there designated batch auctions in which traders simultaneously submit their orders to a central auction mechanism at specific times of days. Quotes from market-makers are indicative rather than firm price offers. The prices and number of nearly all deals of less than £5 million are published by the Stock Exchange (which is the listing authority for all gilts) in the Daily Official List.

In 1994, turnover in the gilt market amounted some £1,545 billion,[1] of which £722 billion was in shorts (0-7 years), £557 billion in mediums (7 - 15 years), £197 billion in longs, £19 billion in variable rate stocks and £50 billion in index-linked stocks. There was a total of some 702,000 transactions, at an average value of some £2.2 million. Customer transactions amounted to £826 billion, some 53% of total turnover. Typically, average trade size is greater in short stocks than in others. For instance, the average bargain size for short stocks in October 1994 amounted to £3 million compared with £1.9 million for others.[2] The average size of trades for customers was smaller - at £1.6 million - than for the market as a whole, at £2.3 million. By way of comparison across markets, the

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1 *London Stock Exchange Quarterly*, Spring 1995.

2 London Stock Exchange *Quality of Markets Monthly Fact Sheet*, October 1994.

average size of trades in UK and Irish equities was considerably smaller, at £68,000, but the average daily number of trades higher at some 31,000 compared with some 2,500 in the gilt market. Overall, the total value of transactions in the gilt market (£124 billion) for October was some nearly three times as high as that for UK and Irish equities (£44 billion).

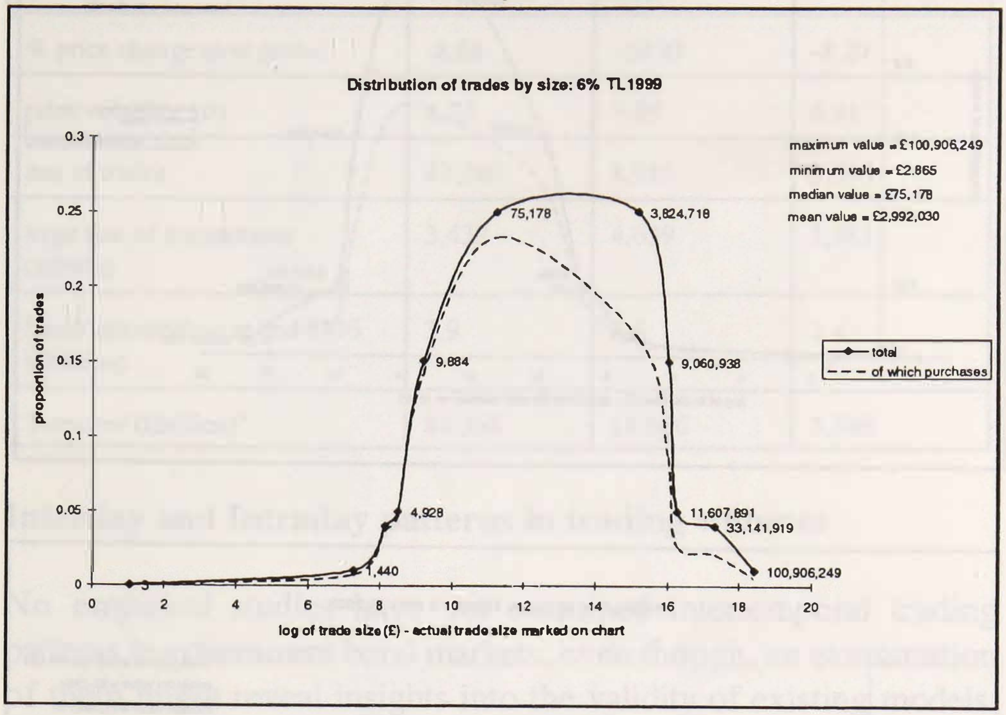
Data

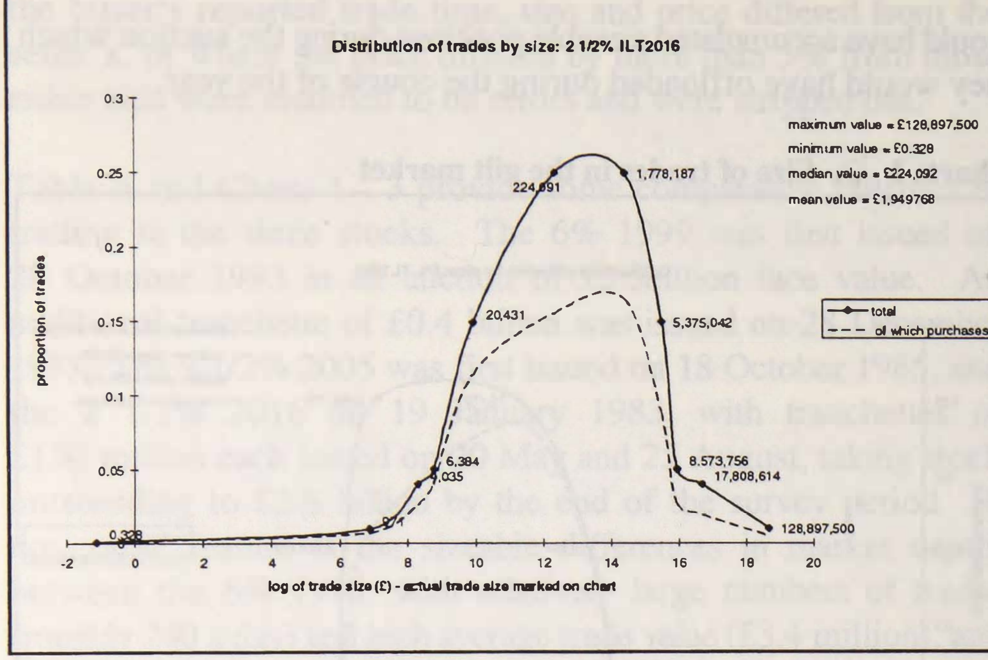
This paper examined trading over a one year period in three stocks that reflected different segments of the gilt market: the 6% Treasury Stock 1999 (short), the 9 1/2% Treasury Stock 2005 (medium) and the 2 1/2% Treasury Stock 2016 (index-linked). Data on some 60,000 transactions from October 1993 to October 1994 were obtained from the London Stock Exchange. The information reported to the Exchange included prices and quantities traded, counterparties, trade times and dates and whether or not the trader was acting as a principal or as an agent. Price quotations were not available.

The quality of the data was generally good. GEMMs and broker-dealers who deal in gilts must submit a trade report to the Exchange within 15 minutes (or 5 minutes if the trade exceeds £100,000). When deals are struck between two reporting firms, trade details from each firm are cross-checked against each other by the Exchange. In addition, market-makers report end of day positions to the Bank of England, which allow cumulative positions to be cross-checked as well. However, when trades occur between a market-maker and a non-reporting firm, the deal is reported by only one counterparty, and there is less certainty of reporting accuracy, particularly as regards trade times. However, reported details are often downloaded from market-makers front-end dealing systems, so even when independent cross checking is not possible, the data ought, in general, to be fairly accurate. Nevertheless, on analysis, some anomalies remained. Trades where the buyer's reported trade time, size and price differed from the seller's, or where the price differed by more than 5% from those either side were assumed to be errors and were stripped out.

Table A and Charts 1 - 3 provide some comparative statistics of trading in the three stocks. The 6% 1999 was first issued on 28 October 1993 in an auction of £3.5billion face value. An additional tranchette of £0.4 billion was issued on 28 December 1993. The 9 1/2% 2005 was first issued on 18 October 1985, and the 2 1/2% 2016 on 19 January 1983, with tranchettes of £150 million each issued on 20 May and 25 August, taking stock outstanding to £2.8 billion by the end of the survey period. A noticeable feature is the sizeable differences in market depth, between the 6% 1999, with relatively large numbers of trades (roughly 240 a day) and high average trade value (£3.4 million), and the 2 1/2% 2016, with relatively few trades (roughly 20 a day) and low average trade value (£2.0 million). The average trade size for the 9 1/2% 2005 was the highest in the sample, at some £4.6 million. Nevertheless, the stocks were all relatively liquid compared to the market as a whole, and average trade sizes relatively large. There were also notable differences in median trade sizes: £75,000 for the 6% 1999 compared with £1 million for the 9 1/2% 2005 and £225,000 for the 2 1/2% 2016. Volatility, as measured simply by the standard deviation of consecutive percentage price changes, was seemingly high for all stocks and was lowest for the deepest stock, though this might merely reflect the smaller time delay between consecutive trades and maturity effects. The distribution of trades, particularly for the 6% 1999, was heavily skewed towards customer purchases. Of 28,195 trades in that stock, 21,651 were purchases. The skew was greatest for averagely sized trades, whereas large trades were reasonably well distributed between purchases and sales. The heavy predominance of purchases may have reflected the fact that the 6% 1999 stock was first issued in October 1993, and that market-makers therefore would have accumulated sizeable positions during the auction which they would have offloaded during the course of the year.

Charts 1 - 3: Size of trades in the gilt market




Distribution of trades by size: 2 1/2% ILT2016
maximum value = £128,897,500
minimum value = £0.328
median value = £224,092
mean value = £1,949768
224,091
1,778,187
20,431
5,375,042
6,384
8,573,756
17,808,614
128,897,500
0.328
total
of which purchases
proportion of trades
log of trade size (£) - actual trade size marked on chart
0.3
0.25
0.2
0.15
0.1
0.05
-2
0
2
4
6
8
10
12
14
16
18
20

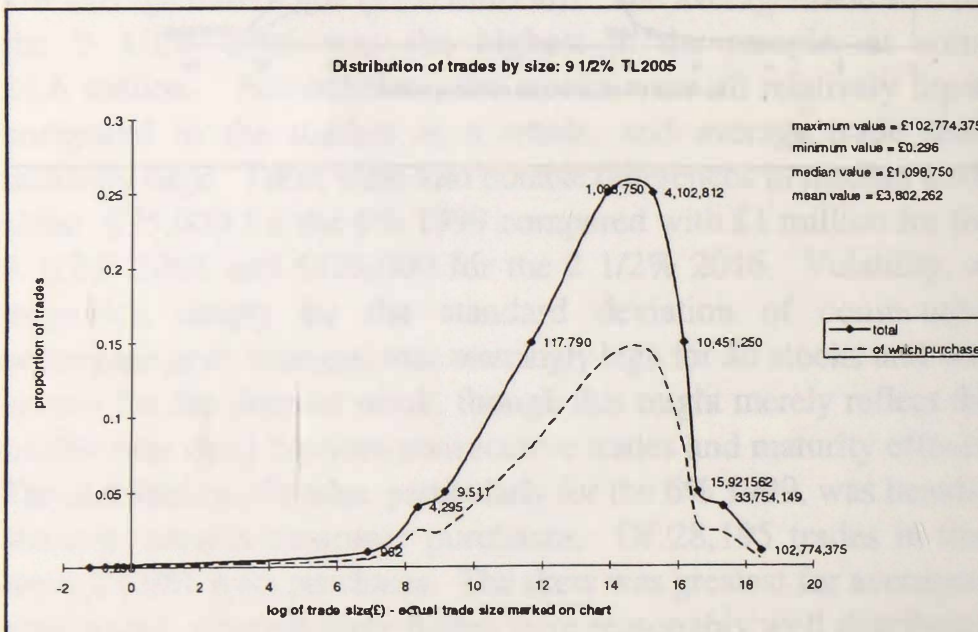

Distribution of trades by size: 9 1/2% TL2005
maximum value = £102,774,375
minimum value = £0.296
median value = £1,098,750
mean value = £3,802,262
4,102,812
117.790
10,451,250
9,511
4,295
962
15,921562
33,754,149
102,774,375
total
of which purchases
proportion of trades
log of trade size(£) - actual trade size marked on chart
0.3
0.25
0.2
0.15
0.1
0.05
-2
0
2
4
6
8
10
12
14
16
18
20

Table A: Comparative statistics, October 1993 - October 1994

Stock	6% TL1999	9 1/2% TL2005	2 1/2% ILT2016
average price	93.76392	112.12949	145.554
% price change over period	-8.08	-10.93	-8.29
price volatility (σ)	4.23	7.09	6.91
nos of trades	47,260	8,915	3,595
avge size of transactions (£000's)	3,432	4,639	1,981
Stock outstanding at end 1993 (£billion)	3.9	4.8	2.4
Turnover (£billion)[3]	84.363	18.566	3.886

Interday and Intraday patterns in trading volumes

No empirical studies have yet examined intertemporal trading patterns in government bond markets, even though, an examination of them might reveal insights into the validity of existing models. This section briefly outlines some stlylised facts about trading patterns in the gilt market over time (Charts 4 - 6). First, trading per month was analysed. There were few signs of any obvious trading patterns - though the number of transactions tended to have been lower in some stocks during the summer and winter months. On the other hand, there was considerable volatility in trading patterns between months, indicating the market might have been prone to fairly rapid swings in liquidity.

Second, trading by day of the week was analysed, for which there was a clearer pattern. The number of transactions, and the share of

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[3] excluding trades with the Bank of England.

turnover, was greater in mid-week, especially Wednesdays, than on Mondays or Fridays for all three stocks.

Chart 4: Percentage of total turnover in each bond taking place each month

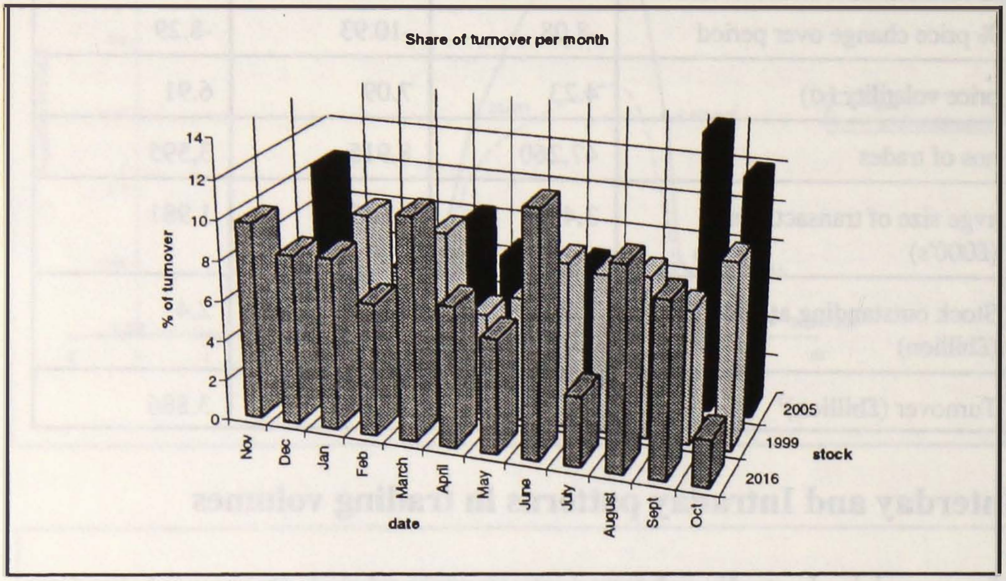
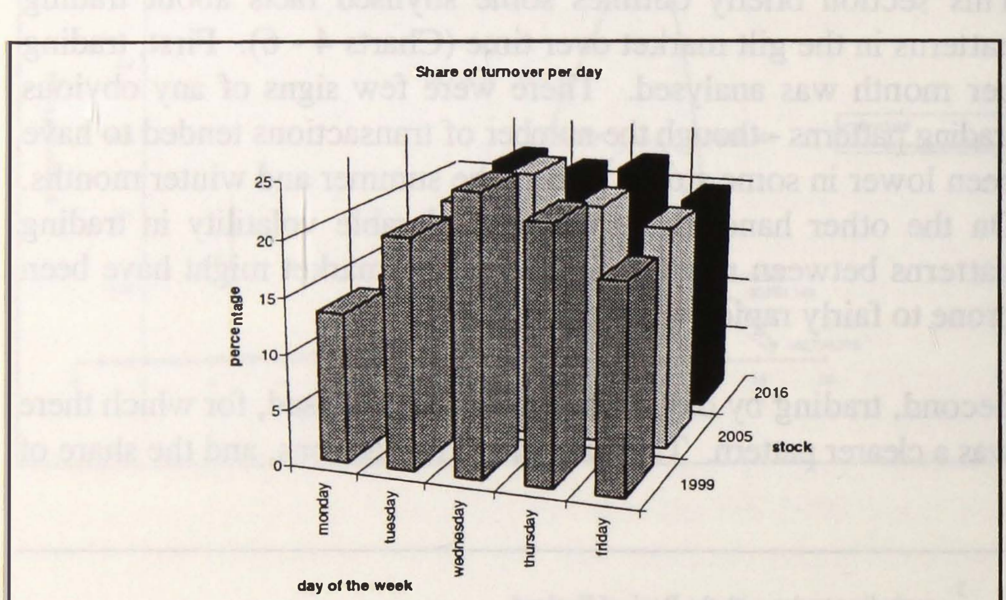
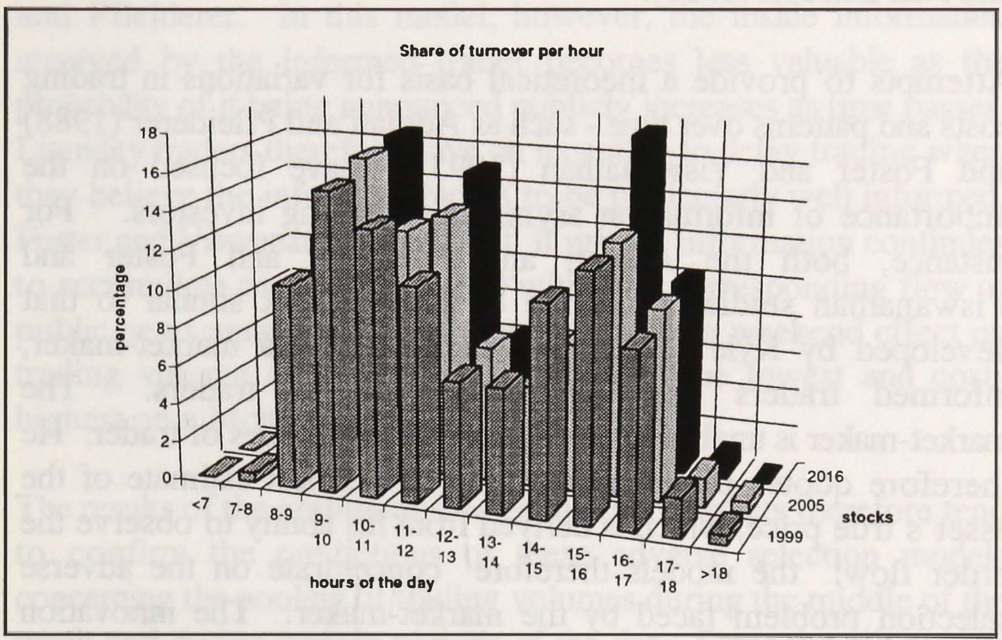


Chart 5: Percentage of total turnover in each bond taking place each day



Third, trading by time of day was analysed. Consistent with findings in other studies, intraday trading volumes demonstrated a U-shaped pattern[4]: the share of transactions was greatest in mid-morning (ie 9am-12pm) and in late afternoon (ie 3pm-4pm). Transactions numbers tailed off rapidly either side of these times, with a noticeable lull over the midday period. There was little variation in trading patterns over time between the different gilt stocks.

Chart 6: Percentage of total turnover in each bond taking place each hour



These findings broadly concur with trading patterns revealed in a number of other markets. Numerous papers have analysed trading patterns and costs over time, with most analysing trading in equities

4 Strictly speaking, the distribution is bimodal - this reflects the fact that, unlike in other markets, there is no official market opening or closing.

markets, and one of the main results uncovered is a pooling of trading at certain times of day or days of the week. For instance, numerous studies show trading volumes to exhibit a U-shaped pattern during the course of the day, with volumes particularly high during the early morning trading sessions: eg Jain and Joh (1988), McInish and Wood (1990), McInish and Wood (1992), Gerety and Mulherin (1992), Brock and Kleidon (1992), Foster and Viswanathan (1993), de Jong, Nijman and Roell (1993) and Lehmann and Modest (1994), Christie and Schultz (1995). Similarly, studies have revealed a significant concentration of trading during the middle of the week, with trading volumes particularly low on Mondays: eg Foster and Viswanathan (1993) and Jain and Joh (1988).

Attempts to provide a theoretical basis for variations in trading costs and patterns over time - such as Admati and Pfleiderer (1988) and Foster and Viswanathan (1993) - have focused on the importance of information asymmetries among investors. For instance, both the Admati and Pfleiderer and Foster and Viswanathan studies make use of a framework similar to that developed by Kyle (1985), in which there is a market-maker, informed traders and uninformed liquidity traders. The market-maker is unable to distinguish between types of trader. He therefore quotes prices on the basis of his best estimate of the asset's true price, which is derived from his ability to observe the order flow: the models therefore concentrate on the adverse selection problem faced by the market-maker. The innovation introduced by Admati and Pfleiderer and Foster and Viswanathan is the assumption that liquidity traders have discretion over the times at which they trade.

In the Admati and Pfleiderer model, liquidity traders are permitted to choose whatever time of day to trade. Given that liquidity traders wish to avoid trading with an informed trader, they may refrain from appearing in the market when they perceive the probability of informed traders being present is high. In equilibrium, all liquidity traders end up trading at the same time of day. While this pooling of liquidity traders does attract informed traders, who clearly have an interest in disguising their presence, Admati and Pfleiderer show that this strategy minimises the costs of liquidity traders, by taking advantage of the lower cost of trading when there is competition among the informed traders. The main predictions of this model, therefore, are that trading volumes should be concentrated during certain periods of the day, and that trading costs should be low when trading volumes are high.

The Foster and Viswanathan approach is similar to that of Admati and Pfleiderer. In this model, however, the inside information received by the informed trader becomes less valuable as the probability of it being announced publicly increases as time passes. Liquidity traders therefore have an incentive to delay trading when they believe the informed traders to be particularly well informed. Foster and Viswanathan show that, if private information continues to accumulate over the weekend without a corresponding flow of public news announcements, there should be a weekend effect on trading volume and costs: volumes should be lowest and costs highest on a Monday.

The results of the empirical studies in other markets therefore tend to confirm the predictions of these adverse selection models concerning the pooling of trading volumes during the middle of the week and during certain periods of the day. Since the gilt market also appears to exhibit a bunching of trading volumes similar to those in other markets, the adverse selection models would suggest that information asymmetries are also present in the gilt market. If not, it suggests that adverse selection models are not a complete explanation for this type of pattern in trading behaviour. Section 3 analyses this proposition in more detail: in particular, it examines the information contained in individual gilts trades.

3. The price formation process

At the core of the price formation process in a dealership market is the manner in which market-makers determine bid and asking prices. Three sets of explanations are generally put forward:

- Transactions costs (eg Demsetz (1968), Tinic (1972)).

- Inventory effects (eg Stoll (1978), Ho and Stoll (1981)). By standing ready to buy or sell securities, dealers' inventories may be driven to sub-optimal levels. The bid-ask spread is the compensation necessary to induce the dealer to hold a non-optimal portfolio.

- Information effects (eg Glosten and Milgrom (1985), Kyle (1985)). If there exist information asymmetries between traders, a spread around the asset's true price will be required to compensate the dealer for the possibility of inadvertently trading with an informed trader.

If the bid-ask spread were determined solely by transactions costs, one would expect observed transactions prices to jump between bid and ask prices, with individual trades having no impact upon the mid-price, as set out by Roll (1984). As noted by Hasbrouck (1988), if inventory effects dominated the price setting process, one would expect prices to move temporarily away from the asset's true value as dealers invited customer trades with which to rebalance portfolios. However, if information effects were important, prices would move to different, permanent equilibria in reaction to trades, as market-makers adjusted their price quotes in response to the incremental information provided by order flow. Similarly, if informed traders on average exploited their information by purchasing or selling large quantities, prices would tend to adjust most markedly following large transactions.

The impact of order flow on price formation is thefore different depending on which of these three factors dominate in any particular market, and there is no reason to presuppose that results from one asset market will automatically translate into another. In equities markets, studies have typically found the information effect to be a significant feature of price setting. On the London Stock Exchange, for instance, Gemmill (1994) and Breedon (1992) found that trade information was significant.

A Vector autoregression approach

One procedure for distinguishing between these factors is the vector autoregression approach (see Hasbrouck (1991)). An inventory adjustment process would induce serial dependence between trades, as may price pressure effects and order fragmentation. Lagged adjustment to new information related to, for instance, transparency regimes, may also lead to a distribution of the information impact over time. As a result, price changes may filter slowly into the market and induce changes in trading patterns, while trades may also induce lagged changes in both prices and trades. In addition, the relationship between the size of trade and its information content may entail non-linear effects, particularly for large trades. For these reasons, this approach assumes that trades and quote revisions may be considered from an econometric point of view as a system characterised by auto- and cross-correlations of a fairly general nature. A vector autoregression may therefore be applied to price and trade data.

In the VAR model, percentage price changes, trade quantities and an indicator variable which measured the direction of trade (ie $x^o_t = +1$ if $x_t > 0$, and $x^o_t = -1$ if $x_t < 0$) were regressed against lagged values for each of the three stocks. To examine the extent of non-linearities, a quadratic term was also added ($x^1_t = x^o_t * x_t^2$). Shwarz and Akaike tests were run to identify the optimal lag structure on the VAR, but, as Hasbrouck also found, the tests generated implausibly long lags (over 200 lags) which did not generate significantly increased predictive power. The lag structure on the VAR was therefore truncated to match the specification on Hasbrouck's model:

$$x_t^o = \sum_{i=1}^{5} \delta_i r_{t=i} + \sum_{i=1}^{5} \varphi_i x_{t-i}^o + \sum_{i=1}^{5} \eta_i x_{t-i} + \sum_{i=1}^{5} \rho_i x_{t-i}^1 + v_{2,t}$$

$$r_t = \sum_{i=1}^{5} \alpha_i r_{t-i} + \sum_{i=0}^{5} \beta_i x_{t-i}^{\bullet} + \sum_{i=0}^{5} \gamma_i x_{t-i} + \sum_{i=0}^{5} \mu_i x_{t-i}^1 + v_{1,t}$$

$$x_t = \sum_{i=1}^{5} \lambda_i r_{t-i} + \sum_{i=1}^{5} \theta_i x_{t-i}^o + \sum_{i=1}^{5} \varsigma_i x_{t-i} + \sum_{i=1}^{5} \chi_i x_{t-i}^1 + v_{3,t}$$

Table B: estimates for the VAR model for the 6% tl1999

Co-efficient groups*		Dependent variables		
		r_t	x^o_t	x_t
r_t	lags	1-5	1-5	1-5
	Σ	-1.652	-2.54E-01	-544380
		(-71.067)	(-2.125)	(-0.913)
x^o_t	lags	0-5	1-5	1-5
	Σ	-3.82E-04	0.806	363168
		(-0.241)	(101.075)	(9.127)
x_t	lags	0-5	1-5	1-5
	Σ	7.47E-10	-7.13E-08	6.20E-02
		(1.288)	(-25.877)	(4.509)
x^1_t/1000,000	lags	0-5	1-5	1-5
	Σ	-7.72E-12	1.31E-09	1.56E-02
		(-0.681)	(23.749)	(56.679)
R^2		0.303	0.291	0.699

Likelihood Ratio Test = 26.197. $\chi^2(60,0.05) = 79.82$

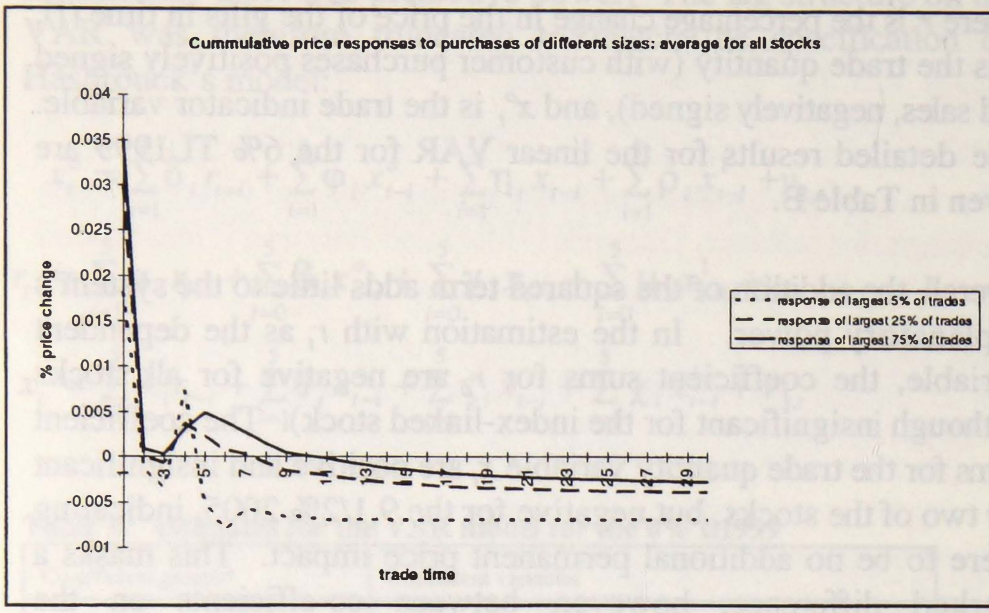
* where ∑ is the sum of co-efficients in each lag group, with the t-statistics for the group in brackets underneath.

where r_t is the percentage change in the price of the gilts in time *(t)*, x_t is the trade quantity (with customer purchases positively signed and sales, negatively signed), and x^0_t is the trade indicator variable. The detailed results for the linear VAR for the 6% TL1999 are given in Table B.

Overall, the addition of the squared term adds little to the system's explanatory power. In the estimation with r_t as the dependent variable, the coefficient sums for r_t are negative for all stocks (although insignificant for the index-linked stock). The coefficient sums for the trade quantity variable x_t are positive and insignificant for two of the stocks, but negative for the 9 1/2% 2005, indicating there to be no additional permanent price impact. This masks a marked difference, however, between co-efficients on the contemporaneous variables and lagged ones. Contemporaneous values of x and x^0 record positive values, while closely lagged values record offsetting negative values, and later lags record values close to zero. This is a clear indication of a normal bid-ask spread. In the equations with the trade quantity measures as the dependent variable, lagged price changes were negative and significantly different to zero for three of the six co-efficients, indicating little consistent responsiveness of trades to price changes. In general, there was a strong serial dependence between trade quantity indicators.

The estimated co-efficients for the system were used to construct impulse response functions for each of the three stocks to simulate the temporary and permanent price behaviour following trades of different sizes. The aggregate results are given in Chart 7.

Chart 7: Impulse response function derived from the VAR



Overall, the VAR model demonstrates the absence of any meaningful permanent price impact: in fact, prices movements for purchases are mildly negative on average. This result indicates fairly clearly the lack of information content contained in individual gilts trades.

Another feature generated by the impulse response function is the moderate degree of price turbulence between trades three and ten. This may indicate some inventory adjustment process. If so, it is small, rapidly incorporated into long-run prices and little different between trades of different sizes - a feature potentially contingent upon the reporting regime in the gilt market.

An event-study approach

Whilst a VAR approach has the advantage that it uses all the data in the sample to infer information about the relationship between order flow and price movement, it has the disadvantage that it can only allow for mild non-linearities in the relationship between the trade size and the price effect. Similarly, the VAR imposes symmetry between the price response following purchases and sales. To examine the impact of individual large trades in more detail, as well as to cross-check on the results obtained by the VAR, an event-study was used. To prepare the data, a procedure was used similar to that employed by Gemmill (1994) and Man Kit Lai (1994). Trades between market-makers and IDBs were stripped out since these would, by and large, reflect market-makers offsetting exposures and should not reflect the arrival of new information. Remaining trades were recorded as either between market-makers and brokers, or between two market-makers. In the latter case, customer purchases (sales) were defined as being those in which the purchasing (selling) market-maker was recorded as acting as the agent, rather than the principal. This left 35,072 usable trades.

Large trades were alternatively defined as the largest 5% of customer purchases and sales over the period in each stock (see Table C). In total, the sample contained 1,754 large trades, the majority of which occurred in the 6% 1999 stock. To prevent the results of this stock overwhelming the other two, aggregate results were calculated as simple averages of the three stocks.

The event-study method initially applied was similar to that used by Gemmill and by Holthausen, Leftwich and Mayers (1990).[5] Mean trade-to-trade excess returns (*Rxit*) for customer purchases and sales were measured for each of the large trades (*b*) in relation

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[5] This exposition is derived from Holthausen *et al.*

Table C: Large trades

Stock	Number of large trades	Average size of large trades (£ million)
6% 1999	1,410	11,607,891
9 1/2% 2005	244	15,921,562
2 1/2% 2016	100	8,573,756

to the mean trade-to-trade return (BEN_i) for each stock (i) in the benchmark period t_{-20} to t_{-11},

$$Rx_{it} = \sum_{b=1}^{x} (R_{bit} - BEN_i)/x, \qquad t = -10,...+15, \; i = 1,2,3$$

where

$$BEN_i = \sum_{b=1}^{Nit} \sum_{t=-20}^{-11} R_{bit} / N_i, \qquad i = 1,2,3$$

and

R_{bit} =trade-to-trade return for stock (i) at trade (t) for block (b),
N_{it} =number of transactions for stock (i) in the benchmark period for trade (t) and,
N_i =the total number of transactions for stock (i) in the benchmark period ie, the sum of the N_{it} from t = -20,...,-11.

In the results presented below the benchmark returns series (BEN_i) were dropped because they were insignificant. The charts and results quoted below are based on cumulative returns where,

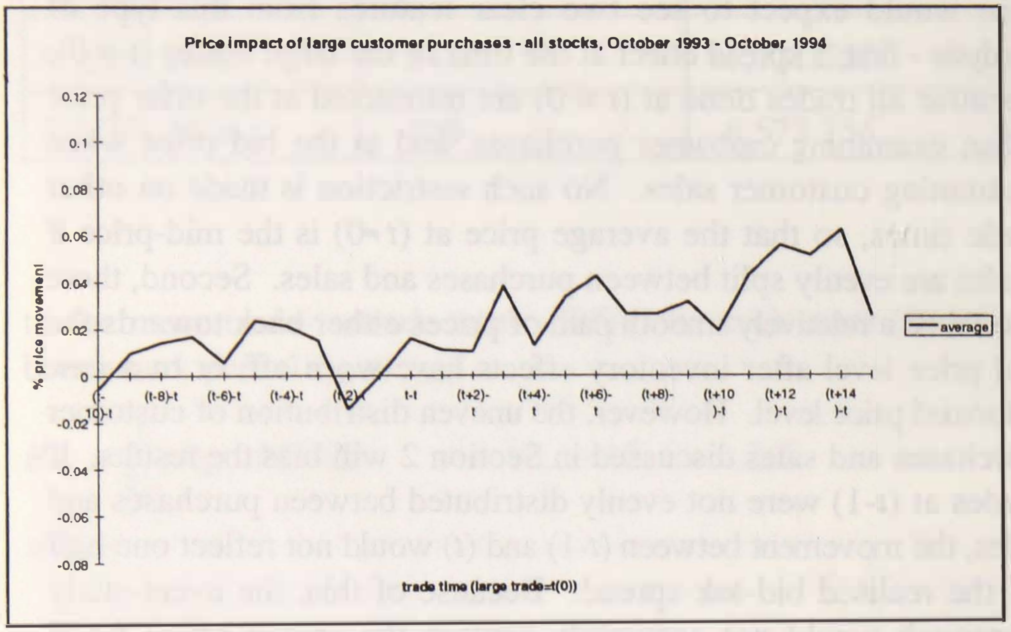
$$C_{it} = \sum_{j=1}^{t} Rx_{ij}$$

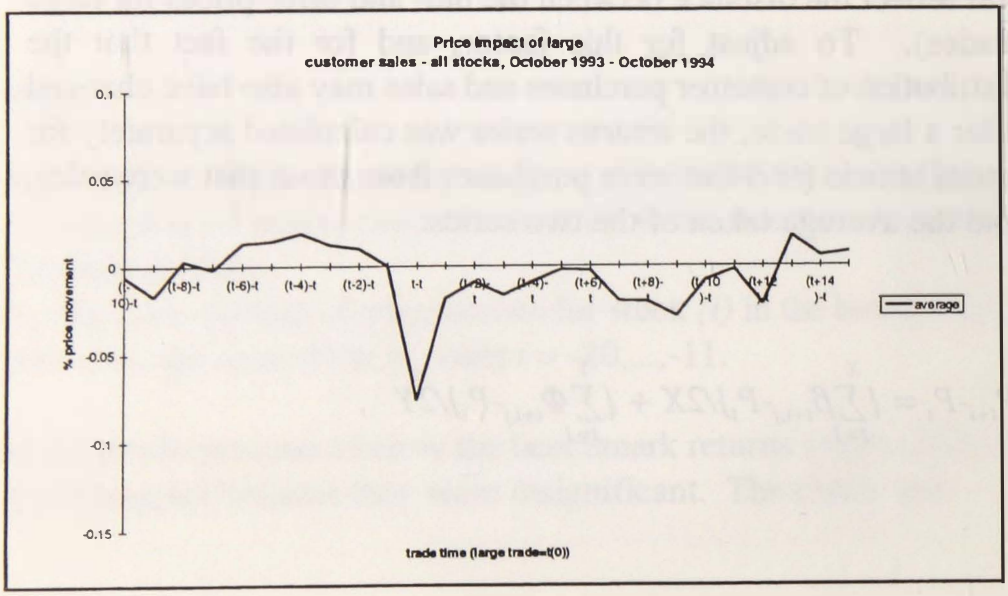
One would expect to see two clear features from this type of analysis - first, a spread effect at the time of the large trades $(t = 0)$, because all trades done at $(t = 0)$ are transacted at the offer price when examining customer purchases, and at the bid price when examining customer sales. No such restriction is made on other trade times, so that the average price at $(t \neq 0)$ is the mid-price if trades are evenly split between purchases and sales. Second, there should be a relatively smooth path of prices either back towards the old price level after inventory effects have worn off, or to a new informed price level. However, the uneven distribution of customer purchases and sales discussed in Section 2 will bias the results. If trades at $(t$-1) were not evenly distributed between purchases and sales, the movement between $(t$-1) and (t) would not reflect one half of the realised bid-ask spread. Because of this, the event-study approach would not accurately capture the spread effect when separated between purchases and sales (though of course, it would still reflect the distance between the bid- and offer-prices for large trades). To adjust for this factor, and for the fact that the distribution of customer purchases and sales may also have changed after a large trade, the returns series was calculated separately for trades at time $(t+i)$ that were purchases from those that were sales, and the average taken of the two series:

$$P_{t+i} - P_t = \{\sum_{J=1}^{X} \beta_{t+i,j} - P_t\}/2X + \{\sum_{J=1}^{Y} \Phi_{t+i,j} - P_t\}/2Y \quad ,$$

where (β) is the value of bid prices at time *(t+i)* and *(*X*)* the number of trades at the bid price, and *(Φ)* is the value of offer prices at time *(t+i)* and *(*Y*)* the number of trades at the offer price. The average price response is shown in charts 8-9.

Charts 8-9: Event-studies





The results show an expected result for customer sales. A clear - but small - negative spread of some 0.07%-0.08% was found, followed by a swift reversion in prices and returns to pre-trade levels. None of the price movements for any of the stocks for any (*t*) after the large trade was significantly different to zero at the 95% level. The results for customer purchases were more difficult to reconcile. In particular was the apparent absence of a significant bid-ask spread, with trades taking place close to the seeming mid-price. Given this, it was surprising that there appeared to be some small positive price movement on average after large trades, although the size of these effects was small in comparison to those found in UK equities markets, and none were significantly different to zero.

Overall, these results tend to confirm the main findings of the VAR. In particular, they show that there is no significant permanent price movement induced by either large purchases or sales of gilts. This implies that even the largest 5% of trades in the market do not contain relevent information about the future course of prices. In addition, there is no substantial temporary price movement that would suggest inventory adjustment.

The estimation of spreads

If adverse selection and - to a lesser extent - inventory adjustment do not play significant roles in price formation, processing costs ought to be the only remaining feature of the determination of market-makers' spreads. One method of testing this proposition is to examine how spreads vary according to trade size and time.

The spreads estimated from the VAR for the different size categories for the 6% 1999 and the 2 1/2% 2016 were in a range between 0.016% and 0.124% of the price, with the majority of estimates clustered around 0.1%. These estimates broadly agree with the spreads quoted by market-makers, which are said to be in the region of 2/32 - 0.0625% - for benchmark stocks, and somewhat higher for less liquid stocks. On the other hand, no meaningful estimate was derived for the 9 1/2% 2005. The results of the event-study can be used to double-check the general magnitude of spreads: these also estimate spreads on large trades to be in the range of 0.07%-0.08%. These are smaller than those derived for the UK equities market. For instance, Breedon (1992) estimated spreads on the London Stock Exchange to be in the region of 0.75-1.0% of the price, while Gemmill (1994) found them to be in the range of 0.5%-0.8%. This difference in size of spreads in the two markets would be consistent with the hypothesis that advserse selection plays an important role in the determination of spreads in the equities market but not in the gilt market.

The main observation to result from Table D is that spreads are declining in trade size, from 0.086% to 0.016% for the 6% 1999 and somewhat less, from 0.124% to 0.092% for the 2 /12% 2016. This result is also broadly consistent with the finding that there is no extraordinary information revealed by large trades in the gilt market: if there were, market-makers would require greater than average compensation for handling a large trade. Nevertheless, it is possible to imagine a game, similar to ones described by Vogler (1993) or Perraudin and Vitale (1994), in which market-makers solicit large trades despite the presence of adverse selection precisely in order to gain an information advantage over their rivals. On the other hand, the fact that spreads are declining in trade size also suggests that inventory control factors are either not the major determinant of spreads or at least not a significant function of trade size - typically, one might expect risk-averse market-makers to require proportionately greater compensation the further they were being asked to move away from their optimal portfolio position. Overall, the results are considered with processing costs being the major determinant of the relationship between trade size and market-makers' spreads in the gilt market, and that processing costs are declining in trade size.

Table D: Estimates of market-makers' bid-ask spread

	Realised spread as a percentage of price - the number of trades in the sample are given in brackets)		
Size distribution of trades	6% 1999	9 1/2% 2005	2 1/2% 2016
0-5%	0.086 (1410)	n/a[6] (244)	0.124 (100)
5-10%	0.086 (1410)	n/a (244)	0.124 (100)
10-25%	0.086 (4230)	n/a (732)	0.124 (298)
25-50%	0.086 (7050)	n/a (1221)	0.124 (498)
50-75%	0.064 (7050)	n/a (1221)	0.122 (498)
75-90%	0.032 (4230)	n/a (732)	0.114 (299)
90-95%	0.016 (1410)	n/a (244)	0.108 (100)
95-100%	n/a (1410)	n/a (244)	0.092 (100)

Spreads on the index-linked stock are larger than on the conventional stock. This result agrees with market reports and is usually ascribed to the lower degree of liquidity in the index-linked

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6 n/a denotes negative spread.

market compared to benchmark conventional stocks. In this context, it is interesting that the decline in spreads as trade size increases is more pronounced in the conventional stock, at some 81%, than in index-linked stocks, at some 25%. This either suggests that economies of scale are less pronounced in order-processing in the index-linked market or that inventory adjustment is relatively more important for large trades in index-linked stocks than in conventional stocks. It is not clear why order-processing costs should be different between different types of stock. On the other hand, the lesser degree of immediacy available for index-linked stocks, the fewer number of index-linked stocks available to be used as hedges for each other and the lack of alternative markets - notably the lack of an index-linked future - for hedging suggest that inventory considerations could well play a greater - though small - role in the price formation process in the index-linked market.

Spreads and trading volume

Information about price formation can also be extracted by analysing spreads by transaction time. As noted in Section 2, the information asymmetry models, such as those of Admati and Pfleiderer (1988) and Foster and Viswanathan (1990), make predictions about the efffect of adverse selection on trading patterns. One of the predictions is that trading costs should be inversely related to trading volumes - as liquidity traders bunch together at times of day when they expect the probability of trading with an informed trader to be lowest. It was not possible to manipulate the data in such a way as to estimate spreads from the VAR on an intraday basis, so Roll covariance estimates of the realised spread were calculated instead. Roll (1984) developed one of the first measures for estimating realised spreads:

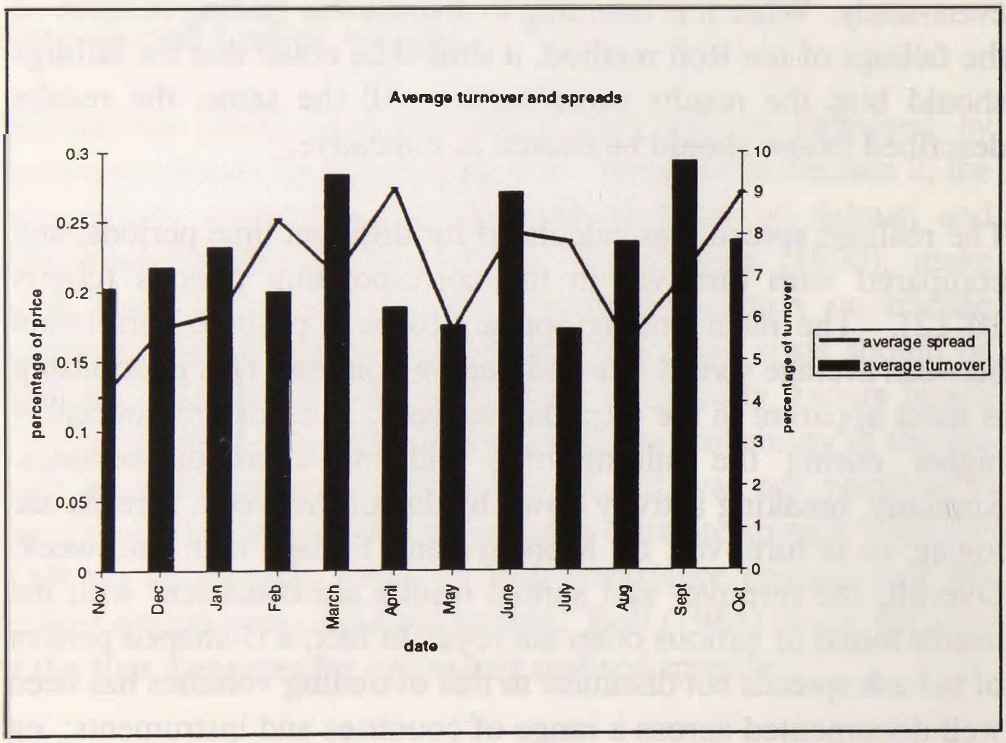
- Spread = $2\sqrt{-\text{covariance}}$

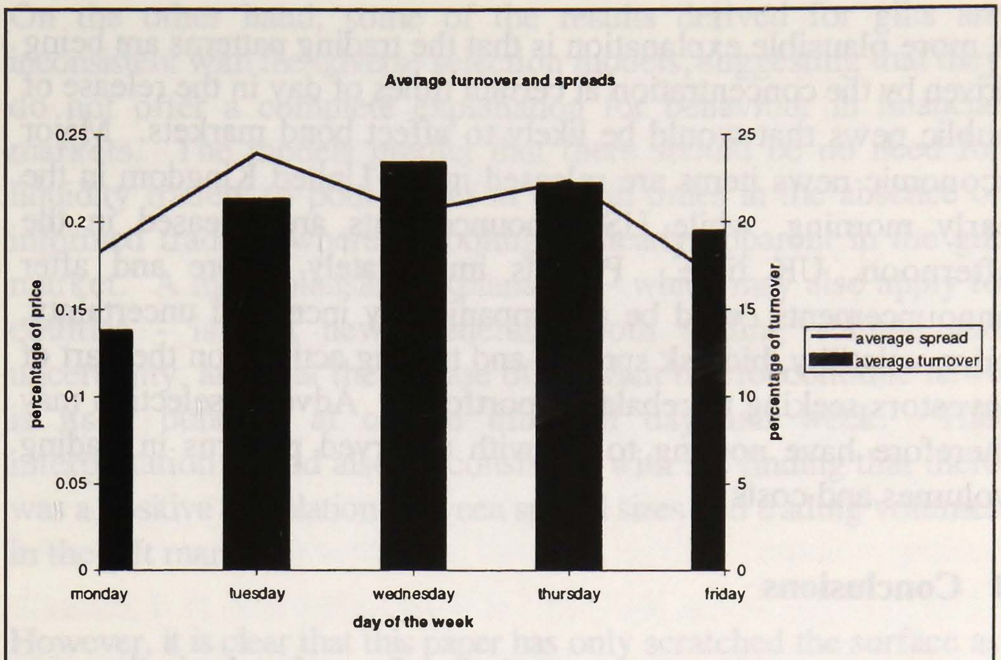
where the covariance is the first-order serial covariance of price changes: intuitively, this method measures the degree to which prices bounce between the bid and ask price. This method has significant drawbacks, however: Stoll (1989) describes how it will underestimate the spread in the presence of either inventory or information effects. Similarly, it will underestimate the spread in the presence of an uneven distribution of trades between purchases and sales, even if there is no positive autocorrelation in prices. However, this latter problem can be allowed for by adjusting the covariance by the conditional probability of consecutive transactions being the same type, as shown by Choi, Salandro and Shastri (1988), where the conditional probability is estimated by a maximum likelihood estimation technique.

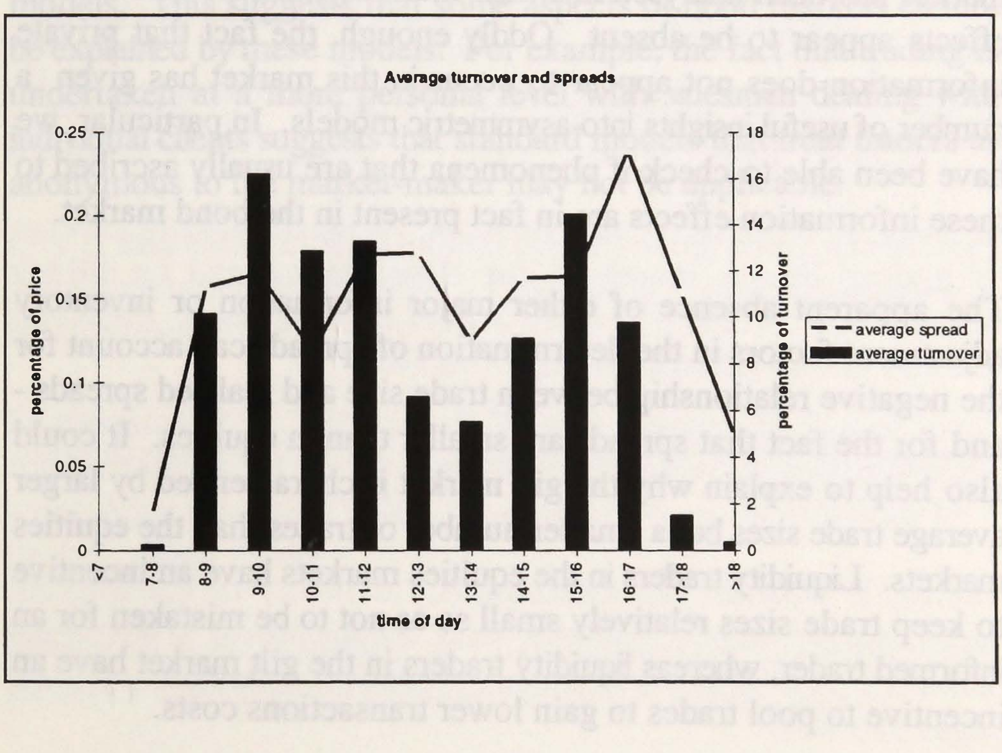
The average of the stocks produced a realised spread for the gilt market of 0.215% of the market price - considerably higher than the estimates produced for the spread using either the VAR or the event-study. While it is tempting to dismiss this finding because of the failings of the Roll method, it should be noted that the failings should bias the results downwards. All the same, the results described below should be treated as indicative.

The realised spread was calculated for different time periods, and compared with turnover in the corresponding periods (charts 10-12). The main finding appears to be a positive correlation between average spread size and trading volume. This relationship is most apparent in the intra-day analysis: spreads are noticeably higher during the mid-morning and mid-afternoon sessions. Similarly, breaking activity down by day of the week, spreads are lower, as is turnover, on Mondays and Fridays than mid-week. Overall, the turnover and spread results are consistent with the results found in various other surveys. In fact, a U-shaped pattern of bid-ask spreads not dissimilar to that of trading volumes has been well documented across a range of countries and instruments: eg Hsieh and Kleidon (1992), McInish and Wood (1992) and Foster and Viswanathan (1993). This finding has proved hard to rationalise within the adverse selection model, although Subrahmanyam (1991) has shown that increased trading can be consistent with higher costs if risk-averse informed traders are introduced and if there are more informed traders at the beginning and end of the day. One explanation has been proposed by Brock and Kleidon (1992). This suggests that, due to market closure at the end of the day, there is a greater demand for liquidity at the start and end of the trading day for hedging purposes. With a fixed supply of market-making capacity over the short term, this could explain the positive correlation between spreads and trading volumes. It is not obvious, however, why the supply of liquidity need be held constant over the course of the day.

Charts 10-12




Average turnover and spreads
percentage of price
0.25
0.2
0.15
0.1
0.05
0
percentage of turnover
25
20
15
10
5
0
monday
tuesday
wednesday
thursday
friday
day of the week
average spread
average turnover


Average turnover and spreads
percentage of price
0.25
0.2
0.15
0.1
0.05
0
percentage of turnover
18
16
14
12
10
8
6
4
2
0
<7
7-8
8-9
9-10
10-11
11-12
12-13
13-14
14-15
15-16
16-17
17-18
>18
time of day
average spread
average turnover

A more plausible explanation is that the trading patterns are being driven by the concentration at certain times of day in the release of public news that would be likely to affect bond markets. Major economic news items are released in the United Kingdom in the early morning, while US announcements are released in the afternoon, UK time. Periods immediately before and after announcements could be accompanied by increased uncertainty, price volatility, bid-ask spreads and trading activity on the part of investors seeking to rebalance portfolios. Adverse selection may therefore have nothing to do with observed patterns in trading volumes and costs.

4 Conclusions

The role of private information and, therefore, of trades in the price formation process has been the major focus of market microstructure models for some time. In this paper, however, a market has been analysed in which these asymmetric information effects appear to be absent. Oddly enough, the fact that private information does not appear to occur in this market has given a number of useful insights into asymmetric models. In particular, we have been able to check if phenomena that are usually ascribed to these information effects are in fact present in the bond market.

The apparent absence of either major information or inventory adjustment factors in the determination of spreads can account for the negative relationship between trade size and realised spreads - and for the fact that spreads are smaller than in equities. It could also help to explain why the gilt market is characterised by larger average trade sizes but a smaller number of trades than the equities markets. Liquidity traders in the equities markets have an incentive to keep trade sizes relatively small so as not to be mistaken for an informed trader, whereas liquidity traders in the gilt market have an incentive to pool trades to gain lower transactions costs.

On the other hand, some of the results derived for gilts are inconsistent with the adverse selection models, suggesting that they do not offer a complete explanation for behaviour in financial markets. The models predict that there should be no need for liquidity traders to pool trades at certain times in the absence of informed traders, whereas pooling is clearly apparent in the gilt market. A more plausible explanation - which may also apply to equities - is that news generates both trading volume and uncertainty, and that the release of relevant macroeconomic news is itself bunched at certain times of day and week. This interpretation would also be consistent with the finding that there was a positive correlation between spread sizes and trading volumes in the gilt market.

However, it is clear that this paper has only scratched the surface as far as the microstructure of bond markets is concerned and a number of results obtained (particularly for measured spreads) are difficult to rationalise in the context of normal microstructure models. This suggests that some aspects of bond markets cannot be explained by these models. For example, the fact that trading is undertaken at a more personal level with salesman dealing with individual clients suggests that standard models that treat traders as anonymous to the market-maker may not be applicable.

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