The Quality of the Italian Treasury Bond Market, Asymmetric Information and Transaction Costs

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ABSTRACT. – This paper analyzes the microstructure of the Italian secondary bond market and of the effects of the 1994 reform and of the introduction of anonymity in 1997. Based on a microstructure model of price formation, we evaluate the relevance of asymmetric information and other microstructure effects, by estimating the VAR representation of the model. We find that market quality improves over time, which we interpret as resulting from the 1994 reform. This is captured both by decreased first order return autocorrelation and by improvement of our market quality indicators. The introduction of anonymity substantially reduces order fragmentation by investors trying to avoid free-riding by less sophisticated traders. No significant evidence of asymmetric information is found.

La qualité du marché secondaire italien des obligations d'État, l'asymétrie d'information et les coûts de transaction

RÉSUMÉ. – Cet article analyse la microstructure du marché secondaire italien des obligations d'État et les effets de la réforme de 1994 et de l'introduction de l'anonymat en 1997. On utilise un modèle de microstructure de la formation des prix et, en considérant la représentation VAR du modèle, nous évaluons l'importance de l'asymétrie d'information et des autres effets de microstructure. Il en résulte que la qualité du marché augmente dans le temps et nous interprétons ce fait comme un résultat de la réforme de 1994. Ceci se traduit par la réduction de l'autocorrélation du 1er ordre des changements de prix et par l'amélioration de la valeur de nos indicateurs de qualité du marché financier. L'introduction de l'anonymat réduit considérablement la fragmentation des ordres des investisseurs cherchant à empêcher le « *free-riding* » d'agents moins sophistiqués. Aucune évidence significative de l'existence d'une asymétrie d'information n'est trouvée.

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We thank B. BIAIS and an anonymous referee for their helpful advice. We also benefitted from conversations with T. ANDERSEN and T. CONLEY. All remaining errors are our own. We acknowledge financial support from *Università Bocconi* (Ricerca di Base).

1 Introduction

The object of this paper is to study the microstructure of the Italian secondary Treasury bond market (*Mercato Telematico dei Titoli di Stato*, MTS), using a unique high frequency data set. MTS is a screen-based market and was created in 1988 with the objective of guaranteeing a transparent and competitive trading environment, which would increase efficiency and rationalize the market for public debt.

The interest in studying MTS stems from several reasons. It is one of the largest Treasury bond markets, the third as far as nominal value of the outstanding bonds after Japan and the US. In 1994, it was subject to a major structural reform, which introduced a number of market-makers, named specialists, in order to increase liquidity. In 1997, anonymity was introduced. These changes significantly altered the original design. A study of the microstructure of this market is a way to evaluate whether the objectives driving the reform have been met and to quantify the effects on market quality.

Following the introduction of trading in euros, the institutional design of MTS has been made a model for EuroMTS, the market for the most liquid Emu government bonds. The organizational model of this new market is very similar to the current structure of the MTS. A group of specialists, satisfying a fixed set of requirements, are nominated by the EuroMTS board and trading is anonymous. This provides further motivation to evaluate the performance of MTS, even after the introduction of anonymity.

Finally, most of the empirical analysis on the microstructure of financial markets has concentrated on stock markets. This is partially due to the unavailability of transaction data on bond markets. Some exceptions are UMLAUF [1993] and FLEMING and REMOLONA [1997 a, b] for the US Treasury market and PROUDMAN [1995] for the UK bond markets. There are many open issues relating to the main theoretical findings from microstructure models. For example, is the distribution of private information among agents trading in the bond market asymmetric? How relevant are inventory control, order processing costs and discreteness for analyzing the quality of the price formation process on these markets?

In Section 2, we describe in detail the institutional features of the MTS and the changes introduced by the successive reforms. We also comment on the data and the characteristics of the issues used for the estimates.

The availability of this data before and after the two reforms enacted on this market enables us to detect changes in the relevance of the different market microstructure effects and relate them to the reforms. In Section 3, a microstructure model of price formation is derived and estimated. It is adopted as a base to discuss both the effects of the reforms introduced over time and the relevance of asymmetric information and other microstructure effects, like inventory control and lagged adjustment (for example, order fragmentation). We evaluate the dimension and composition of transaction costs based on the estimated VAR. We also build an indicator of market quality based on the dispersion of transaction prices around the long run value of the bonds.

We find that, following the 1994 reform, first order return autocorrelation decreases from -0.30 in 1993 to -0.07 and 0.08 in 1995 and 1997, respectively. This indicates that market quality has improved, which is confirmed by the steady rise of our market quality indicator. In 1993, about 60 % of the effective spread can be explained by the presence of transient liquidity effects, while these amount to only 20 % of the spread in 1997. The introduction of anonymity dramatically reduces the positive serial correlation between trades. Our interpretation is that when trades are anonymous investors are less eager to obtain camouflage by splitting their orders. We do not find any asymmetric information effects.

2 Institutional Features

Italy's secondary market for government securities lists approximately 150 bonds and is gaining steadily in significance in terms of volumes traded and number of participants. This screen-based market was created in 1988, in order to regulate an over-the-counter market that had already reached very considerable proportions.

The reform of 1994 introduced the distinction between super primary dealers.[1] The introduction of a number of super primary dealers continuously quoting bid and ask prices for most of the issues traded on MTS was aimed at increasing the liquidity of the market. MTS participants are therefore now divided into three categories: 15 specialists, 24 primary dealers and 180 dealers.[2] The specialists are subject to quantitative and qualitative requirements[3] that are effectively binding and exert a great deal of pressure on their trading activity. In return, they have privileged treatment at certain bond issues and privileged relations with the authorities. Specialists are invited to a monthly meeting which, ideally, should provide them with private information on trading activity and economic conditions.

The system is based on an order book that is publicly displayed on a screen providing bids and offers, each specifying a price and a quantity. Trading in this continuous dealer market was not anonymous until July 1997, when the anony-

1. See Rindi [1999] for a detailed description of the Italian secondary bond market (MTS) and for a simple analysis of market liquidity and market depth.

2. The number of market participants changes every year, after the summer selection undertaken by the Bank of Italy.

3. Specialists are obliged to trade continuously in a set number (around 40) of securities and to guarantee a certain volume. Each must make daily trades amounting to the 2% of the total volume of each category of securities (namely T-bills, credit certificates and bonds) and 3% of the total volume of securities. Moreover, each specialist is obliged to trade 4 securities in lots of predefined size (25 billion lire) on a continuous basis. They also have to satisfy some qualitative constraints, namely: "*distance from volume traded*", "*distance from market spread*" and "*distance from number of bonds traded*". The Bank of Italy continuously monitors the specialists' conduct. These rules have been modified by new regulations, which have been recently approved by the Managing Committee (*Comitato di Gestione*) of the MTS and by the Treasury (July 1998).

mity of trades was introduced. Specialists and primary dealers make prices, posting limit orders, while dealers can only trade against the book to pick off the limit orders at their limit prices. Dealers can therefore only use market orders. Trades are executed according to the following rules: (i) market orders arriving on specialists or primary dealers' screens are executed in chronological order; (ii) orders are automatically executed at the *"best"* quoted price.

New regulations have been prepared by the Committee supervising the market and approved by the Italian government, in view of the privatization of the MTS. According to the new rules, which are designed to allow more efficient market making by the specialists involved, dealers (like investment funds and smaller institutional investors) no longer have access to screen-based trading.[4]

Data Sources and Descriptive Statistics

Our unique data base covers three separate months: October 1993 (21 trading days), March 1995 (19 trading days) and October 1997 (15 trading days). The availability of data on the Italian secondary bond market before and after 1994 and 1997 allows us to evaluate the effects of the reforms enacted in those two years. The data set includes transaction prices, signed quantities traded and corresponding time stamps for all the securities listed in 1993 and 1995 and for the most frequently traded securities in 1997.[5] As noted,

TABLE 1
Descriptive Statistics

	BN93	**2BN93**	**BN95**	**2BN95**	**BN97**	**2BN97**
	1/1/02	1/8/03	1/1/05	1/8/04	1/2/07	1/7/07
	12%	10%	9.50%	8.50%	6.75%	6.75%
# transactions	10859	6385	15304	11473	5529	4703
total traded volume	57519	32873	87553	65051	37563	29358
average daily traded volume	2739	1565	4608	3423	2502	1957
average trade size	5.29	5.14	5.72	5.73	6.7	6.2
s.e	1.56	1.29	2.67	2.91	3.81	3.06
average price	117.54	107.47	80.63	75.8	104.52	104.42
s.e.	0.88	0.93	1	1.03	0.31	0.32
average $\|\Delta P_t\|$	0.013328	0.0128	0.0121	0.0135	0.014	0.011
s.e.	0.027414	0.023	0.02	0.021	0.011	0.015
% buy orders	0.51	0.52	0.49	0.48	0.49	0.51
frequency of price reversal	0.26	0.26	0.23	0.25	0.51	0.33

4. They can contract a good price by contacting a number of specialists over the phone. This way of negotiating is regulated by a set of rules, designed to guarantee transparency.
See Schema regolamento MTS (1988), www.MTSSPA.it/reg/home.htm.

5. The main types of securities traded on the MTS are: Treasury Bills (BOTs), Treasury credit certificates (CCTs) and Treasury bonds (BTPs). For the present analysis, we use 4 BTPs, for practical reasons: as short-term paper, BOTs tend to be traded only for the first few days after issue while CCTs require an *ad hoc* pricing model to factor in their floating interest rate (indexed to BOTs).

only 5 or 6 of the bonds traded are actually liquid, so we ranked all issues by the frequency of transactions and selected the two most heavily traded for each period of the data set, designating them as benchmark (BN) and 2^{nd} benchmark (2BN).

Table 1 shows the characteristics of the issues selected. The difference in terms of number of transactions and total volume traded between the benchmark and second benchmark issue is sizeable, especially for 1993. This temporal pattern reflects the growth of the market over time, which determined an intensification of trading and an increase in the number of heavily traded bonds.

The last row of Table 1 shows the probability of a price reversal, namely, the probability that the sign of the trade switches between consecutive transactions. A low value of this probability is a symptom of significant positive trade autocorrelation. We find that the probability of price reversal increases substantially in 1997, nearly doubling for the benchmark issue with respect to the benchmarks for the other two years. We argue that this is a consequence of the introduction of anonymity, which substantially reduced order fragmentation.

3 Price Formation on the MTS

The market microstructure literature has typically dealt with three sets of factors affecting the price formation process in a dealership market, namely, asymmetric information, inventory control and transaction costs.

Two approaches have been followed in evaluating the relative impact of these effects on the determination of asset prices. One (Stoll [1989], Foster and Viswanathan [1990], George, Kaul and Nimalendran [1991], Lin, Sanger and Booth [1995]) concentrates on the bid-ask spread, decomposing it into order processing, inventory holding and adverse selection costs. The second (Hasbrouck [1988, 1991, 1993] measures the relative importance of asymmetric information as compared to inventory control and other information uncorrelated effects by concentrating on the price impact of trades.

The persistence of the price impact relates to the private information content of a trade, whereas, the effects induced by inventory control, order fragmentation, price discreteness and noise trading are transient. While the price impact of information-motivated trades is persistent, because it will be incorporated in the true value of the asset, liquidity driven trades will only have a transitory effect.

We derive the price impact of trades, adopting the second approach. In 1993 and 1995, the response of trades to own innovations displays features that can be accounted for by the presence of inventory control and lagged adjustment effects, such as order fragmentation, imitative behavior and lagged adjustment to new information. In 1997, we don't find evidence in support of the presence of these effects. We find no significant role for asymmetric information.

The microstructure model we illustrate was first introduced by GLOSTEN [1997] and has been extensively studied by HASBROUCK [1991, 1993, 1995]. It takes into account both the adverse selection component and the inventory cost component of price variability, as well as transaction costs. Based on this model, we estimate a quantitative measure of the "*quality*" of the price discovery process allowed by MTS trading rules. This statistic, introduced by HASBROUCK [1993], is based on the decomposition of transaction prices into a random-walk component, the "*efficient*" bond price, and a residual stationary component, which HASBROUCK defines as a "*pricing error*".[6] The quality of the market is evaluated by estimating the standard deviation of the pricing error, which reflects the dispersion of transaction prices around the fundamental value of the underlying security. A small value of this statistic indicates superior quality of the price discovery process on the market. Under some additional assumptions, we are able to measure the percentage of the effective spread due to the pricing error and the percentage due to fixed order processing costs.

3.1 **A Simple Microstructure Model**

The simple model that we use to describe the price formation process on the MTS is empirical. It offers a heuristic development of the pursued econometric specification, based on the most general findings of the microstructure literature and on the specific features of the market we consider. MTS is a dealer market supported by a computer network on which a number of specialists post price and quantity offers, which are subsequently applied either by specialists themselves or by other dealers who have access to the screen but are not allowed to post limit orders. The timing of events on this market is the following: any new public information is revealed, then market-makers post limit orders, successively agents on the market submit their demands and finally the system matches supply and demand and the transaction price is realized. A feature of this timing is that trades and transaction prices are not jointly determined. This is due to the fact that market-makers post limit orders before observing the order flow for the period and the trading mechanism guarantees that transaction prices are always set equal to bid or ask quotes, according to the sign of the trade.

The model we estimate departs from HASBROUCK, by excluding a contemporaneous impact of trades on prices. This derives from the trading structure in the MTS, which is quote driven and not order driven, as the markets studied by HASBROUCK.

6. This decomposition implies a non-stationary representation of the price series. This is a standard practice used in the analysis of stock market prices. In the case of bond prices, this decomposition is correct as far as the series used does not include the whole life of the asset. A selection of data from the whole price series cannot be considered non stationary.

The autoregressive representation of price changes[7] and trades implied by the model is the following:

$$\Delta p_t = cr + \theta d_t + \sum_{i=1}^{n} \phi_i \Delta p_{t-i} + \sum_{i=1}^{n} \psi_i sx_{t-i} + u_{1,t} \tag{1}$$

$$sx_t = cs + \xi d_t + \sum_{i=1}^{n} \delta_i \Delta p_{t-i} + \sum_{i=1}^{n} \lambda_i sx_{t-i} + u_{2,t} \tag{2}$$

where

$$\begin{cases} sx_t = +1 & \text{if} \quad x_t > 0 \\ sx_t = -1 & \text{if} \quad x_t < 0 \end{cases}$$

$u_{1,t}$ is the price-revision disturbance, $u_{2,t}$ is the trade disturbance and t indexes transactions. The variables cr and cs are constant terms. The reason why we choose an indicator instead of the volume variable is that the volume series is extremely erratic due to a small number of very large transactions.[8] This device reduces heteroskedasticity. The dummy-variable d_t takes on the value 1 if the transaction takes place in the first hour of the day and it takes on the value 0 otherwise.[9]

TABLE 2
Absolute Value of Traded Volume – Frequency Distribution

Billions of lira	**BN93**	**2BN93**	**BN95**	**2BN95**	**BN97**	**2BN97**
5	0.9487	0.9895	0.8912	0.9523	0.7535	0.8174
10	0.0468	0.0081	0.0916	0.0398	0.1785	0.1399
15	0.0024	0.002	0.0098	0.0049	0.0501	0.0324
25	0.0015	0.0002	0.0056	0.0025	0.0154	0.0105
35	0.0002	0.0002	0.0007	0.0001	0.0028	0
45	0.0004	0	0.001	0.0004	0	0

7. Note that the model is formulated in simple returns and the level of prices, and not in the logarithm of transaction prices and continuously compounded returns. Our choice is motivated by the fact that important microstructure effects, such as discreteness, can best be captured by analysing the price level. Moreover, differences in prices for the bonds analyzed are very small (see Table 1), so that inferences regarding returns for different securities can meaningfully be compared. This is not true on stock markets, where transaction prices exhibit a great degree of variability across different stocks.
8. The standard trade size on MTS is 5 billion lire; some trades are for 10 billion and few for amounts which are much higher. See Table 2.
9. We included this variable because price changes at the beginning of each transaction day are much greater then average.

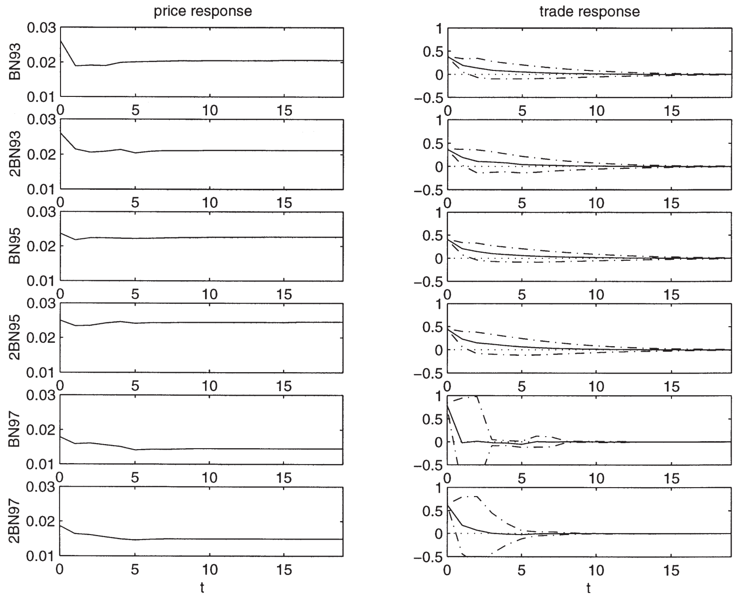
The number of lags included in the estimated VAR was set equal to 5, following HASBROUCK [1993] and PROUDMAN [1995]. This enables us to directly compare our results to theirs.[10]

The estimation results for the six bonds considered are reported in Table 3.

The main findings are: (i) strong, positive trade autocorrelation for 1993 and 1995 for the most liquid bonds; (ii) negative return autocorrelation dramatically decreasing over time; (iii) negligeable impact of trade innovations on prices; (iv) significant coefficients of Δp_{t-1} in the trade equation for most issues considered.

A striking feature of the parameter estimations is the strong positive autocorrelation in trades, which drops dramatically for the most traded issue in 1997 (Table 3). This result is confirmed by the impulse response of trades to its own innovation shown in Figure 1, from which we infer the presence of both inventory control and lagged adjustment for 1993 and 1995 and not for BN97. For 2BN97, lagged adjustment is present, but the adjustment is significantly faster. Since the parameter λ is an indicator of order fragmentation (HASBROUCK and Ho [1987]), this finding together with increased average trade size in 1997 can be interpreted as the effect of the introduction of anonymity. In an anonymous market, the most important market-makers can

FIGURE 1
Impulse Response to an Innovation in Trades



10. Ordinary statistics employed to identify the appropriate order of a VAR model fail to give a useful indication on how many lags to include when the number of observations is very large, as is the case of microstructure applications. Weak dependencies at very long lags still appear to be significant. A discussion on the possible misspecification deriving from truncation of the VAR can be found in HASBROUCK [1995].

TABLE 3
Estimation Results

Return equation: $r_t = cr + \theta d_t + \Sigma_i \phi_i \Delta p_{t-i} + \Sigma_i \varphi_i sx_{t-i} + v_{1,t}$

	BN'93		**BN'95**		**BN'97**		**2BN'93**		**2BN'95**		**2BN'97**	
	Coefficients	*t*-statistics	Coefficients	*t*-statistics	Coefficients	*t*-statistics	Coefficients	*t*-statistics	Coefficients	*t*-statistics	Coefficients	*t*-statistics
Cr	-0.0002	-0.8914	-0.0002	-0.9847	-0.0003	-1.1655	-0.0004	-0.8893	-0.0002	-0.6912	-0.0005	-1.6655
ϕ_1	-0.3053	-28.5687	-0.0721	-7.8111	-0.0870	-3.9595	-0.3438	-25.4143	-0.0514	-4.6703	-0.1092	-5.5904
ϕ_2	-0.1070	-9.4841	-0.0088	-0.9513	-0.0071	-0.3240	-0.1511	-10.4849	-0.0160	-1.4480	-0.0349	-1.7798
ϕ_3	-0.0738	-6.5030	-0.0241	-2.5989	-0.0397	-1.7984	-0.0729	-5.0148	0.0069	0.6224	-0.0233	-1.1868
ϕ_4	-0.0013	-0.1169	-0.0234	-2.5261	-0.0436	-1.9770	-0.0209	-1.4598	0.0163	1.4714	-0.0466	-2.3779
ϕ_5	0.0060	0.5756	-0.0130	-1.4699	-0.0673	-3.0875	-0.0313	-2.3663	-0.0220	-2.1026	-0.0379	-2.0960
φ_1	0.0021	6.3990	-0.0004	-1.4842	-0.0005	-1.3308	0.0034	7.1351	-0.0008	-2.4049	-0.0003	-0.8684
φ_2	0.0010	2.9663	0.0017	6.1433	0.0002	0.4398	0.0003	0.5185	0.0015	4.3563	0.0002	0.5063
φ_3	0.0017	4.8808	0.0008	2.8553	0.0003	0.7312	0.0006	1.0947	0.0007	1.9240	-0.0005	-1.1028
φ_4	0.0006	-1.8090	0.0001	0.4633	0.0002	0.5066	-0.0006	-1.1121	-0.0007	-1.9007	0.0004	0.8981
φ_5	0.0001	-0.3867	-0.0004	-1.6117	0.0000	0.0491	0.0004	0.8144	0.0001	0.3955	0.0002	0.5525
θ	0.0029	3.2982	0.0020	2.4835	0.0008	1.2780	0.0052	3.6706	0.0011	1.1404	0.0018	2.3856
R^2	0.0795		0.0118		0.0179		0.0956		0.0085		0.0185	

TABLE 3 (*continued*)

Estimation Results

Quantity equation: $sx_t = cs + \zeta d_t + \Sigma_t \delta_i \Delta p_{t-i} \Sigma_i \lambda_i sx_{t-i} + v_{2,t}$

	BN'93		BN'95		BN'97		2BN'93		2BN'95		2BN'97	
	Coefficients	*t*-statistics	Coefficients	t-statistics	Coefficients	*t*-statistics	Coefficients	*t*-statistics	Coefficients	*t*-statistics	Coefficients	*t*-statistics
Cs	-0.0126	1.4543	-0,0034	-0.4905	-0.0115	-0,7760	0,0178	0,5677	-0,0111	-1,3465	0,0058	0,3900
δ_1	2.3277	6.5915	2.1071	6.4662	0.0184	0.0150	1.4023	3.6216	2.4266	6.4744	-2.2733	-2.3082
δ_2	1.3781	3.6944	0.0406	0.1238	-0.5459	-0.4447	0.3996	0.9688	-0.0076	-0.0203	-0.4449	-0.4503
δ_3	0.0858	0.2287	-0.4818	-1.4703	-1.2460	-1.0154	0.1545	0.3716	0.4156	1.1032	-1.6244	-1.6443
δ_4	0.0650	0.1746	-0.3672	-1.1215	-1.5987	-1.3028	0.3102	0.7555	0.2317	0.6159	-0.7558	-0.7655
δ_5	-0.0039	-0.0114	-0.0682	-0.2183	-2.6602	-2.1930	-0.2274	-0.6011	-0.0437	-0.1227	-1.2411	-1.3615
λ_1	0.3543	33.1593	0.3842	41.5851	-0.0258	-1.1742	0.3744	27.6700	0.3759	34.1484	0.3556	18.1970
λ_2	0.1334	11.8669	0.1653	16.6702	0.0286	1.2985	0.1199	8.3726	0.1505	12.7371	0.0183	0.8812
λ_3	0.0590	5.2211	0.0514	5.1455	0.0069	0.3120	0.0628	4.3682	0.0421	3.5412	0.0105	0.5044
λ_4	0.0212	1.8931	0.0355	3.5876	-0.0005	-0.0216	0.0170	1.1919	0.0117	0.9959	-0.0129	-0.6178
λ_5	0.0111	1.0853	-0.0002	-0.0258	-0.0100	-0.4575	0.0007	0.0565	0.0105	0.9983	0.0018	0.0964
ζ	-0.0389	-1.3167	-0.0607	-2.1668	0.0155	0.4380	0.0075	0.1846	-0.0553	-1.6919	0.0513	1.3132
R^2	0.2539		0.3005		0.0050		0.2453		0.2750		0.1144	

trade large quantities without incurring in the free-riding costs generated by the existence of smaller market-makers. The latter normally follow the former's strategies in order to exploit their superior ability in trading. In a transparent market, where the identity of market-makers posting limit orders is known to all participants, this induces large market-makers to hide their strategy by fragmenting orders. When the market becomes anonymous, the incentive to fragment large orders decays.

As far as the negative return autocorrelation, captured by the $\phi_i^{\prime}s$, is concerned, we find significant negative values for all three years, but we observe a decreasing tendency over time. First order return autocorrelation is roughly three times as great in 1993 as in 1995 and 1997. This is one of the most significant differences among the parameters estimated with the three series of data, and can be interpreted as the effect of the reforms enacted in 1994.

The negative return autocorrelation cannot be interpreted, as in HASBROUCK [1991], as the effect of measurement errors. Since the recording mechanism for the bonds considered is the same, the variability over time and among different issues cannot be accounted for by this factor. Instead, it can be a signal of reduction of the inventory control effect, which is also supported by the impulse response function of trades. Our inference on the presence of inventory holding costs cannot be conclusive as in HASBROUCK [1991]. Here the data do not allow us to discern each dealer's trading strategy. Transaction data give the bid-ask prices on the market, not the pattern of prices posted by each specialist. If we had these data, the inventory holding cost effect could probably be shown more directly.[11]

Evidence on the presence of asymmetric information can be obtained by studying the cumulative impulse response of price changes to an innovation in trades.[12]

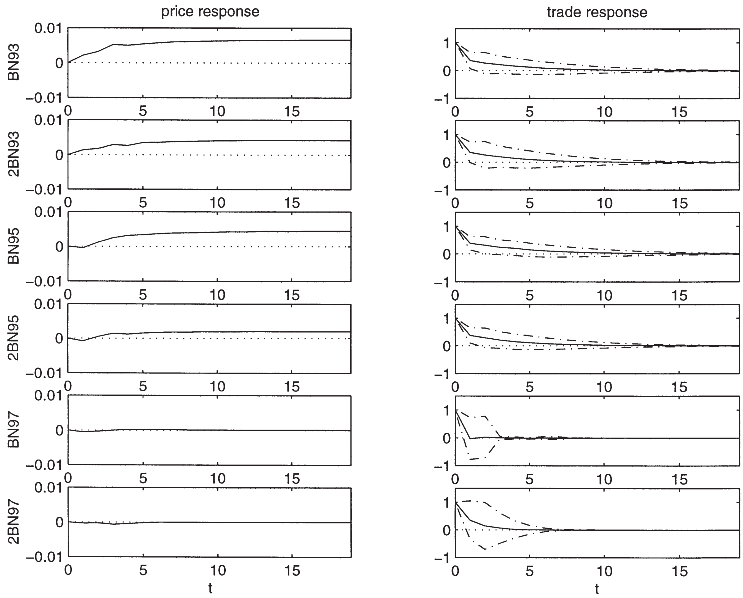
Figure 2 shows the cumulative transaction price revision implied by the VAR model subsequent to an initial buy order for the six bonds considered. The cumulative impact on returns is approximately equal to 0.005 lire for '93 and '95, while for '97 it is approximately zero. These findings allow us to rule out the presence of asymmetric information effects in MTS. The literature on asymmetric information concentrates mainly on stock markets, where the adverse selection component has been found to be significant. PROUDMAN [1995] shows that no private information effects are present in the UK gilt market. Our results resemble the latter's, while they contrast with the results found by HASBROUCK [1993] for the stock market and by UMLAUF [1993], who analyzes the US Treasury bond market. They both detect significant

11. In direct observation of some primary dealers' trading behaviour, we noticed that they kept their assets and liabilities continuously in balance. This behaviour is in part induced by the institutional structure of the market. On MTS, each institution that acts as specialist is obliged to trade a certain amount of bonds every day. Some of these institutions have 5 to 10 traders, each trading an average of 4 to 5 bonds a day. They keep the balance sheet of each bond in such a way that whenever they are short (or long) 5 billion lire, they immediately rebalance their position. This behaviour generally induces negative return autocorrelation.

12. We computed the orthogonalized impulse response functions. Notice that due to the absence of a contemporaneous impact of trades on prices, there is a natural recursive ordering to the model so that identification of innovations in returns and trades is not an issue.

FIGURE 2

Impulse Response to an Innovation in Price Changes



evidence of asymmetric information. UMLAUF's results, however, depend on the particular structure of the US bond market, in which specialists and dealers trade with different categories of brokers.

Finally, we analyze the effect of lagged adjustment to new information, captured by the parameter δ. We find strong impact of past returns on trades for the 1993 and 1995 issues, while we don't find any lagged adjustment to new information for 1997. This suggests that in 1997, the speed of adjustment to new information is higher than in the other years, which can be explained by the reduced importance of order fragmentation strategies and imitative behavior, following the introduction of anonymity.

3.2 Measuring Market Quality

In this section, we estimate transaction costs on MTS following the procedure suggested by HASBROUCK [1993]. We define the pricing error, s_t, as the distance between the transaction price, p_t, and the fundamental value of the security, m_t :

$$s_t = p_t - m_t, \tag{3}$$

where t indexes transaction time. We follow the literature in assuming that the fundamental follows a random walk:

$$m_t = m_{t-1} + \tau_t, \tag{4}$$

where τ_t is the innovation in the fundamental, due to private and public information, $\tau_t = v_{1,t} + \beta v_{2,t}$. The parameter β represents the component of the trade innovation determined by private information. We assume s_t is a covariance stationary, zero mean process, and it can be explained by the presence of lagged adjustment/inventory control effects, asymmetric information and transaction costs. We interpret the estimated standard deviation of the pricing error, σ_s, as a summary measure of market quality. The pricing error is the distance of the transaction price from the efficient price of the asset, and it can be intuitively viewed as the implicit price paid by the buyer $(+s_t)$ or seller $(-s_t)$ of the asset for each transaction. The unconditional expected value of s_t is therefore equal to zero. However, conditional on the information set, agents' quality and market imperfections, the expected value could be different from zero. In our model, the transaction price is determined according to:

$$p_t = q_t + cx_t + \eta_t, \quad (5)$$

where q_t is the quote midpoint, and cx_t is the component of the bid-ask spread which depends on trade size. The variable η_t is mean zero and uncorrelated with past returns, quotes and trades. It reflects fixed order processing costs, price discreteness and other disturbances uncorrelated with the conditioning variables. As pointed out by HASBROUCK [1993], the role of σ_s as a proxy for market quality rests on the premise that, when barriers to trading are reduced, transaction prices reflect the fundamental value of a security more closely. Therefore, the pricing error captures the effect of asymmetric information, lagged adjustment/inventory control, discreteness and fixed trading costs on the bid-ask spread.

To quantify the presence of these distortions on the MTS, we seek to decompose transaction prices into their permanent and temporary components. We identify the fundamental with the permanent component, which is affected by new information only. The transitory component is defined as the difference between the fundamental value and the observed value of the price series in any period. For this model, it is equal to $(-s_t)$. Both m_t and s_t are unobservable. Inference on these variables, is conducted based on the stationary representation of the first difference of transaction prices.[13]

Estimation is based on the VAR model of equations (1) and (2) and thus uses information from both returns and trades.

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13. This procedure was introduced by BEVERIDGE and NELSON [1981]. It amounts to decomposing non-stationary time series z_t in the following way. Apply Wold's theorem to $w_t = z_t - z_{t-1}$, the first difference of z_t, which is stationary. Obtain: $w_t = \mu + \varepsilon_t + \lambda_1 \varepsilon_{t-1} + \ldots$, where ε_t is a stationary, uncorrelated random disturbance. The permanent component $\bar{z}_t$ is given by the sum of the current value of z_t and the sum of the forecast values of the future w_t's when the forecast horizon tends to infinity, *i.e.* $\bar{z}_t = z_t + \left(\sum_1^\infty \lambda_i\right)\varepsilon_t + \left(\sum_2^\infty \lambda_i\right)\varepsilon_{t-1} + \ldots$. Note that increments in $\bar{z}_t$ are affected by new information only.

The transitory component is given by $\bar{z}_t - z_t$. The variable $\bar{z}_t$ only shifts in response to the current innovation in z_t, as can be seen from taking the first difference of $\bar{z}_t$.

Stationarity of Δp_t and x_t enables us to apply Wold's Theorem to the vector process $[\Delta p_t, x_t]'$, which yields the following VMA representation:

$$\begin{bmatrix} \Delta p_t \\ x_t \end{bmatrix} = \Psi(L) v_t, \tag{6}$$

where $\Psi(L)$ is an infinite order matrix polynomial in the lag operator and $v_t = \begin{bmatrix} v_{1,t} \\ v_{2,t} \end{bmatrix}$.

Equations (3) and (4) imply

$$\Delta p_t = \tau_t + (1 - L)s_t. \tag{7}$$

We can therefore derive an expression for the covariance generating function, $h_r(z)$ for Δp_t, where z is a complex scalar:

$$h_r(z) = \Psi_1(z)\mathrm{cov}(v)\Psi_1(z^{-1})' = \sigma_\tau^2 + (1 - z)h_s(z)(1 - z^{-1}),$$

where $\Psi_1(z)$ is the first row of the matrix polynomial $\Psi(\cdot)$, evaluated at z. From this formula, it is evident that the variance of the fundamental innovation, is always identified. It can be computed by setting $z = 1$ and is equal to:

$$\sigma_\tau^2 = \Psi_1(1)\mathrm{cov}(v)\Psi_1(1)'. \tag{8}$$

To estimate σ_s, we impose the identification condition: $\eta_t = 0$, which implies that the estimated value of σ_s is a lower bound. This restriction excludes from the estimate of σ_s all information uncorrelated effects that are also uncorrelated with current and lagged returns and size of trade.

From equations (3), (6) and the restriction $\eta_t = 0$, we derive the following innovations representation for s_t :

$$s_t = \Gamma(L)v_t,$$

where $\Gamma(L)$ is an infinite order polynomial vector in the lag operator. To determine the coefficients of $\Gamma(L)$, we use equation (7), which implies $\Psi_1(L)v_t = \tau_t + (1 - L)\Gamma(L)v_t$. Using the result $\tau_t = \Psi_1(1)v_t$, we can solve for the coefficients of $\Gamma(L)$ from $\Psi_1(L) = \Psi_1(1) + (1 - L)\Gamma(L)$. This yields:

$$\Gamma_i = -\sum_{j=i+1}^{\infty} \Psi_{1,j}, \tag{9}$$

where Γ_i and $\Psi_{1,j}$ are (1×2) vectors corresponding to the $i^{th}$and j^{th} coefficients of the two polynomials. It is now straightforward to obtain the expression for the variance of the pricing error:

$$\sigma_s^2 = \Gamma(1)\text{cov}(v)\Gamma(1)'. \tag{10}$$

Estimates of σ_τ and σ_s were obtained by inverting the estimated VAR(5). The summations in (10) and (8) were computed including all lags at which the estimated VMA coefficients[14] were found to be different from 0. Standard errors for these variables were obtained by applying the delta-method. Results are displayed in Table 4.

TABLE 4
Transaction Cost Measurement

	BN1993	2BN1993	BN1995	2BN1995	BN1997	2BN1997
$\sigma^2_{v,1}$	0.0007	0.0009	0.0006	0.0006	0.0003	0.0003
s.e.	0.0010	0.0013	0.0008	0.0009	0.0005	0.0005
$\sigma^2_{v,2}$	0.7454	0.7526	0.6990	0.7237	0.9941	0.8842
s.e.	1.0542	1.0644	0.9885	1.0235	1.4058	1.2505
$\sigma_{1,2}$	0.0099	0.0099	0.0096	0.0111	0.0141	0.0117
s.e.	0.0246	0.0281	0.0220	0.0240	0.0228	0.0211
σ_τ (1 lag)	0.0190	0.0281	0.0218	0.0234	0.0159	0.0164
σ_s (1 lag)	0.0074	0.0097	0.0019	0.0017	0.0020	0.0023
σ_τ	**0.0212**	**0.0214**	**0.0229**	**0.0245**	**0.0145**	**0.0149**
s.e.	0.0037	0.0032	0.0016	0.0008	0.0060	0.0045
σ_s	0.0094	0.0111	0.0061	0.0033	0.0043	0.0043
s.e.	0.0152	0.0184	0.0437	0.0218	0.0120	0.0054
average realized bid-ask spread	**0.0163**	**0.0155**	**0.0145**	**0.0164**	**0.0141**	**0.0120**
s.e.	0.0293	0.0278	0.0223	0.0268	0.0124	0.0147
ROLL'S bid-ask spread	**0.0218**	**0.0215**	**0.0141**	**0.0132**	**0.0105**	**0.0114**
s.e.	0.0126	0.0136	0.0048	0.0059	0.0031	0.0047
$E\|s_t\|$/(half realized spread) (1 lag)	0.7264	1.0006	0.2097	0.1659	0.2270	0.3067
$E\|s_t\|$/(half realized spread)	**0.9227**	**1.1450**	**0.6731**	**0.3220**	**0.4879**	**0.5733**

14. We used the orthogonalized innovations and the corresponding moving average coefficients.

Table 4 summarizes statistics on market quality.

We report three different measures of transaction costs: the average realized spread, the estimated value of σ_s and ROLL'S bid-ask spread.[15]

They all decrease over time confirming previous results regarding the amelioration of the market. The realized spread is about 0.015 lire on this market and exhibits a slightly decreasing trend over time. We find that the estimated value of σ_s decreases over time. In particular, the value of $\widehat{\sigma}_s$ in 1995 and 1997 is about 50 % of the value for 1993. Furthermore, the component of the average realized spread explained by inventory control and lagged adjustment, at 92 % in 1993, falls to 67 % in 1995 and to 49 % in 1997, according to our estimates.

ROLL'S spread is a standard measure of transaction costs when only order processing costs are present, and it implies equality between the quoted and realized spread. It can be shown (BIAIS *et al.*,[1997]) that, due to this assumption, ROLL'S spread overestimates the realized spread which would be obtained under the hypothesis of asymmetric information, inventory control and lagged adjustment.

Since the VAR results do not provide evidence in favor of the presence of asymmetric information effects, any difference between the value of the average realized spread we estimated and ROLL'S spread should be attributed to the effect of inventory holding costs or lagged adjustment, induced by order fragmentation strategies, imitative behavior or lagged reaction to public news.

For 1993, we find that the bid-ask spread according to ROLL exceeds the value of the average realized bid-ask spread, which confirms our conjecture. However, the relation inverts in the following years. This could be partly attributed to the reduction in the negative return autocorrelation detected in the VAR estimation.[16]

In the last row of Table 4, we report the ratio between the expected transaction cost for a trader and half of the realized spread. This ratio should be equal to 1 in a pure liquidity model[17], where the bid-ask spread can only be justified

15. We calculated the realized bid-ask spread according to the following formula: $S_t = \sum_t I_t(p_t - p_{t-1})$, where S_t is the spread, p_t is transaction price at time t and I_t is an indicator function equal to 1 for reversals that do not correspond to the first transaction within a trading day and 0 otherwise. ROLL'S [1984] measure of the bid-ask spread is defined as $s = 2\sqrt{-cov(\Delta P_t, \Delta P_{t-1})}$, where P_t is the logarithm of the transaction price. In this case, it was calculated as the mean of ROLL'S bid-ask spread for each trading day available in the sample. Notice that s is a percentage measure of the spread. We transformed it into levels by multiplying it with the mean price of the bond.

16. As pointed out in CAMPBELL, LO and MCKINLEY [1997], ROLL'S estimate of the effective spread often produces controversial results (like negative spreads) because it doesn't use all available information, *i.e.* the fact that bid-ask spreads are positive, and the underlying model is often mispecified with respect to the structure of the market. Nevertheless, the reduced importance of the inventory control effects cannot explain the average realized bid-ask spread exceeding ROLL'S spread.

17. If the initiator of a trade always incurs in a positive cost, which is symmetric, then $|s_t|$ is a measure of this cost in any transaction. Under the assumption of normality, $E|s_t| \simeq 0.8\sigma_s$ is the expected transaction cost for a trader. In a pure liquidity model, in which all trades occur at the bid or at the ask and trades convey no information, one would expect $E|s_t|$ to be approximately equal to one half of the effective spread.

by order processing costs. By imposing the identification condition $\eta_t = 0$, we excluded a fixed processing cost component from the estimated value of s_t. Thus, we expect the half realized spread to exceed our estimate of $E|s_t|$. This conjecture is confirmed by our results. We find that, in 1993, 92 % of the effective half-spread is attributable to discrepancies between the efficient price and the transaction price, while the proportion goes down to only 67 % and 49 % for 1995 and 1997, respectively. We conclude that approximately 8 % of the realized spread for 1993, 33 % for 1995 and 51 % for 1997 can be attributed to order processing costs. In his analysis of the NYSE, HASBROUCK [1993] found that the ratio of the expected absolute value of the pricing error to the half spread was approximately 25 % over the whole sample of firms. Thus, for that market, approximately 75 % of the realized spread can be accounted for by order processing costs. However, HASBROUCK'S procedure for the estimation of σ_s consists in truncating the summations in (8) and (10) at lag 1. We display the estimates based on truncation in Table 4, rows seven, eight and seventeen.

Based on this procedure, order processing costs account for 28 % of the average realized spread for 1993, 80 % and 78 % for 1995 and 1997 respectively. Therefore, our findings are in line with those of HASBROUCK for the NYSE. However, having found an important role for lagged adjustment effects, we adopt the non-truncated estimate of σ_s as our measure of market quality, and conclude that inventory control and lagged adjustment effects indeed explain an important component of the realized spread on the MTS, even in 1997.

4 Conclusions

This paper studies the microstructure of the Italian secondary bond market, using a unique data set including tick by tick Treasury bond prices and signed quantities, and assesses the effects of the 1994 reform and of the introduction of anonymity in 1997. The paper also addresses the issue of the relevance of asymmetric information in bond markets.

Our results suggest that a substantial improvement in market quality occurred over time. Evidence on this was obtained both from estimated first order return autocorrelation, which dramatically decreases over time, and from our estimated measure of transaction costs. A strong negative value of the first order serial correlation in returns is generally related to inventory control effects, reflecting some form of bid-ask bounce or noise in prices. We interpret the threefold reduction in this variable from 1993 to 1997 as an indication of improved market quality, due to 1994 reform. The standard deviation of the transitory component of the transaction price captures, under our formulation, the extent of mispricing due to asymmetric information and inventory control, lagged adjustment to information and noise trading. We found that these effects account for 92 % of the effective spread in 1993, 67 % in 1995 and 49 % in 1997. The remaining fraction of the realized spread can be attributed to fixed order processing costs or variations in the spread due to exogenous market events.

According to our results, the most striking consequence of the introduction of anonymity is a strong reduction in trade autocorrelation. For the most traded issues, first order trade autocorrelation from the VAR estimation falls from 0.35 in 1993 to -0.03 in 1997. Anonymity prevents free-riding by less sophisticated traders, therefore, we interpret this result as the reduced tendency by investors to split their trades in order to camouflage their trading strategy.

With these results in hand, it is possible to provide an overall evaluation of the effects of the reforms enacted in 1994 and 1997 on the microstructure of the MTS. In 1994, a number of selected dealers were designated to act as market-makers, with the task of continually quoting bid and ask prices on a wide variety of bonds traded on this market. This reform seems to have improved the quality of the market dramatically, by reducing the difference between transaction prices and the long run value of securities caused by transient liquidity effects, such as inventory control. The introduction of anonymity at the beginning of 1997 reduced the adoption of order fragmentation strategies by market-makers, thereby increasing the speed with which new information is incorporated into prices. However, we find that transient liquidity effects still explain 50 % of the effective spread in 1997.

Increased market tightness over time has not been accompanied by higher average trade size. On MTS, the average trade size is 6.5 billion lire (approximately US$4 million), which is still very small compared to the other most important secondary bond markets (DM 25 million in Germany, FF 100-500 million in France and US$ 50 million in the US). ■

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